Manual for Package PGFPLOTS

2D/3D Plots in LaTeX, Version 1.14

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Abstract

PGFPLOTS draws high–quality function plots in normal or logarithmic scaling with a user-friendly interface directly in TeX. The user supplies axis labels, legend entries and the plot coordinates for one or more plots and PGFPLOTS applies axis scaling, computes any logarithms and axis ticks and draws the plots. It supports line plots, scatter plots, piecewise constant plots, bar plots, area plots, mesh– and surface plots, patch plots, contour plots, quiver plots, histogram plots, box plots, polar axes, ternary diagrams, smith charts and some more. It is based on Till Tantau's package PGF/TikZ.

Contents

Chapter 1

Introduction

This package provides tools to generate plots and labeled axes easily. It draws normal plots, logplots and semi-logplots, in two and three dimensions. Axis ticks, labels, legends (in case of multiple plots) can be added with key-value options. It supports line plots, scatter plots, piecewise constant plots, bar plots, area plots, mesh– and surface plots, patch plots, contour plots, quiver plots, histogram plots, box plots, polar axes, ternary diagrams, smith charts and some more. It can cycle through a set of predefined line/marker/color specifications.

In summary, its purpose is to simplify the generation of high-quality function and/or data plots, and solving the problems of

- consistency of document and font type and font size,

- direct use of T<small>E</small>X math mode in axis descriptions,

- consistency of data and figures (no third party tool necessary),

- inter-document consistency using preamble configurations and styles.

Although not necessary, separate `.pdf` or `.eps` graphics can be generated using the `external` library developed as part of Ti*k*Z.

You are invited to use PGFPLOTS for visualization of medium sized data sets in two and three dimensions. It is based on Till Tantau's package PGF/Ti*k*Z.

Chapter 2

About PGFPLOTS: Preliminaries

This section contains information about upgrades, the team, the installation (in case you need to do it manually) and troubleshooting. You may skip it completely except for the upgrade remarks.

PGFPLOTS is built completely on TikZ/PGF. Knowledge of TikZ will simplify the work with PGFPLOTS, although it is not required.

However, note that this library requires at least PGF version 2.10. At the time of this writing, many TeX-distributions still contain the older PGF version 1.18, so it may be necessary to install a recent PGF prior to using PGFPLOTS.

2.1 Components

PGFPLOTS comes with two components:

1. the plotting component (which you are currently reading) and

2. the PGFPLOTSTABLE component which simplifies number formatting and postprocessing of numerical tables. It comes as a separate package and has its own manual pgfplotstable.pdf.

2.2 Upgrade remarks

This release provides a lot of improvements which can be found in all detail in `ChangeLog` for interested readers. However, some attention is useful with respect to the following changes.

2.2.1 New Optional Features

PGFPLOTS has been written with backwards compatibility in mind: old TeX files should compile without modifications and without changes in the appearance. However, new features occasionally lead to a different behavior. In such a case, PGFPLOTS will deactivate the new feature[1].

Any new features or bugfixes which cause backwards compatibility problems need to be activated *manually* and *explicitly*. In order to do so, you should use

```
\usepackage{pgfplots}
\pgfplotsset{compat=1.14}
```

in your preamble. This will configure the compatibility layer.

You should have at least `compat`=1.3. The suggested value is printed to the `.log` file after running TeX. Here is a list of changes which are inactive unless one uses a suitable `compat` level:

1. PGFPLOTS 1.14 changes the way non-uniform colormaps are handled by the system and activates advanced `colormap` operations (see `of colormap`).

2. PGFPLOTS 1.13 repairs axis labels in polar axis and ensures that the color chosen by `shader`=`flat` is independent of `z buffer` and `mesh/ordering`. Furthermore, it enables `stack negative`=`separate` for all stacked bar plots. Older compatibility levels are present to keep workarounds by end-users.

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[1]In case of broken backwards compatibility, we apologize – and ask you to submit a bug report. We will take care of it.

3. PGFPLOTS 1.12 activates `lua backend` and defines `boxplot/estimator`=Excel.

4. PGFPLOTS 1.11 changes the `axis cs`: it is now the default coordinate system. If you write `\draw` (1,2) -- (2,2); PGFPLOTS will automatically treat it as `\draw` (axis cs:1,2) -- (axis cs:2,2);.

5. PGFPLOTS 1.10 has no differences to 1.9 with respect to compatibility.

6. PGFPLOTS 1.9 comes with a preset to combine `ybar stacked` and `nodes near coords`. Furthermore, it suppresses empty increments in stacked bar plots. In order to activate the new preset, you have to use `compat`=1.9 or higher.

7. PGFPLOTS 1.8 comes with a new revision for alignment of label- and tick scale label alignment. Furthermore, it improves the bounding box for `hide axis`. This revision is enabled with `compat`=1.8 or higher.

   The configuration `compat`=1.8 is *nessecary* to repair `axis lines`=center in three–dimensional axes.

8. PGFPLOTS 1.7 added new options for bar widths defined in terms of axis units. These are enabled with `compat`=1.7 or higher.

9. PGFPLOTS 1.6 added new options for more accurate scaling and more scaling options for `\addplot`3 `graphics`. These are enabled with `compat`=1.6 or higher.

10. PGFPLOTS 1.5.1 interprets circle- and ellipse radii as PGFPLOTS coordinates (older versions used PGF unit vectors which have no direct relation to PGFPLOTS). In other words: starting with version 1.5.1, it is possible to write `\draw` circle[radius=5] inside of an axis. This requires `\pgfplotsset`{`compat`=1.5.1} or higher.

    Without this compatibility setting, circles and ellipses use low–level canvas units of PGF as in earlier versions.

11. PGFPLOTS 1.5 uses `log origin`=0 as default (which influences logarithmic bar plots or stacked logarithmic plots). Older versions keep `log origin`=infty. This requires `\pgfplotsset`{`compat`=1.5} or higher.

12. PGFPLOTS 1.4 has fixed several smaller bugs which might produce differences of about 1–2pt compared to earlier releases. This requires `\pgfplotsset`{`compat`=1.4} or higher.

13. PGFPLOTS 1.3 comes with user interface improvements. The technical distinction between "behavior options" and "style options" of older versions is no longer necessary (although still fully supported).

    This is always activated.

14. PGFPLOTS 1.3 has a new feature which allows to *move axis labels tight to tick labels* automatically. This is strongly recommended. It requires `\pgfplotsset`{`compat`=1.3} or higher.

    Since this affects the spacing, it is not enabled be default.

15. PGFPLOTS 1.3 supports reversed axes. It is no longer necessary to use workarounds with negative units.

    Take a look at the `x dir`=reverse key.

    Existing workarounds will still function properly. Use `\pgfplotsset`{`compat`=1.3} or higher together with `x dir`=reverse to switch to the new version.

2.2.2 Old Features Which May Need Attention

1. The `scatter/classes` feature produces proper legends as of version 1.3. This may change the appearance of existing legends of plots with `scatter/classes`.

2. Starting with PGFPLOTS 1.1, `\tikzstyle` should *no longer be used* to set PGFPLOTS options.

   Although `\tikzstyle` is still supported for some older PGFPLOTS options, you should replace any occurance of `\tikzstyle` with `\pgfplotsset`{⟨*style name*⟩`/.style`={⟨*key-value-list*⟩}} or the associated `/.append style` variant. See Section 4.18 for more detail.

I apologize for any inconvenience caused by these changes.

/pgfplots/compat=1.14|1.13|1.12|1.11|1.10|1.9|1.8|1.7|1.6|1.5.1|1.5|1.4|1.3|pre 1.3|default (initially default)

The preamble configuration

```
\usepackage{pgfplots}
\pgfplotsset{compat=1.14}
```

allows to choose between backwards compatibility and most recent features. This key is designed to be the first encountered PGFPLOTS key in a document as it prepares global options.

Occasionally, you might want to use different versions in the same document. Then, provide

```
\begin{figure}
    \pgfplotsset{compat=1.4}
    ...
    \caption{...}
\end{figure}
```

in order to restrict the compatibility setting to the actual context (in this case, the figure environment).

See the output of your .log file to get a suggested value for compat.

Use \pgfplotsset{compat=default} to restore the factory settings.

Although typically unnecessary, it is also possible to activate only selected changes and keep compatibility to older versions in general:

/pgfplots/compat/path replacement=⟨version⟩
/pgfplots/compat/labels=⟨version⟩
/pgfplots/compat/scaling=⟨version⟩
/pgfplots/compat/scale mode=⟨version⟩
/pgfplots/compat/empty line=⟨version⟩
/pgfplots/compat/plot3graphics=⟨version⟩
/pgfplots/compat/bar nodes=⟨version⟩
/pgfplots/compat/BB=⟨version⟩
/pgfplots/compat/bar width by units=⟨version⟩
/pgfplots/compat/pgfpoint substitution=⟨version⟩
/pgfplots/compat/general=⟨version⟩

Let us assume that we have a document with \pgfplotsset{compat=1.3} and you want to keep it this way.

In addition, you realized that version 1.5.1 supports circles and ellipses. Then, use
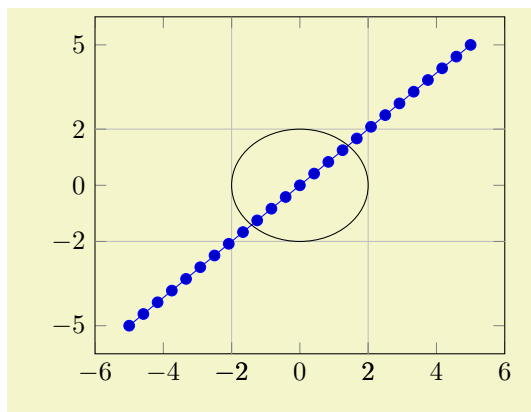

```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
% preamble:
\pgfplotsset{compat=1.3,compat/path replacement=1.5.1}
\begin{tikzpicture}
\begin{axis}[
    extra x ticks={-2,2},
    extra y ticks={-2,2},
    extra tick style={grid=major}]
    \addplot {x};
    \draw (axis cs:0,0) circle[radius=2];
\end{axis}
\end{tikzpicture}
```

All of these keys accept the possible values of the compat key.

The compat/path replacement key controls how radii of circles and ellipses are interpreted.

The compat/labels key controls how axis labels are aligned: either uses adjacent to ticks or with an absolute offset. As of 1.8, it also enables an entirely new revision of the axis label styles. In most cases, you will see no difference – but it repairs axis lines=center in three–dimensional axes.

The compat/scaling key controls some bugfixes introduced in version 1.4 and 1.6: they might introduce slight scaling differences in order to improve the accuracy.

The `compat/plot3graphics` controls new features for `\addplot3 graphics`.

The `compat/scale mode` allows to enable/disable the warning "The content of your 3d axis has CHANGED compared to previous versions" because the `axis equal` and `unit vector ratio` features where broken for all versions before 1.6 and have been fixed in 1.6.

The `compat/empty line` allows to write empty lines into input files in order to generate a jump. This requires `compat=1.4` or newer. See `empty line` for details.

The `compat/BB` changes to bounding box to be tight even in case of `hide axis`.

The `compat/bar width by units` allows to express `bar width`=1 (i.e. in terms of axis units).

The `compat/bar nodes` activates presets for `ybar stacked` and `nodes near coords`. In addition, it enables `stacked ignores zero` for stacked bar plots.

The `compat/general` key controls `log origin`, `lua backend`, `enable tick line clipping`, and `boxplot/estimator`.

The `compat/pgfpoint substitution` key determines if `axis cs` is the default coordinate system (as of 1.11).

The detailed effects can be seen on the beginning of this section.

The value ⟨*version*⟩ can be `default`, a version number, and `newest`. The value `default` is the same as `pre 1.3` (up to insignificant changes). The use of `newest` is strongly *discouraged*: it might cause changes in your document, depending on the current version of PGFPLOTS. Please inspect your `.log` file to see suggestions for the best possible version.

2.3 The Team

PGFPLOTS has been written mainly by Christian Feuersänger with many improvements of Pascal Wolkotte and Nick Papior Andersen as a spare time project. We hope it is useful and provides valuable plots.

If you are interested in writing something but don't know how, consider reading the auxiliary manual TeX-programming-notes.pdf which comes with PGFPLOTS. It is far from complete, but maybe it is a good starting point (at least for more literature).

2.4 Acknowledgements

I thank God for all hours of enjoyed programming. I thank Pascal Wolkotte and Nick Papior Andersen for their programming efforts and contributions as part of the development team. I thank Jürnjakob Dugge for his contribution of `hist/density`, matlab scripts for `\addplot3 graphics`, excellent user forum help and helpful bug reports. I thank Stefan Tibus, who contributed the `plot shell` feature. I thank Tom Cashman for the contribution of the `reverse legend` feature. Special thanks go to Stefan Pinnow for his continuous efforts to test PGFPLOTS, to discuss requirements, to request features and bug fixes which lead to numerous quality improvements, and to adapt and integrate the `colorbrewer` library. Furthermore, I thank Prof. Schweitzer for many fruitful discussions and his initial encouragement to start such a package. Thanks to Dr. Meine for his ideas and suggestions. Special thanks go to Markus Böhning for proof-reading all the manuals of PGF, PGFPLOTS, and PGFPLOTSTABLE. Thanks to Vincent A. Traag for bringing `colorbrewer` colors to PGFPLOTS. Thanks as well to the many international contributors who provided feature requests or identified bugs or simply improvements of the manual!

Last but not least, I thank Till Tantau and Mark Wibrow for their excellent graphics (and more) package PGF and Ti*k*Z, which is the base of PGFPLOTS.

2.5 Installation and Prerequisites

2.5.1 Licensing

This program is free software: you can redistribute it and/or modify it under the terms of the GNU General Public License as published by the Free Software Foundation, either version 3 of the License, or (at your option) any later version.

This program is distributed in the hope that it will be useful, but WITHOUT ANY WARRANTY; without even the implied warranty of MERCHANTABILITY or FITNESS FOR A PARTICULAR PURPOSE.

See the GNU General Public License for more details.

A copy of the GNU General Public License can be found in the package file

```
doc/latex/pgfplots/gpl-3.0.txt
```

You may also visit http://www.gnu.org/licenses.

2.5.2   Prerequisites

PGFPLOTS requires PGF. You should generally use the most recent stable version of PGF. PGFPLOTS is used with

```
\usepackage{pgfplots}
\pgfplotsset{compat=yourversion}
```

in your preamble (see Section 4.1 for information about how to use it with ConTEXt and plain TEX).

The compat=⟨yourversion⟩ entry should be added to activate new features, see the documentation of the compat key for more details.

There are several ways how to teach TEX where to find the files. Choose the option which fits your needs best.

2.5.3   Installation in Windows

Windows users often use MikTEX which downloads the latest stable package versions automatically. You do not need to install anything manually here.

If you want to install or more recent version of PGFPLOTS than the one shipped with MikTEX, you can proceed as follows. MikTEX provides a feature to install packages locally in its own TEX-Directory-Structure (TDS). The basic idea is to unzip PGFPLOTS in a directory of your choice and configure the MikTEX Package Manager to use this specific directory with higher priority than its default paths. If you want to do this, start the MikTEX Settings using "Start ≫ Programs ≫ MikTEX ≫ Settings". There, use the "Roots" menu section. It contains the MikTEX Package directory as initial configuration. Use "Add" to select the directory in which the unzipped PGFPLOTS tree resides. Then, move the newly added path to the list's top using the "Up" button. Then press "Ok". For MikTEX 2.8, you may need to uncheck the "Show MikTEX-maintained root directories" button to see the newly installed path.

MikTEX complains if the provided directory is not TDS conform (see Section 2.5.6 for details), so you can't provide a wrong directory here. This method does also work for other packages, but some packages may need some directory restructuring before MikTEX accepts them.

2.5.4   Installation of Linux Packages

Typically, PGFPLOTS can be installed using the TEX package manager. A common distribution is TEX-Live. In this case you can write

```
sudo tlmgr install pgfplots
```

in order to install PGFPLOTS.

2.5.5   Installation in Any Directory - the TEXINPUTS Variable

You can simply install PGFPLOTS anywhere on your harddrive, for example into

```
/foo/bar/pgfplots.
```

Then, you set the TEXINPUTS variable to

```
TEXINPUTS=/foo/bar/pgfplots/tex//:
```

The trailing ':' tells TEX to check the default search paths after /foo/bar/pgfplots. The double slash '//' tells TEX to search all subdirectories.

If the TEXINPUTS variable already contains something, you can append the line above to the existing TEXINPUTS content.

Furthermore, you should set TEXDOCS as well,

```
TEXDOCS=/foo/bar/pgfplots/doc//:
```

so that the TeX-documentation system finds the files `pgfplots.pdf` and `pgfplotstable.pdf` (on some systems, it is then enough to use `texdoc pgfplots`).

Starting with PGFPLOTS 1.12, you may also need to adopt LUAINPUTS:

```
LUAINPUTS=/foo/bar/pgfplots//:
```

should usually do the job.

Please refer to your operating systems manual for how to set environment variables.

2.5.6 Installation Into a Local TDS Compliant `texmf`-Directory

PGFPLOTS comes in a "TeX Directory Structure" (TDS) conforming directory structure, so you can simply unpack the files into a directory which is searched by TeX automatically. Such directories are `~/texmf` on Linux systems, for example.

Copy PGFPLOTS to a local `texmf` directory like `~/texmf`. You need at least the PGFPLOTS directories `tex/generic/pgfplots` and `tex/latex/pgfplots`. Then, run `texhash` (or some equivalent path-updating command specific to your TeX distribution).

The TDS consists of several sub directories which are searched separately, depending on what has been requested: the sub directories `doc/latex/⟨package⟩` are used for (LaTeX) documentation, the sub-directories `doc/generic/⟨package⟩` for documentation which apply to LaTeX and other TeX dialects (like plain TeX and ConTeXt which have their own, respective sub-directories) as well.

Similarly, the `tex/latex/⟨package⟩` sub-directories are searched whenever LaTeX packages are requested. The `tex/generic/⟨package⟩` sub-directories are searched for packages which work for LaTeX *and* other TeX dialects.

Do not forget to run `texhash`.

2.5.7 Installation If Everything Else Fails...

If TeX still doesn't find your files, you can copy all `.sty` and all `.code.tex`-files (perhaps all `.def` files as well) into your current project's working directory. In fact, you need everything which is in the `tex/latex/pgfplots` and `tex/generic/pgfplots` sub directories.

Please refer to http://www.ctan.org/installationadvice/ for more information about package installation.

2.6 Troubleshooting – Error Messages

This section discusses some problems which may occur when using PGFPLOTS. Some of the error messages are shown in the index, take a look at the end of this manual (under "Errors").

2.6.1 Problems with available Dimen-registers

To avoid problems with the many required TeX-registers for PGF and PGFPLOTS, you may want to include

```
\usepackage{etex}
```

as first package. This avoids problems with "no room for a new dimen" in most cases. It should work with any modern installation of TeX (it activates the e-TeX extensions).

2.6.2 Dimension Too Large Errors

The core mathematical engine of PGF relies on TeX registers to perform fast arithmetics. To compute $50 + 299$, it actually computes `50pt+299pt` and strips the `pt` suffix of the result. Since TeX registers can only contain numbers up to ± 16384, overflow error messages like "Dimension too large" occur if the result leaves the allowed range. Normally, this should never happen – PGFPLOTS uses a floating point unit with data range $\pm 10^{324}$ and performs all mappings automatically. However, there are some cases where this fails. Some of these cases are:

1. The axis range (for example, for x) becomes *relatively* small. It's no matter if you have absolutely small ranges like $[10^{-17}, 10^{-16}]$. But if you have an axis range like $[1.99999999, 2]$, where a lot of significant digits are necessary, this may be problematic.

   I guess I can't help here: you may need to prepare the data somehow before PGFPLOTS processes it.

2. This may happen as well if you only view a very small portion of the data range.

   This happens, for example, if your input data ranges from $x \in [0, 10^6]$, and you say `xmax`=10.

   Consider using the `restrict x to domain*`=⟨*min*⟩:⟨*max*⟩ key in such a case, where the ⟨*min*⟩ and ⟨*max*⟩ should be (say) four times of your axis limits (see page 387 for details).

3. The `axis equal` key will be confused if x and y have a very different scale.

4. You may have found a bug – please contact the developers.

2.6.3 Restrictions for DVI-Viewers and `dvipdfm`

PGF is compatible with

- `latex`/`dvips`,

- `latex`/`dvipdfm`,

- `pdflatex`,

- ⋮

However, there are some restrictions: I don't know any DVI viewer which is capable of viewing the output of PGF (and therefor PGFPLOTS as well). After all, DVI has never been designed to draw something different than text and horizontal/vertical lines. You will need to view the postscript file or the pdf-file.

Then, the DVI/pdf combination doesn't support all types of shadings (for example, the `shader`=`interp` is only available for `dvips`, `pdftex`, `dvipdfmx`, and `xetex` drivers).

Furthermore, PGF needs to know a *driver* so that the DVI file can be converted to the desired output. Depending on your system, you need the following options:

- `latex`/`dvips` does not need anything special because `dvips` is the default driver if you invoke `latex`.

- `pdflatex` will also work directly because `pdflatex` will be detected automatically.

- `lualatex` will also be detected automatically.

- `latex`/`dvipdfm` requires to use

  ```
  \def\pgfsysdriver{pgfsys-dvipdfm.def}
  %\def\pgfsysdriver{pgfsys-pdftex.def}
  %\def\pgfsysdriver{pgfsys-dvips.def}
  %\def\pgfsysdriver{pgfsys-dvipdfmx.def}
  %\def\pgfsysdriver{pgfsys-xetex.def}
  %\def\pgfsysdriver{pgfsys-luatex.def}
  \usepackage{pgfplots}.
  ```

  The uncommented commands could be used to set other drivers explicitly.

Please read the corresponding sections in [7, Section 7.2.1 and 7.2.2] if you have further questions. These sections also contain limitations of particular drivers.

The choice which won't produce any problems at all is `pdflatex`.

2.6.4 Problems with TeX's Memory Capacities

PGFPLOTS can handle small up to medium sized plots. However, TeX has never been designed for data plots – you will eventually face the problem of small memory capacities. See Section 6.1 for how to enlarge them.

2.6.5 Problems with Language Settings and Active Characters

Both PGF and PGFPLOTS use a lot of active characters – which may lead to incompatibilities with other packages which define active characters. Compatibility is better than in earlier versions, but may still be an issue. The manual compiles with the `babel` package for english and french, the `german` package does also work. If you experience any trouble, let me know. Sometimes it may work to disable active characters temporarily (`babel` provides such a command).

2.6.6 Other Problems

Please read the mailing list at

http://sourceforge.net/projects/pgfplots/support.

Perhaps someone has also encountered your problem before, and maybe he came up with a solution.

Please write a note on the mailing list if you have a different problem. In case it is necessary to contact the authors directly, consider the addresses shown on the title page of this document.

Chapter 3

Step–by–Step Tutorials

3.1   Introduction

Visualization of data is often necessary and convenient in order to analyze and communicate results of research, theses, or perhaps just results.

PGFPLOTS is a visualization tool. The motivation for PGFPLOTS is that you as end–user provide the data and the descriptions as input, and PGFPLOTS takes care of rest such as choosing suitable scaling factors, scaling to a prescribed target dimension, choosing a good displayed range, assigning tick positions, drawing an axis with descriptions placed at appropriate places.

PGFPLOTS is a solution for an old problem of visualization in LaTeX: its descriptions use the same fonts as the embedding text, with exactly the same font sizes. Its direct embedding in LaTeX makes the use of LaTeX's powerful math mode as easy as possible: for any kind of axis descriptions up to user–defined annotations. It features document–wide line–styles, color schemes, markers... all that makes up consistency.

PGFPLOTS offers high–quality. At the same time, it is an embedded solution: it is largely independent of 3rd party–tools, although it features import functions to benefit from available tools.

Its main goal is: you provide your data and your descriptions – and PGFPLOTS runs without more input. If you want, you can customize what you want.

3.2   Solving a Real Use–Case: Function Visualization

In this section, we assume that you want to visualize two functions. The first function is given by means of a data table. The second function is given by means of a math expression. We would like to place the two results side–by–side, and we would like to have "proper" alignment (whatever that means).

As motivated, we have one data table. Let us assume that it is as shown below.

```
x_0      f(x)
# some comment line
3.16693000e-05    -4.00001451e+00
1.00816962e-03    -3.08781504e+00
1.98466995e-03    -2.88058811e+00
2.96117027e-03    -2.75205040e+00
3.93767059e-03    -2.65736805e+00
4.91417091e-03    -2.58181091e+00
5.89067124e-03    -2.51862689e+00
....
9.89226496e-01    2.29825980e+00
9.90202997e-01    2.33403276e+00
9.91179497e-01    2.37306821e+00
9.92155997e-01    2.41609413e+00
9.93132498e-01    2.46412019e+00
9.94108998e-01    2.51860712e+00
9.95085498e-01    2.58178769e+00
9.96061999e-01    2.65733975e+00
9.97038499e-01    2.75201383e+00
9.98014999e-01    2.88053559e+00
9.98991500e-01    3.08771757e+00
9.99968000e-01    3.99755546e+00
```

Note that parts of the data file have been omitted here because it is a bit lengthy. The data file

(and all others referenced in this manual) are shipped with PGFPLOTS; you can find them in the subfolder `doc/latex/pgfplots/plotdata`.

3.2.1 Getting the Data Into TEX

Our first step is to get the data table into PGFPLOTS. In addition, we want axis descriptions for the `x` and `y` axes and a `title` on top of the plot.

Our first version looks like
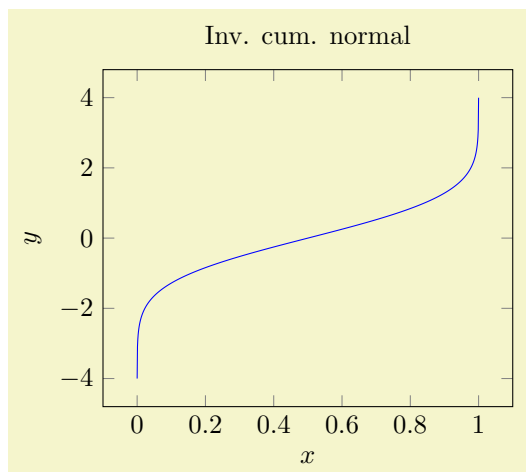

```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
%\documentclass{article}
%\usepackage{pgfplots}
%\pgfplotsset{compat=1.5}

%\begin{document}

\begin{tikzpicture}
\begin{axis}[
    title=Inv. cum. normal,
    xlabel={$x$},
    ylabel={$y$},
]
\addplot[blue] table {invcum.dat};
\end{axis}
\end{tikzpicture}
%\end{document}
```

The code listing already shows a couple of important aspects:

1. As usual in LATEX, you include the package using `\usepackage{pgfplots}`.

2. Not so common is `\pgfplotsset{compat=1.5}` .

   A statement like this should always be used in order to (a) benefit from a more-or-less recent feature set and (b) avoid changes to your picture if you recompile it with a later version of PGFPLOTS.

   Note that PGFPLOTS will generate some suggested value into your log file (since 1.6.1). The minimum suggested version is `\pgfplotsset{compat=1.3}` as this has great effect on the positioning of axis labels.

3. PGFPLOTS relies on TikZ and PGF. You can say it is a "third party package" on top of TikZ/PGF.

   Consequently, we have to write each PGFPLOTS graph into a TikZ picture, hence the picture environment given by `\begin{tikzpicture}` ... `\end{tikzpicture}`.

4. Each axis in PGFPLOTS is written into a separate environment. In our case, we chose `\begin{axis}` ... `\end{axis}` as this is the environment for a normal axis.

   There are more axis environments (like the `\begin{loglogaxis}` ... `\end{loglogaxis}` environment for logarithmic axes).

   Although PGFPLOTS runs with default options, it accepts keys. Lots of keys. Typically, you provide all keys which you "want to have" in square brackets "somewhere" and ignore all other keys.

   Of course, the main difficulty is to get an overview over the available keys and to find out how to use them. This reference manual and especially its Section 4 has been designed for online browsing: it contains hundreds of cross-referenced examples. Opening the manual in a pdf viewer and searching it for keywords will hopefully jump to a good match from which you can jump to *the* reference section (for example about tick labels, tick positions, plot handlers etc). It is (and will always be) the most reliable source of detail information about all keys.

   Speaking about the reference manual: note that most pdf viewers also have a function to "jump back to the page before you clicked on a hyperlink" (for Acrobat Reader, open the menu View / Toolbars / More Tools and activate the "Previous View" and "Next View" buttons which are under "Page Navigation Toolbar").

   Note that the code listing contains two sets of keys: the first is after `\begin{axis}[ .... ]` and the second right after `\addplot[...]`. Note furthermore that the option list after the axis has been

indented: each option is on a separate line, and each line has a tab stop as first character. This is a good practice. Another good practice is to place a comma after the last option (in our case, after the value for `ylabel`). This allows to add more keys easily – and you won't forget the comma. It does not hurt at all. The second "set" of keys after `\addplot` shows that indentation and trailing comma a really just a best-practice: we simply said `\addplot[blue]`, meaning that the plot will be placed in blue color, without any plot `mark`. Of course, once another option would be added here, it would be best to switch to indentation and trailing comma:

```
\addplot[
    blue,
    mark=*,
]
table {invcum.dat};
```

5. Inside of an axis, PGFPLOTS accepts an `\addplot` ... ; statement (note the final semicolon).

   In our case, we use `\addplot table`: it loads a table from a file and plots the first two columns.

   There are, however, more input methods. The most important available inputs methods are `\addplot expression` (which samples from some mathematical expression) and `\addplot table` (loads data from tables), and a combination of both which is also supported by `\addplot table` (loads data from tables and applies mathematical expressions). Besides those tools which rely only on builtin methods, there is also an option to calculated data using external tools: `\addplot gnuplot` which uses gnuplot as "desktop calculator" and imports numerical data, `\addplot shell` (which can load table data from any system call), and the special `\addplot graphics` tool which loads an *image* together with meta data and draws only the associated axis.

   In our axis, we find a couple of tokens: the first is the mandatory `\addplot` token. It "starts" a further plot. The second is the option list for that plot, which is delimited by square brackets (see also the notes about best-practices above). The name "option list" indicates that this list can be empty. It can also be omitted completely in which case PGFPLOTS will choose an option list from its current `cycle list` (more about that in a different lecture). The next token is the keyword "`table`". It tells PGFPLOTS that table data follows. The keyword "`table`" also accepts an option list (for example, to choose columns, to define a different `col sep` or `row sep` or to provide some math expression which is applied to each row). More on that in a different lecture. The next token is {invcum.dat}: an argument in curly braces which provides the table data. This argument is interpreted by "plot table". Other input types would expect different types of arguments. In our case, the curly braces contain a file name. Plot table expects either a file name as in our case or a so-called "inline table". An inline table means that you would simply insert the contents of your file inside of the curly braces. In our case, the table is too long to be inserted into the argument, so we place it into a separate file. Finally, the last (mandatory!) token is a semicolon. It terminates the `\addplot` statement.

6. Axis descriptions can be added using the keys `title`, `xlabel`, `ylabel` as we have in our example listing.

   PGFPLOTS accepts lots of keys — and sometimes it is the art of finding just the one that you were looking for. Hopefully, a search through the table of contents of the reference manual and/or a keyword search through the entire reference manual will show a hit.

3.2.2   Fine–Tuning of the First Picture

While looking at the result of Section 3.2.1, we decide that we want to change something. First, we decide that the open ends on the left and on the right are disturbing (perhaps we have a strange taste – or perhaps we know in advance that the underlying function is not limited to any interval). Anyway, we would like to show it only in the y interval from -3 to $+3$.

We can do so as follows:
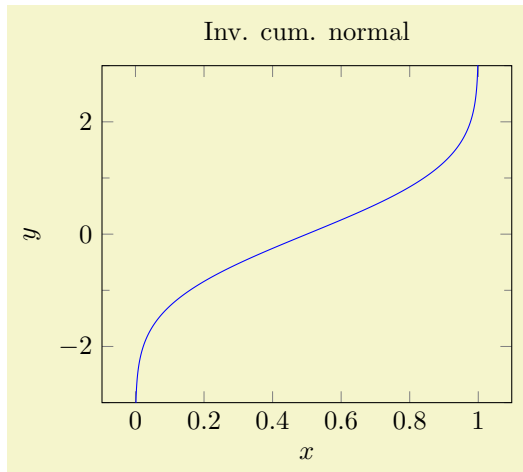
```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
\begin{axis}[
    title=Inv. cum. normal,
    xlabel={$x$},
    ylabel={$y$},
    ymin=-3, ymax=3,
    minor y tick num=1,
]
\addplot[blue] table {invcum.dat};
\end{axis}
\end{tikzpicture}
```

We added three more options to the option list of the axis. The first pair is `ymin=-3` and `ymax=3`. Note that we have placed them on the same line although we said the each should be on a separate line. Line breaks are really optional; and in this case, the two options appear to belong together. They define the *display* limits. Display limits define the "window" of the axis. Note that any `\addplot` statements might have more data (as in our case). They would still generate graphics for their complete set of data points! The keys `ymin,ymax,xmin,xmax` control only the *visible* part, i.e. the axis range. Everything else is clipped away (by default). The third new option is `minor y tick num`=1 which allows to customize minor ticks. Note that minor ticks are only displayed if the major ticks have the same distance as in our example.

Note that we could also have modified the `width` and/or `height` of the figure (the keys have these names). We could also have used one of the predefined styles like `tiny` or `small` in order to modify not just the graphics, but also use different fonts for the descriptions. We could also have chosen to adjust the unspecified limits: either by fixing them explicitly (as we did for y above) or by modifying the `enlargelimits` key (for example using `enlargelimits`=false).

We are now satisfied with the first picture and we would like to add the second one.

3.2.3   Adding the Second Picture with a Different Plot

As motivated, our goal is to have two separate axes placed side–by–side. The second axis should show a function given as math expression. More precisely, we want to show the density function of a normal distribution here (which is just a special math expression).

We simply start a new `tikzpicture` and insert a new `axis` environment (perhaps by copy-pasting our existing one). The `\addplot` command is different, though:
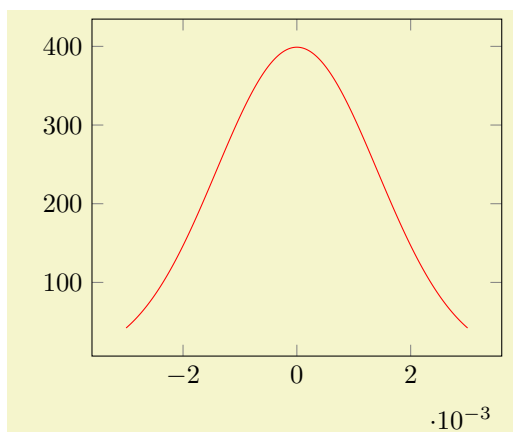

```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
\begin{axis}[
]
% density of Normal distribution:
\addplot[
    red,
    domain=-3e-3:3e-3,
    samples=201,
]
    {exp(-x^2 / (2e-3^2)) / (1e-3 * sqrt(2*pi))};
\end{axis}
\end{tikzpicture}
```

We see that it has an axis environment with an empty option list. This is quite acceptable: after all, it is to be expected that we will add options eventually. Even if we don't: it does not hurt. Then, we find the expected `\addplot` statement. As already explained, `\addplot` statements initiate a new plot. It is followed by an (optional) option list, then by some keyword which identifies the way input coordinates are provided, then arguments, and finally a semicolon. In our case, we find an option list which results in a red plot. The two keys `domain` and `samples` control how our math expression is to be evaluated: `domain` defines the sampling interval in the form `a:b` and `samples`=N expects the number of samples inserted into the sampling

interval. Note that `domain` merely controls which samples are taken; it is independent of the displayed axis range (and both can differ significantly). If the keyword defining how coordinates are provided is missing, PGFPLOTS assumes that the next argument is a math expression. Consequently, the first token after the option list is a math expression in curly braces. We entered the density function of a normal distribution here (compare Wikipedia).

Note that the axis has an axis multiplier: the x tick labels have been chosen to be -2, 0, and 2 and an extra x tick scale label of the form '$\cdot 10^{-3}$'. These tick scale labels are quite convenient are are automatically deduced from the input data. We will see an example with the effects of `scaled x ticks`=false at the end of this tutorial.

Inside of the math expression, you can use a lot of math functions like exp, sin, cos, sqrt, you can use exponents using the `a^b` syntax, and the sampling variable is `x` by default. Note, however, that *trigonometric functions operate on degrees* by default! If you need to sample the sinus function, you can use `\addplot`[domain=0:360] {sin(x)};. This is quite uncommon. You can also use `\addplot`[domain=0:2*pi] {sin(deg(x))};. This samples radians (which is more common). But since the math parser expects degrees, we have to convert `x` to degrees first using the `deg()` function. See also `trig format plots`=rad. The math parser is written in TEX(it does not need any third-party tool). It supports the full range of a double precision number, even though the accuracy is about that of a single precision number. This is typically more than sufficient to sample any function accurately. If you ever encounter difficulties with precision, you can still resort to `\addplot gnuplot` in order to invoke the external tool gnuplot as "coordinate calculator".

The experienced reader might wonder about *constant* math expressions `domain`=-3e-3:3e-3, 2e-3^2, and `1e-3` rather than some variable name like "mu" or 'sigma'. This is actually a matter of taste: both is supported and we will switch to variable names in the next listing.

The main part of our step here is still to be done: we wanted to place two figures side–by–side. This can be done as follows:
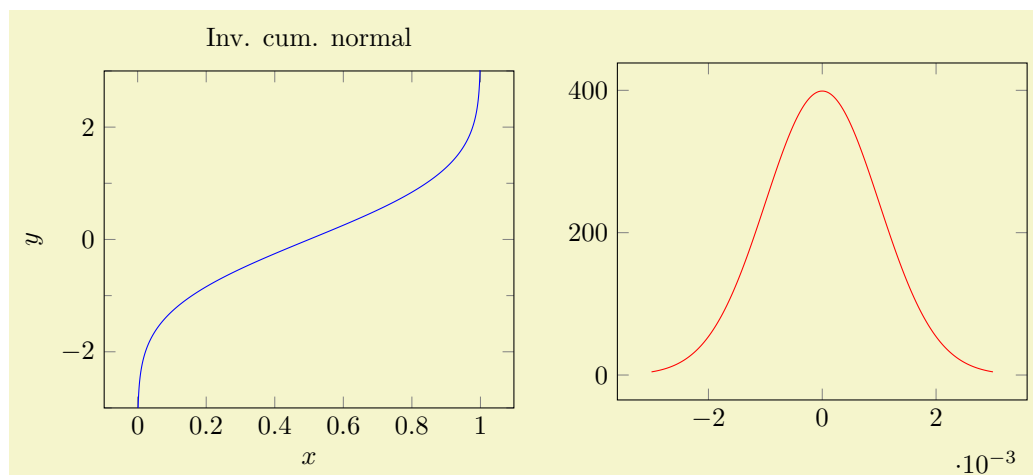
```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
\begin{axis}[
    title=Inv. cum. normal,
    xlabel={$x$},
    ylabel={$y$},
    ymin=-3, ymax=3,
    minor y tick num=1,
]
\addplot[blue] table {invcum.dat};
\end{axis}
\end{tikzpicture}% - avoid white space
%
\hskip 10pt % insert a non-breaking space of specified width.
%
\begin{tikzpicture}
\begin{axis}[
]
% density of Normal distribution:
\newcommand\MU{0}
\newcommand\SIGMA{1e-3}
\addplot[
    red,
    domain=-3*\SIGMA:3*\SIGMA,
    samples=201,
]
    {exp(-(x-\MU)^2 / 2 / \SIGMA^2) / (\SIGMA * sqrt(2*pi))};
\end{axis}
\end{tikzpicture}
```

The listing above shows the two separate picture environments: the first is simply taken as-is from the previous step and the second is new. Note that both are simply placed adjacent to each other: we only inserted comment signs to separate them. This approach to place graphics side–by–side is common in TeX: it works for \includegraphics in the same way. You could, for example, write

```
\includegraphics{image1}%
%
\hskip 10pt % insert a non-breaking space of specified width.
%
\includegraphics{image2}
```

to place two graphics next to each other. This here is just the same (except that our graphics occupy more code in the .tex file).

Note that there is also a comment sign after \end{tikzpicture}. This is not just a best-practice: it is necessary to suppress spurious spaces! In TeX, every newline character is automatically converted to a white space (unless you have an empty line, of course). In our case, we want no white spaces.

In our second picture, we see the effects of switch our math expression to constant definitions as promised earlier. The interesting part starts with two constants which are defined by means of two \newcommand s: we define \MU to be 0 and \SIGMA to be 1e-3. This is one way to define constants (note that such a definition of constants should probably introduce round braces if numbers are negative, i.e. something like \newcommand\negative{(-4)}).

3.2.4 Fixing the Vertical Alignment and Adjusting Tick Label Positions

Note that even though our individual pictures look quite good, the combination of both is not properly aligned. The experienced reader identifies the weak point immediately: the bounding box of the two images differs, and they are aligned at their baseline (which is the bottom edge of the picture). In particular, the xlabel=x of the left picture and the automatically inserted scaling label \cdot 10^{-3} of the right picture cause an unwanted vertical shift. We want to fix that in the next step.

Besides the bad alignment, we find it a little bit misleading that the axis descriptions of the second picture are between both pictures. We would like to move them to the right.

Let us present the result first:

```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}[baseline]
\begin{axis}[
    title=Inv. cum. normal,
    xlabel={$x$},
    ylabel={$y$},
    ymin=-3, ymax=3,
    minor y tick num=1,
]
\addplot[blue] table {invcum.dat};
\end{axis}
\end{tikzpicture}%
%
\hskip 10pt % insert a non-breaking space of specified width.
%
\begin{tikzpicture}[baseline]
\begin{axis}[
    yticklabel pos=right,
]
% density of Normal distribution:
\newcommand\MU{0}
\newcommand\SIGMA{1e-3}
\addplot[red,domain=-3*\SIGMA:3*\SIGMA,samples=201]
    {exp(-(x-\MU)^2 / 2 / \SIGMA^2) / (\SIGMA * sqrt(2*pi))};
\end{axis}
\end{tikzpicture}
```

This listing has a couple of modifications. The most important one is the we added an option list to the tikzpicture environment: the baseline option. This option shifts the picture up or down such that the canvas coordinate $y = 0$ is aligned at the baseline of the surrounding text. In PGFPLOTS, the $y = 0$ line is the lower edge of the box. This simple feature allows both axes to be aligned vertically: now, their boxes are aligned rather than the lower edges of their bounding boxes. The option baseline needs to be provided to all pictures for which this shifting should be done – in our case, to all which are to be placed in one row. Keep in mind that it is an option for \begin{tikzpicture}.

The second change is rather simple: we only added the option yticklabel pos=right to the second axis. This moves all tick labels to the right, without changing anything else.

Note that there is much more to say about alignment and bounding box control. After all, we did not really change the bounding box - we simply moved the pictures up or down. There is also the use-case where we want horizontal alignment: for example if the two pictures should be centered horizontally or if they should be aligned with the left- and right end of the margins. The associated keys \begin{tikzpicture}[trim axis left, trim axis right] and \centering are beyond the scope of this tutorial, please refer to Section 4.19 for details.

3.2.5   Satisfying Different Tastes

We are now in a position where the figures as such are in a good shape.

However, an increase in knowledge will naturally lead to an increase in questions. Some of these questions will be part of other how-to lectures. But the most commonly asked questions are addressed here (feel free to email some more if you believe that I should include another hotspot):

1. How can I get rid of that 10^{-3}-label?

2. How can I modify the number printing?

3. How can I have one single line per axis rather than a box?

This here gives brief hints where to look in this reference manual for more details. We modify the appearance of the second picture according to the questions above:

```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
\begin{axis}[
    axis lines=left,
    scaled ticks=false,
    xticklabel style={
        rotate=90,
        anchor=east,
        /pgf/number format/precision=3,
        /pgf/number format/fixed,
        /pgf/number format/fixed zerofill,
    },
]
% density of Normal distribution:
\newcommand\MU{0}
\newcommand\SIGMA{1e-3}
\addplot[red,domain=-3*\SIGMA:3*\SIGMA,samples=201]
    {exp(-(x-\MU)^2 / 2 / \SIGMA^2)
      / (\SIGMA * sqrt(2*pi))};
\end{axis}
\end{tikzpicture}
```
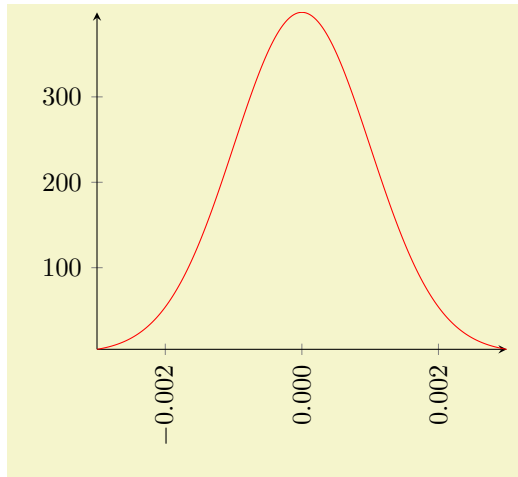
The appearance of the axes as such can be controlled by means of the `axis lines` key. It accepts the values `left`, `right`, `box`, `center`, `none` (and also `top`, `bottom`, `middle` which are aliases). The `xticklabel style` key modifies a predefined style (note the use of indentation here!). A style is a collection of keys which are applied in a specific context. Styles are very useful and are widely used by PGFPLOTS. In our case, we adjust a couple of options like rotation, alignment (the `anchor` option), and number printing options. The precise details of these individual options is beyond the scope of this tutorial. The keys actually belong to TikZ - and the TikZ manual is the reference for these keys (although PGFPLOTS also covers most of the topics). The complete set of number printing options is available in both the TikZ manual [7] and the manual for PGFPLOTSTABLE which is shipped with PGFPLOTS. A brief extract can be found in Section 4.13.

3.2.6 Finishing Touches: Automatic Generation of Individual Pdf Graphics

As last step in this lecture, I would like to talk about one technical topic. Typically, a TeXdocument starts quite simple: a little bit of text, perhaps one or two pictures. But they tend to grow. And eventually, you will encounter one of the weak points of PGFPLOTS: the graphics are involved and TeXconsumes a lot of time to generate them. Especially if it keeps regenerating them even though they did not change at all. The fact that we need to rerun the pdflatex processor all the time makes things worse.

Fortunately, there are solutions. A simple solution is: why can't we write each individual graphics into a separate `.pdf` file and use `\includegraphics` to include it!? The answer is: yes, we can. And it is surprisingly simple to do so.

In order to convert every `tikzpicture` environment automatically to an external graphics *without* changing any line of code in the TeXfile, we can simply write the following two lines into the document's preamble:

```
\usepgfplotslibrary{external}
\tikzexternalize

...
\begin{document}
...
\end{document}
```

But now, we *have to provide a command-line switch to pdflatex*:

```
pdflatex -shell-escape myfile.tex
```

This works out-of-the box with `pdflatex`. If you use `latex/dvips`, `lualatex`, `dvipdfm` or any other TeXderivate, you need to modify the option `\tikzexternalize[system call=....]` (which is, unfortunately, system-dependent, especially for the postscript variants).

It might be too much to discuss how to define individual file names or how to modify the file name generation strategy. There is also the `\tikzexternalize`[mode=list and make] feature which generates a GNU Make file to allow `\label`/`\ref` to things inside of the external graphics and which supports the generation of all images in parallel (if you have a multi-core PC).

Details of the external library can be found in Section 7.1 (but only a brief survey) and, in all depth, in the TikZ reference manual [7].

3.2.7 Summary

We learned how to create a standard axis, and how to assign basic axis descriptions. We also saw how to plot functions from a data table (in our case a tab-separated file, but other delimiters as in csv files are also supported) and from math expressions. We saw that PGFPLOTS does a reasonable good job at creating a fully-featured axis automatically (like scaling the units properly, choosing tick positions and labels). We also learned how to improve vertical alignment and how to customize the appearance of an axis.

Next steps might be how to draw multiple plots into the same axis, how to employ scatter plots of PGFPLOTS, how to generate logarithmic axes, or how to draw functions of two variables. Some of these aspects will be part of further how-to lectures.

3.3 Solving a Real Use–Case: Scientific Data Analysis

In this section, we assume that you did some scientific experiment. The scientific experiment yielded three input data tables: one table for each involved parameter $d = 2$, $d = 3$, $d = 4$. The data tables contain "degrees of freedom" and some accuracy measurement "l2_err". In addition, they might contain some meta-data (in our case a column "level"). For example, the data table for $d = 2$ might be stored in `data_d2.dat` and may contain

```
dof         l2_err      level
5           8.312e-02   2
17          2.547e-02   3
49          7.407e-03   4
129         2.102e-03   5
321         5.874e-04   6
769         1.623e-04   7
1793        4.442e-05   8
4097        1.207e-05   9
9217        3.261e-06   10
```

The other two tables are similar, we provide them here to simplify the reproduction of the examples. The table for $d = 3$ is stored in `data_d3.dat`, it is

```
dof         l2_err      level
7           8.472e-02   2
31          3.044e-02   3
111         1.022e-02   4
351         3.303e-03   5
1023        1.039e-03   6
2815        3.196e-04   7
7423        9.658e-05   8
18943       2.873e-05   9
47103       8.437e-06   10
```

Finally, the last table is `data_d4.dat`

```
dof         l2_err      level
9           7.881e-02   2
49          3.243e-02   3
209         1.232e-02   4
769         4.454e-03   5
2561        1.551e-03   6
7937        5.236e-04   7
23297       1.723e-04   8
65537       5.545e-05   9
178177      1.751e-05   10
```

What we want is to produce three plots, each dof versus `l2_err`, in a loglog plot. We expect that the result is a line in a loglog plot, and we are interested in its slope $\log e(N) = -a \log(N)$ because that characterizes our experiment.

3.3.1   Getting the Data into TeX

Our first step is to get one of our data tables into PGFPLOTS. In addition, we want axis descriptions for the x and y axes and a title on top of the plot.

Our first version looks like
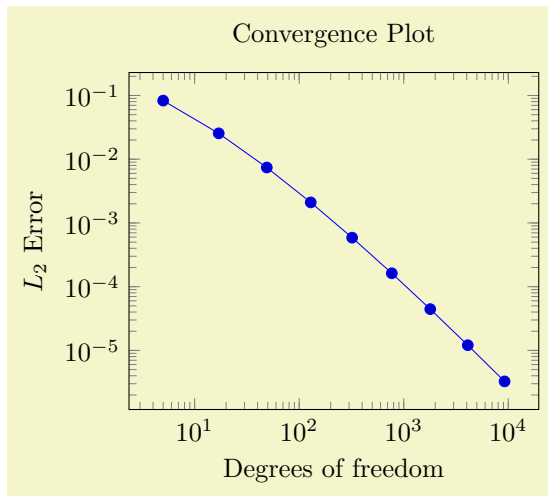
Our example is similar to that of the lecture in Section 3.2.1 in that it defines some basic axis descriptions by means of `title`, `xlabel`, and `ylabel` and provides data using `\addplot table`. The only difference is that we used `\begin{loglogaxis}` instead of `\begin{axis}` in order to configure logarithmic scales on both axes. Note furthermore that we omitted any options after `\addplot`. As explained in Section 3.2.1, this tells PGFPLOTS to consult its `cycle list` to determine a suitable option list.

3.3.2   Adding the Remaining Data Files of Our Example.

PGFPLOTS accepts more than one `\addplot ...  ;` command – so we can just add our remaining data files:

You might wonder how PGFPLOTS chose the different line styles. And you might wonder how to modify them. Well, if you simply write `\addplot` without options in square brackets, PGFPLOTS will automatically choose styles for that specific plot. Here "automatically" means that it will consult its current `cycle list`: a list of predefined styles such that every `\addplot` statement receives one of these styles. This list is customizable to a high degree.

Instead of the `cycle list`, you can easily provide style options manually. If you write

`\addplot[`⟨*options*⟩`] ...,`

PGFPLOTS will only use ⟨*options*⟩ and will ignore its `cycle list`. If you write a plus sign before the square brackets as in

`\addplot+[`⟨*options*⟩`] ...,`

PGFPLOTS will append ⟨*options*⟩ to the automatically assigned cycle list.

3.3.3   Add a Legend and a Grid

A legend is a text label explaining what the plots are. A legend can be provided for one or more `\addplot` statements using the `legend entries` key:


```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
\begin{loglogaxis}[
    title=Convergence Plot,
    xlabel={Degrees of freedom},
    ylabel={$L_2$ Error},
    grid=major,
    legend entries={$d=2$,$d=3$,$d=4$},
]
\addplot table {data_d2.dat};
\addplot table {data_d3.dat};
\addplot table {data_d4.dat};
\end{loglogaxis}
\end{tikzpicture}
```
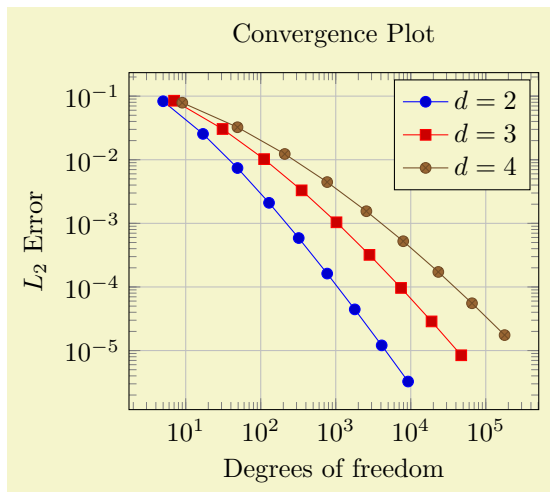
Here, we assigned a comma-separated list of text labels, one for each of our `\addplot` instructions. Note the use of math mode in the text labels. Note that if any of your labels contains a comma, you have to surround the entry by curly braces. For example, we could have used `legend entries`=`{{$d=2$},{$d=3$},{$d=4$}}` — PGFPLOTS uses these braces to delimit arguments and strips them afterwards (this holds for any option, by the way).

Our example also contains grid lines for which we used the `grid`=`major` key. It activates major grid lines in all axes.

You might wonder how the text labels map to `\addplot` instructions. Well, they are mapped by index. The first label is assigned to the first plot, the second label to the second plot and so on. You can exclude plots from this counting if you add the `forget plot` option to the plot (using `\addplot`+`[forget plot]`, for example). Such plots are excluded from both cycle lists and legends.

3.3.4   Add a Selected Fit-line

Occasionally, one needs to compute linear regression lines through input samples. Let us assume that we want to compute a fit line for the data in our fourth data table (`data_d4.dat`). However, we assume that the interesting part of the plot happens if the number of degrees of freedom reaches some asymptotic limit (i.e. is very large). Consequently, we want to assign a high uncertainty to the first points when computing the fit line.

PGFPLOTS offers to combine table input and mathematical expressions (note that you can also type pure mathematic expressions, although this is beyond the scope of this example). In our case, we employ this feature to create a completely new column - the linear regression line:
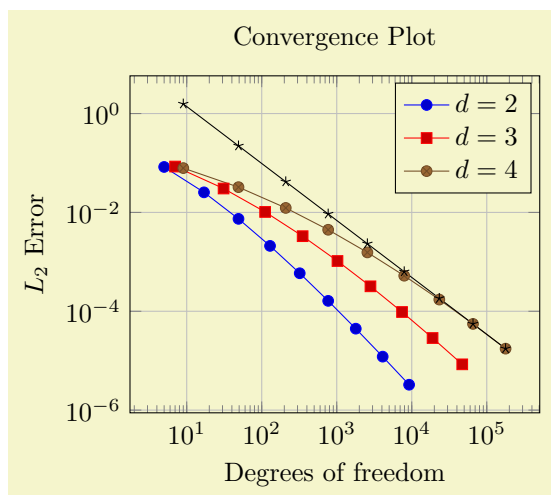
```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
%\usepackage{pgfplotstable}
%...
\begin{tikzpicture}
\begin{loglogaxis}[
    title=Convergence Plot,
    xlabel={Degrees of freedom},
    ylabel={$L_2$ Error},
    grid=major,
    legend entries={$d=2$,$d=3$,$d=4$},
]
\addplot table {data_d2.dat};
\addplot table {data_d3.dat};
\addplot table {data_d4.dat};
\addplot table[
    x=dof,
    y={create col/linear regression={y=l2_err,
      variance list={1000,800,600,500,400,200,100}}}]
  {data_d4.dat};
\end{loglogaxis}
\end{tikzpicture}
```
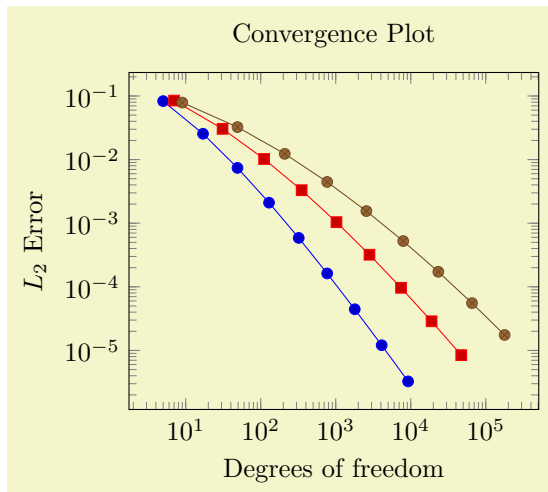
Note that we added a further package: `pgfplotstable`. It allows to postprocess tables (among other things. It also has a powerful table typesetting toolbox which rounds and formats numbers based on your input CSV file).

Here, we added a fourth plot to our axis. The first plot is also an `\addplot table` statement as before – and we see that it loads the data file `data_d4.dat` just like the plot before. However, it has special keys which control the coordinate input: `x=dof` means to load x coordinates from the column named "dof". This is essentially the same as in all of our other plots (because the "dof" column is the first column). It also uses `y={create col/.......}`. This lengthy statement defines a completely new column. The `create col/linear regression` prefix is a key which can be used whenever new table columns can be generated. As soon as the table is queried for the first time, the statement is evaluated and then used for all subsequent rows. The argument list for `create col/linear regression` contains the column name for the function values `y=l2_err` which are to be used for the regression line (the x arguments are deduced from `x=dof` as you guessed correctly). The `variance list` option is optional. We use it to assign variances (uncertainties) to the first input points. More precisely: the first encountered data point receives a variance of 1000, the second 800, the third 600, and so on. The number of variances does not need to match up with the number of points; PGFPLOTS simply matches them with the first encountered coordinates.

Note that since our `legend entries` key contains only three values, the regression line has no legend entry. We could easily add one, if we wanted. We can also use `\addplot+[forget plot] table[....]` to explicitly suppress the generation of a legend as mentioned above.

Whenever PGFPLOTS encounteres mathematical expressions, it uses its built-in floating point unit. Consequently, it has a very high data range – and a reasonable precision as well.

3.3.5 Add an Annotation using Ti*k*Z: a Slope Triangle

Often, data requires interpretation – and you may want to highlight particular items in your plots. This "highlight particular items" requires to draw into an axis, and it requires a high degree of flexibility. Users of Ti*k*Z would say that Ti*k*Z is a natural choice – and it is.

In our use-case, we are interested in slopes. We may want to compare slopes of different experiments. And we may want to show selected absolute values of slopes.

Here, we use Ti*k*Z to add custom annotations into a PGFPLOTS axis. We choose a particular type of a custom annotation: we want to mark two points on a line plot. One way to do so would be to determine the exact coordinates and to place a graphical element at this coordinate (which is possible using `\draw` .... `(1e4,1e-5)` ...). Another (probably simpler) way is to use the `pos` feature to identify a position "25% after the line started".

Based on the result of Section 3.3.4, we find
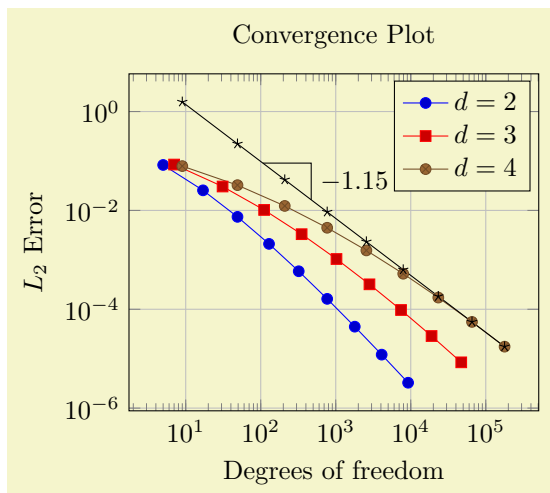
```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
%\usepackage{pgfplotstable}
%...
\begin{tikzpicture}
\begin{loglogaxis}[
    title=Convergence Plot,
    xlabel={Degrees of freedom},
    ylabel={$L_2$ Error},
    grid=major,
    legend entries={$d=2$,$d=3$,$d=4$},
]
\addplot table {data_d2.dat};
\addplot table {data_d3.dat};
\addplot table {data_d4.dat};
\addplot table[
    x=dof,
    y={create col/linear regression={y=l2_err,
     variance list={1000,800,600,500,400,200,100}}}]
    {data_d4.dat}
    % save two points on the regression line
    % for drawing the slope triangle
    coordinate [pos=0.25] (A)
    coordinate [pos=0.4]  (B)
    ;
% save the slope parameter:
\xdef\slope{\pgfplotstableregressiona}

% draw the opposite and adjacent sides
% of the triangle
\draw (A) -| (B)
    node [pos=0.75,anchor=west]
    {\pgfmathprintnumber{\slope}};
\end{loglogaxis}
\end{tikzpicture}
```

The example is already quite involved since we added complexity in every step. Before we dive into the details, let us take a look at a simpler example:
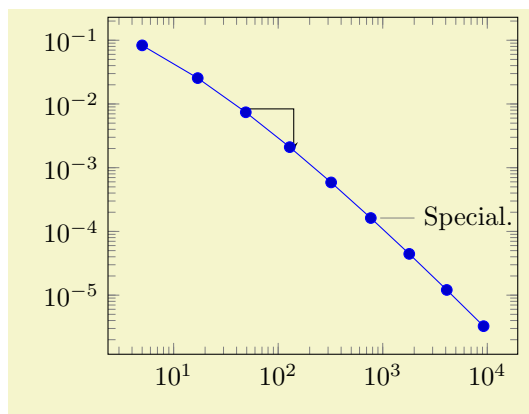

```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
\begin{loglogaxis}
\addplot table {data_d2.dat}
    coordinate [pos=0.25] (A)
    coordinate [pos=0.4]  (B)
    ;

\draw[-stealth] (A) -| (B);

\node[pin=0:Special.] at (769,1.623e-04) {};

\end{loglogaxis}
\end{tikzpicture}
```

Here, we see two annotation concepts offered by PGFPLOTS : the first is to insert drawing commands right after an \addplot command (but before the closing semicolon). The second is to add standard TikZ commands, but use designated PGFPLOTS coordinates. Both are TikZ concepts. The first is what we want here: we want to identify two coordinates which are "somewhere" on the line. In our case, we define two named coordinates: coordinate A at 25% of the line and coordinate B at 40% of the line. Then, we use \draw (A) -| (B) to draw a triangle between these two points. The second is only useful if we know some absolute coordinates in advance.

Coming back to our initial approach with the regression line, we see that it uses the first concept: it introduces named coordinates after \addplot, but before the closing semicolon. The statement \xdef\slope introduces a new macro. It contains the (expanded due to the "eXpanded DEFinition") value of \pgfplotstableregressiona which is the slope of the regression line. In addition to the slope triangle, we also add a node in which we typeset that value using \pgfmathprintnumber.

Note that the example above is actual a "happy case": it can happen easily that labels which are added inside of the axis environment are clipped away:
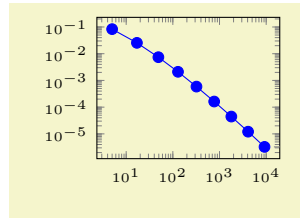
```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
\begin{loglogaxis}[
    tiny,
]
\addplot table {data_d2.dat}
    node [pos=1,pin=0:Special.] {}
    ;
\end{loglogaxis}
\end{tikzpicture}
```

The example above combines the `pos` label placement with the node's label. Note that the small style `tiny` installs a PGFPLOTS preset which is better suited for very small plots – it is one of the many supported scaling parameters. The problem here is apparent: the text of our extra node is clipped away. Depending on your data, you have a couple of solutions here:

- use `clip`=false to disable clipping of plot paths at all,

- use `clip mode`=individual to enable clipping only for plot paths,

- draw the node outside of the axis environment but inside of the picture environment.

The first attempt works quite well for most figures:
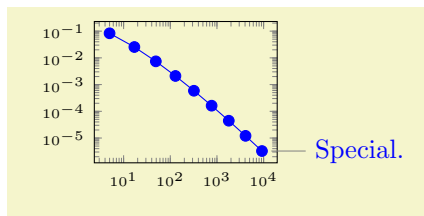

```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
\begin{loglogaxis}[
    tiny,
    clip=false,
]
\addplot table {data_d2.dat}
    node [pos=1,pin=0:Special.] {}
    ;
\end{loglogaxis}
\end{tikzpicture}
```

Note that this approach in which the nodes are placed before the closing semicolon implies that nodes inherit the axis line style and color.

3.3.6 Summary

We learned how to define a (logarithmic) axis, and how to assign basic axis descriptions. We also saw once more how to use one or more `\addplot table` commands to load table data into PGFPLOTS . We took a brief look into regression and TikZ drawing annotations.

We also encountered the `tiny` style which is one of the ways to customize the size of an axis. Others are `width`, `height`, the other predefined size styles like `normalsize`, `small`, or `footnotesize`, and the two different scaling modes `/pgfplots/scale` and `/tikz/scale` (the first scales only the axis, the second also the labels).

Next steps might be how to visualize functions using line plots, how to align adjacent graphics properly (even if the axis descriptions vary), how to employ scatter plots of PGFPLOTS , or how to draw functions of two variables.

3.4 Use–Cases involving Scatter Plots

Assuming that we are more–or–less familiar with the basics of the preceding tutorials, we would like to draw a scatter plot. A scatter plot is one in which markers indicate the important information.

There are many different kinds of scatter plots and this section covers a couple of them.

3.4.1 Scatter Plot Use–case A

In this subsection, we address the following scatter plot use–case: assume that we are given a couple of special (x, y) coordinates along with color data at every vertex. We would like to draw markers at the positions and choose individual colors depending on the color data.

Importing the Data File

We assume that our input data is given as a table containing much more columns than we need. The first couple of rows are as follows:

```
# ordering=colwise,  basis=BASIS_HAT_HIER, number points=1657,
# (max)level(s): (7,8), domain=[0,1] x [0,6.2831853]
x_0             x_1             f(x)            l_0             i_0
0               0               0               0               0
0               0.024543693     -0.00054758064  0               0
0               0.049087385     -0.0021903226   0               0
0               0.073631078     -0.00054758064  0               0
0               0.09817477      -0.0095006552   0               0
```

What we need is the first and second column to get the x and y coordinate values, respectively, and the third column `f(x)` to choose color values. The color values are very small and have a high range: there are values of order 10^{-6} and there are values of order 1. Such ranges are best shown on a logarithmic scale, which is why we will resort to some logarithmic scale on the absolute values of this column. Thus, a requirement will be to accept a math expression (involving logs) on the color data column.

Note that the data file (and all others referenced in this manual) are shipped with PGFPLOTS; you can find them in the subfolder `doc/latex/pgfplots/plotdata`.

We learned already how to read table data from a file, so our first step is relatively straight–forward.
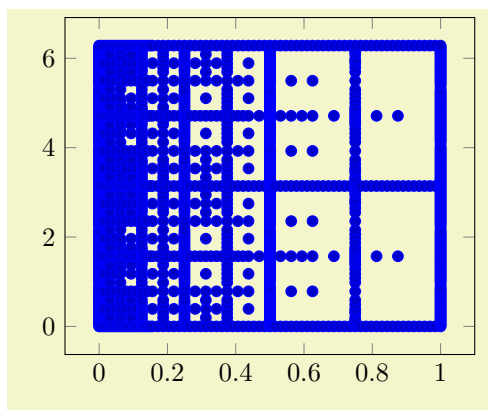

```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
\begin{axis}
\addplot+[only marks] table
    {concat_VV_together_grid.dat};
\end{axis}
\end{tikzpicture}
```

Here, the only non–trivial variation is the option `only marks` which is given after the plus sign. Keep in mind that `\addplot+[⟨options⟩]` means that PGFPLOTS shall combine the set of options of its `cycle list` with ⟨options⟩. In our case, `only marks` does what it says. The `only marks` plot handler is the most simple scatter plot: it uses the same color for every marker.

Note that `\addplot table` takes the first column as `x` and the second as `y` (which matches our input file perfectly).

Fine Tuning

We agree that our initial import has unsuitable displayed limits: there is too much white space around the interesting plot area. In addition, the markers overlap because they are too large. We can modify the appearance as follows:
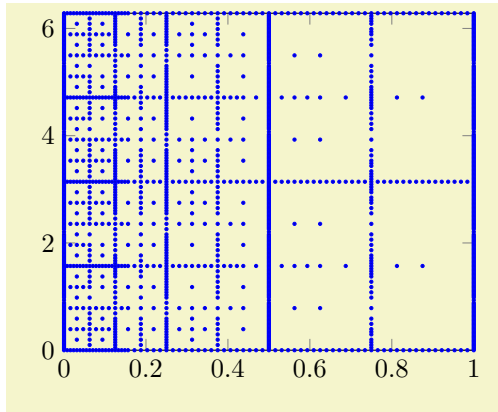
```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
\begin{axis}[
    enlargelimits=false,
]
\addplot+[only marks,mark size=0.6pt]
    table {concat_VV_together_grid.dat};
\end{axis}
\end{tikzpicture}
```

As before, we assume that we add more options after \begin{axis}. Consequently, we introduced suitable indentation and a trailing comma after the option. Note that enlargelimits is typically active; it means that PGFPLOTS increases the displayed range by 10% by default. Deactivating it produces tight limits according to the input data.

Our second option is mark size – using an absolute size (about the radius or half size of the marker).

Color Coding According To Input Data

We are quite close to our goal, except for the colors. As discussed, our input file contains three columns and the third one should be used to provide color information. In our case, the data file has a column named f(x).


```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
\begin{axis}[
    enlargelimits=false,
    colorbar,
]
\addplot+[
    only marks,
    scatter,
    point meta={ln(1e-6+abs(\thisrow{f(x)}))/ln(10)},
    mark size=0.6pt,
]
table
    {concat_VV_together_grid.dat};
\end{axis}
\end{tikzpicture}
```
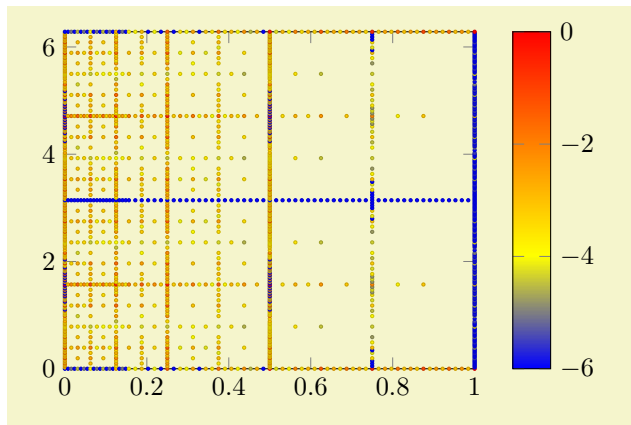
We added a couple of options to our example: the options scatter, and point meta, colorbar. The option scatter has a slightly misleading name as we already had a scatter plot before we added that option. It activates scatter plots with individual appearance: without further options, it chooses individual colors for every marker. The "individual colors" are based on something which is called "point meta" in PGFPLOTS. The point meta is typically a scalar value for every input coordinate. In the default configuration , it is interpreted as "color data" for the coordinate in question. This also explains the other option: point meta=... tells PGFPLOTS which values are to be used to determine colors. Note that the default value

of `point meta` is to use the y coordinate. In our case, we have a complicated math expression which is related to our input file: it contains small quantities in column `f(x)` which are based shown on a logarithmic scale as their differ over a huge range. Since a logarithm must not have a non-positive argument, we have $10^{-6} + \mathrm{abs}(\cdots)$ as expression which ensures that the argument is never smaller than `10^{-6}` and that is is positive. The divider `/ln(10)` means that we have logarithms base 10. But the key point of the whole complicated expression can be summarized as follows:

1. We can use `\thisrow{⟨column name⟩}` to refer to table columns. Here, "this row" means to evaluate the table for the "data point which is being read from the current row".

2. We can combine `\thisrow` with any complicated math expression.

The third new option `colorbar` activates the color bar on the right hand side (as you guessed correctly). We see that the smallest value is -6 which corresponds to our value `1e-6` in the math expression.

   You might wonder how a scalar value (the number stored in the `f(x)` column) results in a color. PGFPLOTS computes the minimum and maximum value of all such numbers. Then, it maps every number into a `colormap`. A `colormap` defines a couple of colors and interpolates linearly between such colors. That means that the smallest value of `point meta` is mapped to the first color in a `colormap` whereas the largest value of `point meta` is mapped to the last color in the `colormap`. All others are mapped to something in–between.

   More information about `colormap` and `point meta` can be found in Section 4.7.6 and in Section 4.8.

3.4.2   Scatter Plot Use–case B

As already mentioned, there are various use–cases for scatter plots. The default configuration of the `scatter` key is to read numeric values of `point meta` and choose colors by mapping that value into the current `colormap`.

   A different application would be to expect symbolic input (some string) and choose different markers depending on that input symbol.

   Suppose that you are given a sequence of input coordinates of the form (x, y) ⟨*class label*⟩ and that you want to choose marker options depending on the ⟨*class label*⟩. A PGFPLOTS solution could be
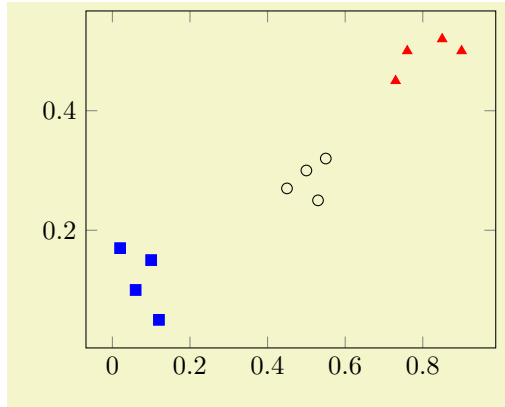

```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
\begin{axis}

\addplot[
    scatter,
    only marks,
    point meta=explicit symbolic,
    scatter/classes={
      a={mark=square*,blue},%
      b={mark=triangle*,red},%
      c={mark=o,draw=black}},
]
table[meta=label] {
    x       y       label
    0.1     0.15    a
    0.45    0.27    c
    0.02    0.17    a
    0.06    0.1     a
    0.9     0.5     b
    0.5     0.3     c
    0.85    0.52    b
    0.12    0.05    a
    0.73    0.45    b
    0.53    0.25    c
    0.76    0.5     b
    0.55    0.32    c
};
\end{axis}
\end{tikzpicture}
```

As in our previous use–case in Section 3.4.1, we have the options `scatter`, `only marks`, and a configuration how to retrieve the `point meta` values by means of the `meta` key. One new key is `point meta`=explicit symbolic: it tells PGFPLOTS that any encountered values of `point meta` are to be interpreted as string symbols. Furthermore, it tells PGFPLOTS that the every input coordinate comes with an explicit value (as opposed to a common math expression, for example). The other different option is `scatter/classes`. As

you guessed from the listing, it is a map from string symbol to marker option list. This allows to address such use–cases in a simple way.

This example has actually been replicated from the reference manual section for `scatter/classes`.

3.4.3 Scatter Plot Use–case C

Finally, this tutorial sketches a further use–case for scatter plots: given a sequence of coordinates (x, y) with individual string labels, we want to draw the string label at the designated positions.

This can be implemented by means of the `nodes near coords` feature of PGFPLOTS, which is actually based on `scatter`:


```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
\begin{axis}[
    enlargelimits=0.2,
]
\addplot+[nodes near coords,only marks,
    point meta=explicit symbolic]
table[meta=label] {
    x    y   label
    0.5  0.2 1
    0.2  0.1 t2
    0.7  0.6 3
    0.35 0.4 Y4
    0.65 0.1 5
};
\end{axis}
\end{tikzpicture}
```
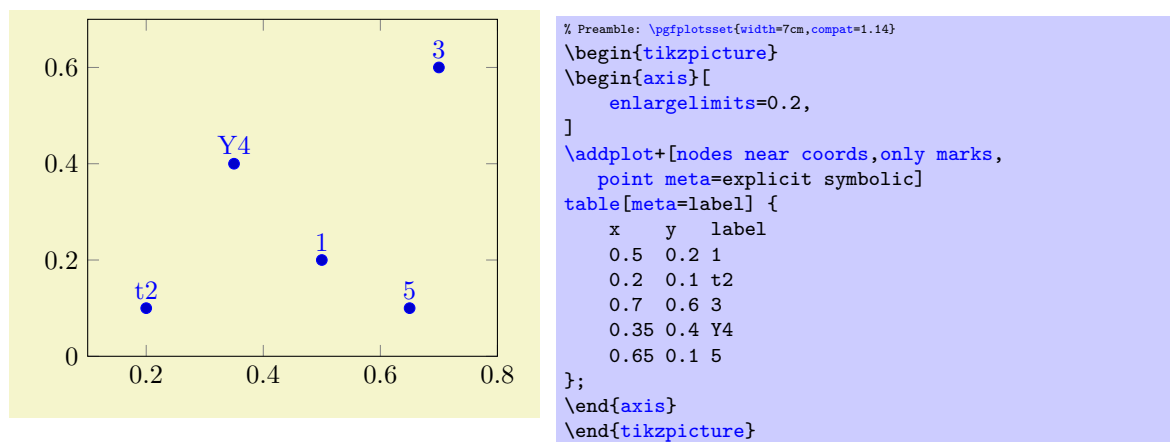
In this case, we have `point meta`=explicit symbolic in order to express the fact that our labels are of textual form (see the reference manual section for `nodes near coords` for applications of *numeric* labels). The remaining stuff is done by the implementation of `nodes near coords`. Note that enlarged the axis limits somewhat in order to include the text nodes in the visible area.

There is much more to say about `scatter` plots, and about `nodes near coords`. Please consider this subsection as a brief pointer to Section 4.5.12 in the reference manual.

3.4.4 Summary

We learned how to generate scatter plots with single color using `only marks`, scatter plots with individually colored markers using the `scatter` key, scatter plots with specific marker styles depending on some class label using `scatter/classes` and text nodes using `nodes near coords`.

Furthermore, we introduced the concept of "`point meta` data": once as (scalar valued) color data, once as symbolic class label and once as text label.

There is much more to say, especially about `point meta` which is introduced and explained in all depth in Section 4.8.

There is also more to say about `scatter` plots, for example how to generate scatter plots with individually sized markers and/or colors (by relying on `\pgfplotspointmetatransformed`, see the reference manual section for `visualization depends on`). In addition, `scatter` plots can be customized to a high degree which is explained in Section 4.5.12.

3.5 Solving a Real Use–Case: Functions of Two Variables

In this tutorial, we assume that we have two functions for which we seek a plot: the first is a sampled function given by a huge data file and the second is the math expression $g(x, y) = \exp(-x^2 - y^2) \cdot x$.

Our first function actually consists of two data files: the first file contains some scattered data which is used to discretized ("sample") a function and the second file contains data for the function as such. Our requirement here is two draw *two* graphs into the same axis: one in which the function is plotted as a smooth, colored surface and one in which the scattered data file should be on top of the surface because it provides more detail how the function was represented in the computer.

The second function which is given as math expression should be visualized using a contour plot.

3.5.1   Surface Plot from Data File

Our first step is to load the data file and to plot a surface.

Clearly, functions of two variables require a more sophisticated input format: they are typically sampled on a unified grid with $n \times m$ points, i.e. n points for x and m points for y, resulting in a total of matrix with $n \cdot m$ values $f_{ij} = f(x_i, y_i)$. How can we read matrix data? And what if you have more than just the z value? A standard way is to write the matrix to a table, either in row–wise ordering or in column–wise ordering (both are common).

Here, we assume that our function values are written to a table in which the y values vary from line to line. Here is an extract of the data file (which is too large to list it here):

```
# ordering=colwise,   number points=1089,
# (max)level(s): (5,5), domain=[0,1] x [0,6.2831853]
x_0             x_1             f(x)            l_0             i_0
0               0               0               0               0
0               0.19634954      0.038239818     0               0
0               0.39269908      0.14662768      0               0
⋮
0               5.8904862       0.14662768      0               0
0               6.0868358       0.038239818     0               0
0               6.2831853       6.9388939e-18   0               0

0.03125         0               3.0517578e-05   5               1
0.03125         0.19634954      0.030093496     5               1
0.03125         0.39269908      0.1146012       5               1
0.03125         0.58904862      0.24129102      5               1
0.03125         0.78539816      0.38946059      5               1
0.03125         0.9817477       0.53949733      5               1
⋮
```

Note that the data file (and all others referenced in this manual) are shipped with PGFPLOTS; you can find them in the subfolder doc/latex/pgfplots/plotdata.

The input file contains x_0, x_1, and $f(x_0, x_1)$ in columns named x_0, x_1, and f(x), respectively. In addition, it contains some meta data which is irrelevant for us here.

Note that our input file contains *empty lines* whenever x_0 changes. This is a common data format which simplifies the detection of "scanline length". A scanline is one line in the input matrix, for example the line consisting of all points with $x_0 = 0$. With such scanlines, PGFPLOTS can automatically deduce the size of the input matrix.

In order to plot the file as a surface, we proceed as in the previous example by using \addplot table. However, we have to use \addplot3 to indicate that a three–dimensional result is expected:
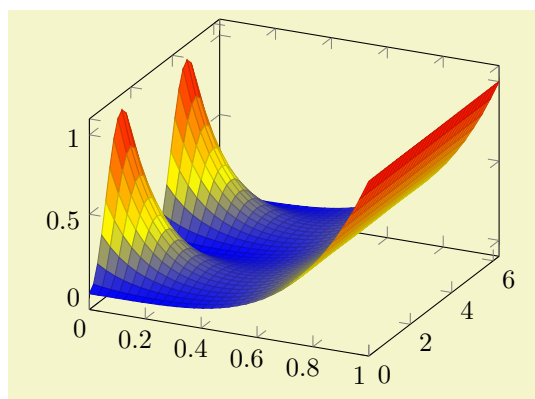

```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
\begin{axis}
\addplot3[surf,mesh/ordering=y varies]
    table {concat_VV_together.dat};
\end{axis}
\end{tikzpicture}
```

The example looks familiar compared to our results of the preceding tutorials: a tikzpicture environment containing an axis environment and the mentioned \addplot3 command. The option list contains surf, which tells PGFPLOTS how to visualize the input data. The key mesh/ordering=y varies tells PGFPLOTS how to decode the input matrix. This is important; otherwise PGFPLOTS would have chosen x varies which does not match our file.

Note that we there is no need to configure either mesh/rows=$\langle N \rangle$ or mesh/cols=$\langle N \rangle$ here because these parameters are automatically deduced from the scan line lengths marked by empty lines in our input file.

Since our `\addplot3 table` statement does not contain any hints which columns should be plotted, PGFPLOTS simply plots the first three columns against each other.

The colors of a `surf` plot are chosen from the function values (unless you configure some other value for `point meta`; this is similar to the scatter plot example). In case of a function of two variables, the function value is the third column.

3.5.2 Fine–Tuning

In order to stress how colors are to be mapped to values, we add a color bar. In addition, we rotate the view a little bit and add axis labels. Furthermore, we would like to have a smooth color mapping.

We end up at
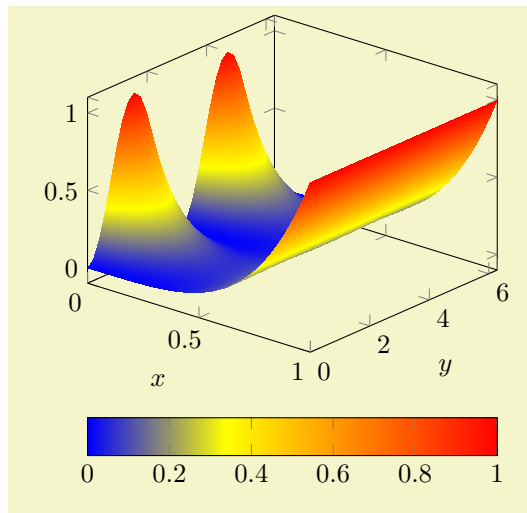

```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
\begin{axis}[
    view/h=40,
    colorbar horizontal,
    xlabel=$x$, ylabel=$y$,
]
\addplot3[surf,mesh/ordering=y varies,
    shader=interp]
    table {concat_VV_together.dat};
\end{axis}
\end{tikzpicture}
```

Here, `view/h` rotates the "horizontal" parts of the view (only). It chooses a new view angle for the orthographic projection. As you guessed, there is also a `view/v` key and a `view={⟨h⟩}{⟨v⟩}` variant.

The key `colorbar horizontal` is a style which activates a `colorbar` and configures it to be displayed horizontally. The labels are placed using `xlabel` and `ylabel` as we saw it before for visualizations of one–dimensional functions. A Colorbar uses the current `colormap` and adds axis descriptions to show how values are mapped to colors.

The `shader=interp` key activates a smooth color interpolation.

3.5.3 Adding Scattered Data on Top of the Surface

As motivated earlier, we have a second data set, one which characterizes how the function has been represented in some computer simulation. We would like to add the second data set as scatter plot on top of the function.

The data set as such is the very same as the one used in Section 3.4.1, so we do not need to list it here again. However, we have to include the two–dimensional scatter data into the three–dimensional axis in a suitable way. We chose to place it on a fixed z value as follows:
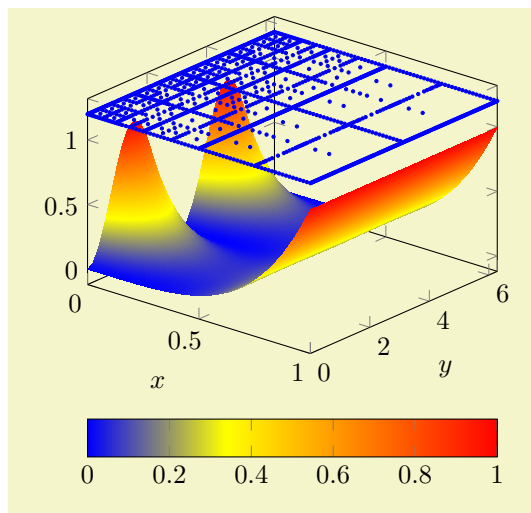
```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
\begin{axis}[
    view/h=40,
    colorbar horizontal,
    xlabel=$x$, ylabel=$y$,
]
\addplot3[surf,mesh/ordering=y varies,
    shader=interp]
    table {concat_VV_together.dat};

\addplot3[blue,mark=*,
    mark options={fill=blue!80!black},
    only marks,mark size=0.6pt]
table[z expr=1.2]
    {concat_VV_together_grid.dat};
\end{axis}
\end{tikzpicture}
```

Now, we have two `\addplot3 table` statements in the same axis. None of them uses the `cycle list` as we used explicit option lists. The first is our surface plot. Note that it is plotted before the scatter plot: PGFPLOTS cannot handle depth information between adjacent `\addplot` statements. It does, however, handle `z buffer` information for data of a single `\addplot` statement. The second plot is our scatter plot: we recognize `only marks` and `mark size` from Section 3.4.1. In addition, we configured some color and marker options.

An important aspect is `\addplot3 table[z expr=1.2]` – it tells PGFPLOTS how to choose z values for the input file (otherwise, PGFPLOTS would have used the third column of that file). This is a convenient way to insert two–dimensional data into a three–dimensional axis, provided you have *table* data. There is also a different way which works for both tables and math expressions (or other input types). This different way is to install a `z filter`, but that is beyond the scope of this tutorial for now.

3.5.4   Computing a Contour Plot of a Math Expression

This section addresses the second part of our use–case example: a function of two variables given by a math expression.

Our function of interest is $x \exp(-x^2 - y^2)$. We start as in our tutorial for one–dimensional functions given by a math expression (compare Section 3.2.3): by using an `\addplot` statement which is followed by a math expression in curly braces. However, we rely on `\addplot3` as in the preceding section:
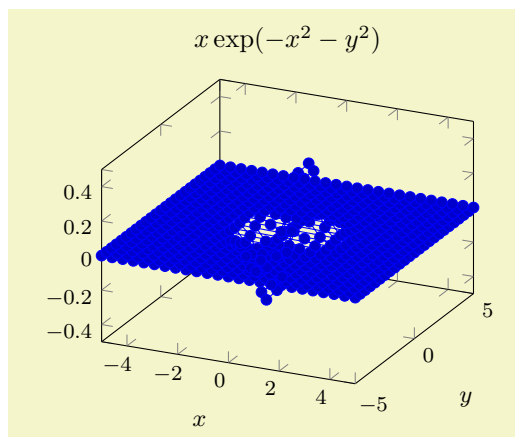

```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
\begin{axis}[
    title={$x \exp(-x^2-y^2)$},
    xlabel=$x$, ylabel=$y$,
    small,
]
\addplot3
    {exp(-x^2-y^2)*x};
\end{axis}
\end{tikzpicture}
```

Our example contains a basic axis environment with `title`, `xlabel`, `ylabel` and the `small` key which are already known from the preceding tutorials. The `\addplot3` has no options and is immediately followed by the math expression. The absence of options tells PGFPLOTS to rely on its `cycle list`. This, in turn configures `mark=*` with `blue` color – and a line plot. A line plot combined with `\addplot3` is of limited use; it merely connects all incoming points. Since points are sampled as a matrix (line–by–line). Our next step will be to define a suitable plot handler.

Note, however, that our math expression depends on `x` and `y`. These two variables are the sampling variables of PGFPLOTS in its default configures: both are sampled in the `domain` of interest using the correct

number of `samples`. The `\addplot`3 statement takes care of computing $N \cdot M$ points in the correct sequence where N is the number of `samples` for x and M is `samples y`, the number of samples used for y.

We can see that our sampling `domain` is too large. Switching to a smaller `domain` focusses on the interesting parts of our function:

```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
\begin{axis}[
    title={$x \exp(-x^2-y^2)$},
    xlabel=$x$, ylabel=$y$,
    small,
]
\addplot3[
    surf,
    domain=-2:2,
    domain y=-1.3:1.3,
]
    {exp(-x^2-y^2)*x};
\end{axis}
\end{tikzpicture}
```

Here, we introduced an option list after `\addplot`3. Since we provided the option list without the leading plus sign '`+`', PGFPLOTS does not consider its `cycle list` at all (and switches off `mark`s and the default color settings). We added `domain` and `domain y` in order to restrict the sampling domain in a suitable way. If we would have omitted `domain y`, the y domain would use the same value as the x `domain`.

As you might have guessed, the `surf` key has the main use–case of providing a connection to the previous tutorial section: it is one of the natural visualizations for functions of two variables. As in the preceding section, the color has been deduced from the function value $z = f(x, y)$ (more precisely, by relying on the default configuration `point meta=f(x)`).

The next step is to switch to contour plots by replacing '`surf`' by '`contour gnuplot`':

```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
\begin{axis}[
    title={$x \exp(-x^2-y^2)$},
    xlabel=$x$, ylabel=$y$,
    small,
]
\addplot3[
    contour gnuplot,
    domain=-2:2,
    domain y=-1.3:1.3,
]
    {exp(-x^2-y^2)*x};
\end{axis}
\end{tikzpicture}
```

Now, we have a contour plot – although it is not quite what we had in mind. First, there are so few contour lines that it is hard to see anything (especially since the `line width` is too small). Furthermore, the `view` direction is unfamiliar.

We add the `view` option with the argument for "view from top" and configure the number of contour lines using the `contour/number` key and the `line width` using the `thick` style:
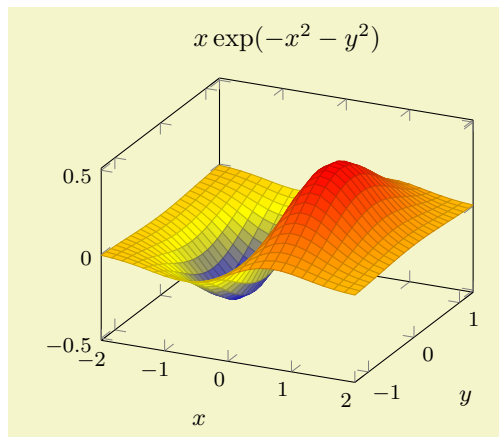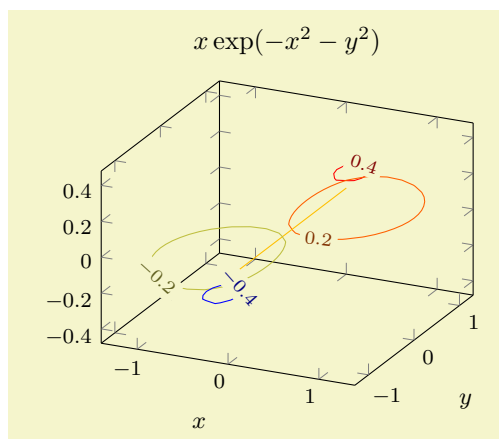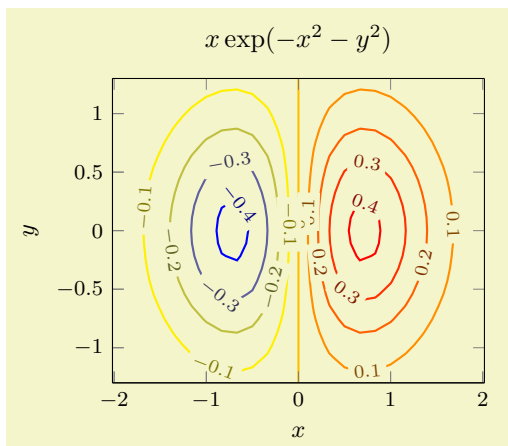
```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
\begin{axis}[
    title={$x \exp(-x^2-y^2)$},
    enlarge x limits,
    view={0}{90},
    xlabel=$x$, ylabel=$y$,
    small,
]
\addplot3[
    domain=-2:2,
    domain y=-1.3:1.3,
    contour gnuplot={number=14},
    thick,
]
    {exp(-x^2-y^2)*x};
\end{axis}
\end{tikzpicture}
```

This is what we wanted to achieve. Note that `contour gnuplot` accepts options which have the key prefix `contour/`. In this context, the prefix is optional.

Note that `contour gnuplot` is different from almost all other plot handlers of PGFPLOTS with respect to one aspect: it relies on an *external* tool to compute coordinates whereas all other PGFPLOTS plot handlers depend on TeX alone and do not need 3rd party tools. The non–linear algorithm to compute contour lines is currently unavailable in PGFPLOTS which is stressed by the name '`contour gnuplot`'. Consequently, you can only reproduce the example if you have `gnuplot` installed. PGFPLOTS invokes the executable name '`gnuplot`', i.e. the executable must be on your search path (the `PATH` environment variable must contain it). And, more importantly, you have to tell LaTeX that it is allowed to launch 3rd party executables while processing your `.tex` file. Typically, you have to add the argument `-shell-escape` to your TeX executable, i.e. one of

    `latex -shell-escape` ⟨*texfilename*⟩

or

    `pdflatex -shell-escape` ⟨*texfilename*⟩

or

    `lualatex -shell-escape` ⟨*texfilename*⟩

or

    `xelatex -shell-escape` ⟨*texfilename*⟩.

Note that it is occasionally named in a different way like "`-enable-write18`". The interaction with `gnuplot` is controlled by means of temporary input- and output files.

Note that `contour gnuplot` and `\addplot gnuplot` are two ways to extend the built-in capabilities of PGFPLOTS by means of `gnuplot`'s math library, although their use is optional.

3.5.5 Summary

We have sketched how to load a data table containing a sampled function of two variables, and we learned how to visualize such data as `surf`ace plot. We learned how to rotate the `view`, how to change the color `shader` of `surf`ace plots, how to enabled `colorbar`s, and how to add `scatter` plots on top of surface plots. Furthermore, we encountered the first contour plot as an example for how to sample a function of two variables by means of builtin methods of PGFPLOTS.

It should be stressed that PGFPLOTS needs no external tool to generate such plots (except for `contour gnuplot` which is the only exception): every computer with a decent version of PGFPLOTS can regenerate these plots.

There is more to say about three–dimensional axes, in particular regarding `mesh/ordering`, parametric plots, perhaps line plots in three dimensions or other plot types. Furthermore, there are some limitations regarding the `z buffer`ing, i.e. how PGFPLOTS decides which parts of the figure are in front of others. These items can be read in Section 4.6 and its sub–sections.

You might also be interested in styles to change the appearance of a three–dimensional axis, compare Section 4.11.

Chapter 4

The Reference

4.1 TEX-dialects: LaTeX, ConTEXt, plain TEX

The starting point for PGFPLOTS is an `axis` enviroment like `axis` or the logarithmic variants `semilogxaxis`, `semilogyaxis` or `loglogaxis`.

Each environment is available for LaTeX, ConTEXt and plain TEX:

LaTeX: \usepackage{pgfplots} \pgfplotsset{compat=1.14} and

```
\begin{tikzpicture}
\begin{axis}
...
\end{axis}
\end{tikzpicture}
```

```
\begin{tikzpicture}
\begin{semilogxaxis}
...
\end{semilogxaxis}
\end{tikzpicture}
```

Here, the \pgfplotsset{compat=1.14} key should be set to at least version 1.3. Otherwise PGF-PLOTS assumes that your document has been generated years ago and attempts to run in backwards compatibility mode as good as it can.

Since LaTeX is the default for many people, this manual only shows LaTeX examples. A full document sceleton can be found below this enumeration.

ConTEXt: \usemodule[pgfplots] \pgfplotsset[compat=1.14] and

```
\starttikzpicture
\startaxis
...
\stopaxis
\stoptikzpicture
```

```
\starttikzpicture
\startsemilogxaxis
...
\stopsemilogxaxis
\stoptikzpicture
```

A complete ConTEXt–example file can be found in

```
doc/context/pgfplots/pgfplotsexample.tex.
```

plain TEX: \input pgfplots.tex \pgfplotsset{compat=1.14} and

```
\tikzpicture
\axis
...
\endaxis
\endtikzpicture
```

```
\tikzpicture
\semilogxaxis
...
\endsemilogxaxis
\endtikzpicture
```

A complete plain–TEX–example file can be found in

```
doc/plain/pgfplots/pgfplotsexample.tex.
```

For LaTeX, a complete example will look somehow like this:

```
\documentclass[a4paper]{article}

% for dvipdfm:
%\def\pgfsysdriver{pgfsys-dvipdfm.def}
\usepackage{pgfplots}
\pgfplotsset{compat=1.6}% <-- moves axis labels near ticklabels (respects tick label widths)

\begin{document}
\begin{figure}
    \centering
    \begin{tikzpicture}
        \begin{loglogaxis}[xlabel=Cost,ylabel=Error]
        \addplot coordinates {
            (5,      8.31160034e-02)
            (17,     2.54685628e-02)
            (49,     7.40715288e-03)
            (129,    2.10192154e-03)
            (321,    5.87352989e-04)
            (769,    1.62269942e-04)
            (1793,   4.44248889e-05)
            (4097,   1.20714122e-05)
            (9217,   3.26101452e-06)
        };
        \addplot coordinates {
            (7,      8.47178381e-02)
            (31,     3.04409349e-02)
            (111,    1.02214539e-02)
            (351,    3.30346265e-03)
            (1023,   1.03886535e-03)
            (2815,   3.19646457e-04)
            (7423,   9.65789766e-05)
            (18943, 2.87339125e-05)
            (47103, 8.43749881e-06)
        };
        \legend{Case 1,Case 2}
        \end{loglogaxis}
    \end{tikzpicture}
    \caption{A larger example}
\end{figure}
\end{document}
```

If you use `latex` / `dvips` or `pdflatex`, no further modifications are necessary. For `dvipdfm`, you should use the `\def\pgfsysdriver` line as indicated above in the examples (see also Section 2.6.3).

4.2   The Axis-Environments

There is an axis environment for linear scaling, two for semi-logarithmic scaling and one for double-logarithmic scaling.

\begin{tikzpicture}[⟨options of tikz⟩]
    ⟨environment contents⟩
\end{tikzpicture}

This is the graphics environment of TikZ. It produces a single picture and encloses also every axis.

Instead of using the environment version, there is also a shortcut command

\tikz{⟨picture content⟩}

which can be used alternatively.

\begin{axis}[⟨options⟩]
    ⟨environment contents⟩
\end{axis}

The axis environment for normal plots with linear axis scaling.

The 'every linear axis' style key can be modified with

```
\pgfplotsset{every linear axis/.append style={...}}
```

to install styles specifically for linear axes. These styles can contain both TikZ- and PGFPLOTS options.

\begin{semilogxaxis}[⟨*options*⟩]
  ⟨*environment contents*⟩
\end{semilogxaxis}

The axis environment for logarithmic scaling of x and normal scaling of y. Use

```
\pgfplotsset{every semilogx axis/.append style={...}}
```

to install styles specifically for the case with xmode=log, ymode=normal.

The logarithmic scaling means to apply the natural logarithm (base e) to each x coordinate. Furthermore, ticks will be typeset as $10^{⟨exponent⟩}$, see Section 4.13 for more details.

\begin{semilogyaxis}[⟨*options*⟩]
  ⟨*environment contents*⟩
\end{semilogyaxis}

The axis environment for normal scaling of x and logarithmic scaling of y,

The style 'every semilogy axis' will be installed for each such plot.

The same remarks as for semilogxaxis apply here as well.

\begin{loglogaxis}[⟨*options*⟩]
  ⟨*environment contents*⟩
\end{loglogaxis}

The axis environment for logarithmic scaling of both, x and y axes. As for the other axis possibilities, there is a style 'every loglog axis' which is installed at the environment's beginning.

The same remarks as for semilogxaxis apply here as well.

They are all equivalent to

```
\begin{axis}[
    xmode=log|normal,
    ymode=log|normal]
...
\end{axis}
```

with properly set variables 'xmode' and 'ymode' (see below).

4.3 The \addplot Command: Coordinate Input
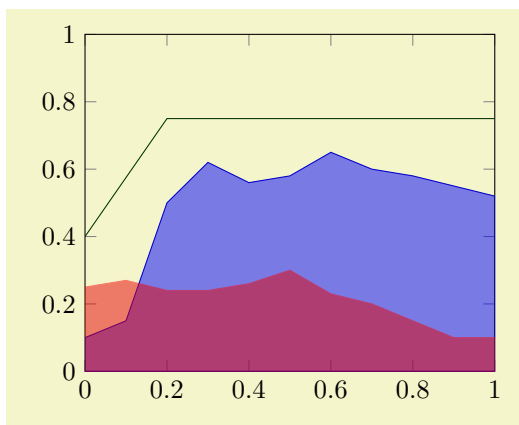

```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
\begin{axis}[ymin=0,ymax=1,enlargelimits=false]
\addplot
    [blue!80!black,fill=blue,fill opacity=0.5]
coordinates
{(0,0.1)    (0.1,0.15)  (0.2,0.5)   (0.3,0.62)
 (0.4,0.56) (0.5,0.58)  (0.6,0.65)  (0.7,0.6)
 (0.8,0.58) (0.9,0.55)  (1,0.52)}
|- (0,0) -- cycle;

\addplot
    [red,fill=red!90!black,opacity=0.5]
coordinates
{(0,0.25)   (0.1,0.27)  (0.2,0.24)  (0.3,0.24)
 (0.4,0.26) (0.5,0.3)   (0.6,0.23)  (0.7,0.2)
 (0.8,0.15) (0.9,0.1)   (1,0.1)}
|- (0,0) -- cycle;

\addplot[green!20!black] coordinates
    {(0,0.4) (0.2,0.75) (1,0.75)};
\end{axis}
\end{tikzpicture}
```
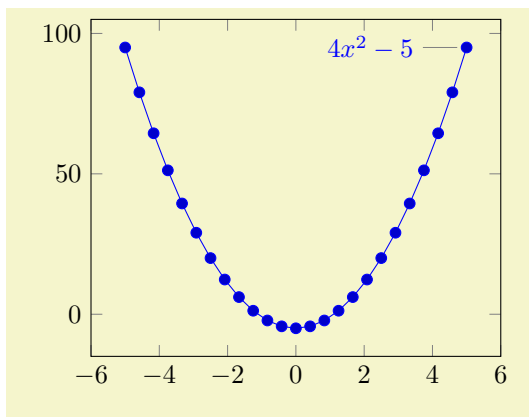
```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
\begin{axis}
\addplot+[id=parable,domain=-5:5]
    gnuplot{4*x**2 - 5}
    node[pin=180:{$4x^2-5$}]{};
\end{axis}
\end{tikzpicture}
```
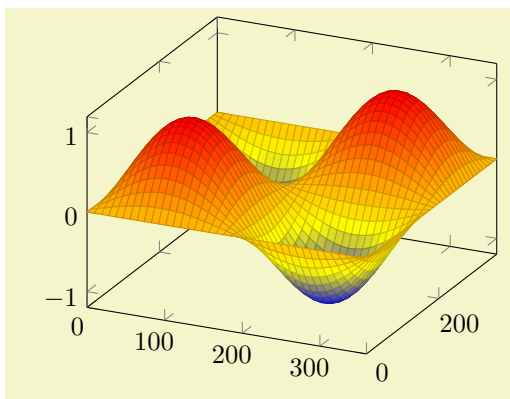


```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
    \begin{axis}[surf,domain=0:360,samples=40]
    \addplot3[surf,domain=0:360,samples=40]
        {sin(x)*sin(y)};
    \end{axis}
\end{tikzpicture}
```
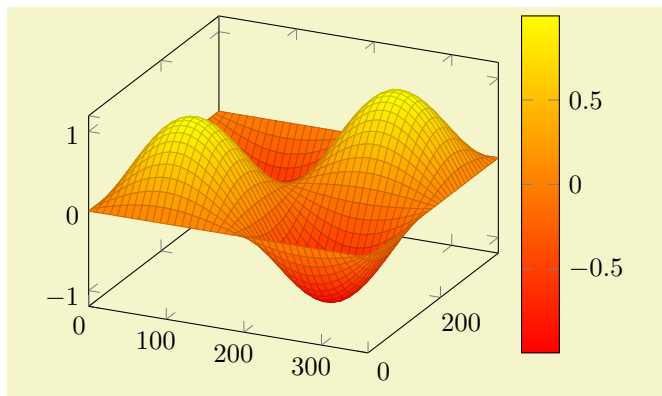


```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
    \begin{axis}[colormap/redyellow,colorbar]
    \addplot3[surf,
        domain=0:360,samples=40]
        {sin(x)*sin(y)};
    \end{axis}
\end{tikzpicture}
```
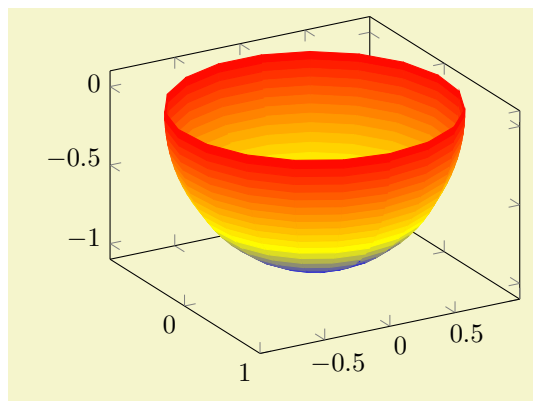
```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
\begin{axis}[view={60}{30}]
    \addplot3[surf,shader=flat,
        samples=20,
        domain=-1:0,y domain=0:2*pi,
        z buffer=sort]
        ({sqrt(1-x^2) * cos(deg(y))},
         {sqrt( 1-x^2 ) * sin(deg(y))},
         x);
\end{axis}
\end{tikzpicture}
```

Inside of an axis environment, the \addplot command is the main user interface. It comes in two variants: \addplot for two–dimensional visualization and \addplot3 for three–dimensional visualization.

\addplot[⟨options⟩] ⟨input data⟩ ⟨trailing path commands⟩;

This is the main plotting command, available within each axis environment. It can be used one or more times within an axis to add plots to the current axis. There is also an \addplot3 command which is described in Section 4.6.

It reads point coordinates from one of the available input sources specified by ⟨input data⟩, updates limits, remembers ⟨options⟩ for use in a legend (if any) and applies any necessary coordinate transformations (or logarithms).

The ⟨options⟩ can be omitted in which case the next entry from the cycle list will be inserted as ⟨options⟩. These keys characterize the plot's type like linear interpolation with sharp plot, smooth plot, constant interpolation with const plot, bar plot, mesh plots, surface plots or whatever and define colors, markers and line specifications[1]. Plot variants like error bars, the number of samples or a sample domain can also be configured in ⟨options⟩.

The ⟨input data⟩ is one of several coordinate input tools which are described in more detail below. Finally, if \addplot successfully processed all coordinates from ⟨input data⟩, it generates TikZ paths to realize the drawing operations. Any ⟨trailing path commands⟩ are appended to the final drawing command, allowing to continue the TikZ path (from the last plot coordinate).

Some more details:

- The style /pgfplots/every axis plot will be installed at the beginning of ⟨options⟩. That means you can use

  ```
  \pgfplotsset{every axis plot/.append style={...}}
  ```

  to add options to all your plots - maybe to set line widths to thick. Furthermore, if you have more than one plot inside of an axis, you can also use

  ```
  \pgfplotsset{every axis plot no 3/.append style={...}}
  ```

  to modify options for the plot with number 3 only. The first plot in an axis has number 0.

- The ⟨options⟩ are remembered for the legend. They are available as 'current plot style' as long as the path is not yet finished or in associated error bars.

- See Subsection 4.7 for a list of available markers and line styles.

- For log plots, PGFPLOTS will compute the natural logarithm $\log(\cdot)$ numerically using a floating point unit developed for this purpose[2]. For example, the following numbers are valid input to \addplot.

---

[1]In version 1.2.2 and earlier, there was an explicit distinction between "behaviour" options like error bars, domain, number of samples etc. and "style options" like color, line width, markers etc. This distinction is obsolete now, simply collect everything into ⟨options⟩.

[2]This floating point unit is available as TikZ library as part of TikZ.
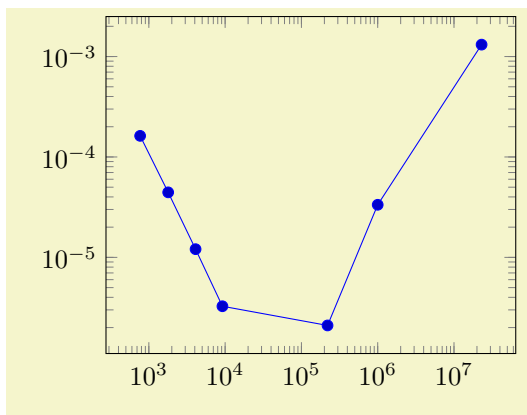
```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
\begin{loglogaxis}
\addplot coordinates {
    (769,    1.6227e-04)
    (1793,   4.4425e-05)
    (4097,   1.2071e-05)
    (9217,   3.2610e-06)
    (2.2e5, 2.1E-6)
    (1e6,    0.00003341)
    (2.3e7, 0.00131415)
};
\end{loglogaxis}
\end{tikzpicture}
```

You can represent arbitrarily small or very large numbers as long as its logarithm can be represented as a TeX-length (up to about 16384). Of course, any coordinate $x \leq 0$ is not possible since the logarithm of a non-positive number is not defined. Such coordinates will be skipped automatically (using the initial configuration unbounded coords=discard).

- For normal (non–logarithmic) axes, PGFPLOTS applies floating point arithmetics to support large or small numbers like 0.00000001234 or $1.234 \cdot 10^{24}$. Its number range is much larger than TeX's native support for numbers. The relative precision is between 4 and 7 significant decimal digits for the mantissa.

  As soon as the axes limits are completely known, PGFPLOTS applies a transformation which maps these floating point numbers into TeX-precision using transformations

$$T_x(x) = 10^{s_x} \cdot x - a_x \text{ and } T_y(y) = 10^{s_y} \cdot y - a_y \text{ and (for 3D plots) } T_z(y) = 10^{s_z} \cdot z - a_z$$

  with properly chosen integers $s_x, s_y, s_z \in \mathbb{Z}$ and shifts $a_x, a_y, a_z \in \mathbb{R}$. Section 4.25 contains a description of disabledatascaling and provides more details about the transformation.

- Some of the coordinate input routines use the powerful \pgfmathparse feature of PGF to read their coordinates, among them plot coordinates, plot expression and plot table. This allows to use mathematical expressions as coordinates which will be evaluated using the floating point routines (this applies to logarithmic and linear scales).

- PGFPLOTS automatically computes missing axis limits. The automatic computation of axis limits works as follows:

  1. Every coordinate will be checked. Care has been taken to avoid TeX's limited numerical capabilities.

  2. Since more than one \addplot command may be used inside of \begin{axis}...\end{axis}, all drawing commands will be postponed until \end{axis}.

\addplot+[⟨options⟩] ...;

   Does the same like \addplot[⟨options⟩] ...; except that ⟨options⟩ are *appended* to the arguments which would have been taken for \addplot ... (the element of the default list).

   Thus, you can combine cycle list and ⟨options⟩.
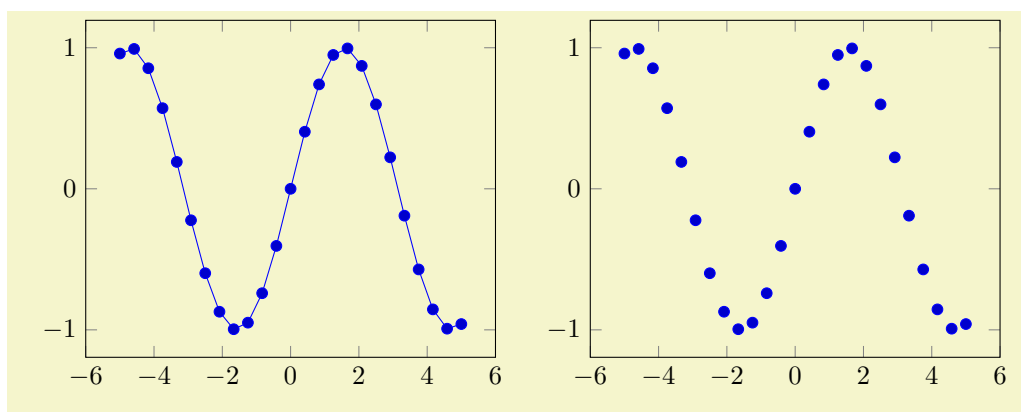
```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
\begin{axis}
\addplot {sin(deg(x))};
\end{axis}
\end{tikzpicture}

\begin{tikzpicture}
\begin{axis}
\addplot+[only marks] {sin(deg(x))};
\end{axis}
\end{tikzpicture}
```

The distinction is as follows: \addplot ... (without options) lets PGFPLOTS select colors, markers and linestyles automatically (using cycle list). The variant \addplot+[⟨option⟩] ... will use the same automatically determined styles, but in addition it uses ⟨options⟩. Finally, \addplot[⟨options⟩] (without the +) uses only the manually provided ⟨options⟩.

/pgfplots/empty line=auto|none|scanline|jump   (initially auto)

Controls how empty lines in the input coordinate stream are to be interpreted. You should ensure that you have \pgfplotsset{compat=1.4} or newer in your preamble and leave this key at its default empty line=auto.

Empty lines can occur between the coordinates of \addplot coordinates or successive rows of the data file input routines \addplot table (and \addplot file).

The choice auto checks if the current plot type is mesh or surf. If so, it uses scanline. If the current plot type is some other plot type (like a standard line plot), it uses jump. Note that the value auto for non-mesh plots results in none if compat=1.3 or older is used. In other words: you have to write \pgfplotsset{compat=1.4} or newer to let PGFPLOTS interpret empty lines as jump in standard line plots:
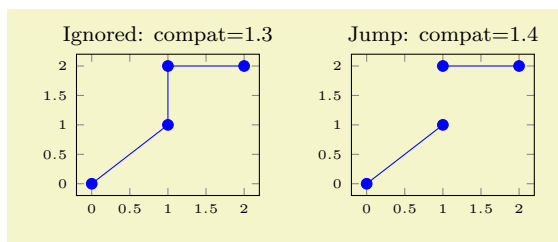

```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
    \begin{axis}[tiny,
        title={Ignored: compat=1.3},
        compat=1.3]
    \addplot table {
    A B
    0 0
    1 1

    1 2
    2 2
    };
    \end{axis}
\end{tikzpicture}
\begin{tikzpicture}
    \begin{axis}[tiny,
        title={Jump: compat=1.4},
        compat=1.4]
    \addplot table {
    A B
    0 0
    1 1

    1 2
    2 2
    };
    \end{axis}
\end{tikzpicture}
```

The choice scanline is only useful for mesh and surf: it is used to decode a matrix from a coordinate stream. If an empty line occurs once every N data points, the "scanline" length is N. This information, together with mesh/ordering and the total number of points, allows to deduce the matrix size. However, the distance between empty lines has to be consistent: if the first two empty lines have a distance of 2 and the next comes after 5, PGFPLOTS will ignore the information and will expect explicit matrix sizes using mesh/rows and/or mesh/cols. The choice scanline is ignored if mesh input=patches. It has no effect for other plot types.

The choice `none` will silently discard any empty line in the input stream.

The choice `jump` tells PGFPLOTS to generate a jump.

4.3.1   Coordinate Lists

`\addplot` **coordinates** `{⟨coordinate list⟩};`
`\addplot[⟨options⟩]` **coordinates** `{⟨coordinate list⟩} ⟨trailing path commands⟩;`
`\addplot3 ...`

The '`\addplot coordinates`' command is like that provided by TikZ and reads its input data from a sequence of point coordinates, encapsulated in round braces.
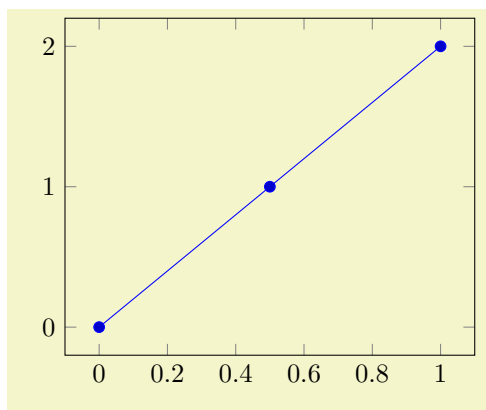
```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
\begin{axis}
\addplot coordinates {
    (0,0)
    (0.5,1)
    (1,2)
};
\end{axis}
\end{tikzpicture}
```

You should only use this input format if you have short diagrams and you want to provide mathematical expressions for each of the involved coordinates. Any data plots are typically easier to handle using a table format and `\addplot table`.

The coordinates can be numbers, but they can also contain mathematical expressions like `sin(0.5)` or `\h*8` (assuming you defined `\h` somewhere). However, expressions which involve round braces need to be encapsulated in a further set of curly braces, for example `({sin(0.5)},{cos(0.1)})`.

You can also supply error coordinates (reliability bounds) if you are interested in error bars. Simply append the error coordinates with '`+- (⟨ex,ey⟩)`' (or `+- (⟨ex,ey,ez⟩)`) to the associated coordinate:
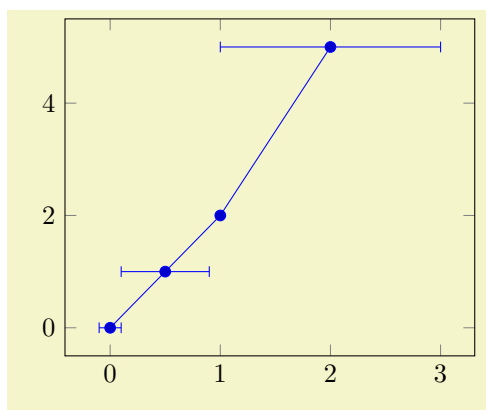
```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
\begin{axis}
\addplot+[error bars/.cd,x dir=both,x explicit]
coordinates {
    (0,0)    +- (0.1,0)
    (0.5,1) +- (0.4,0.2)
    (1,2)
    (2,5)    +- (1,0.1)
};
\end{axis}
\end{tikzpicture}
```

or

```
\addplot coordinates {
    (900,1e-6) +- (0.1,0.2)
    (2600,5e-7) +- (0.2,0.5)
    (4000,7e-8) +- (0.1,0.01)
};
```

These error coordinates are only used in case of error bars, see Section 4.12. You will also need to configure whether these values denote absolute or relative errors.

The coordinates as such can be numbers as `+5`, `-1.2345e3`, `35.0e2`, `0.00000123` or `1e2345e-8`. They are not limited to TeX's precision.

Furthermore, `coordinates` allows to define "meta data" for each coordinate. The interpretation of meta data depends on the visualization technique: for scatter plots, meta data can be used to define colors or style associations for every point (see page 112 for an example). Meta data (if any) must be provided after the coordinates and after error bar bounds (if any) in square brackets:
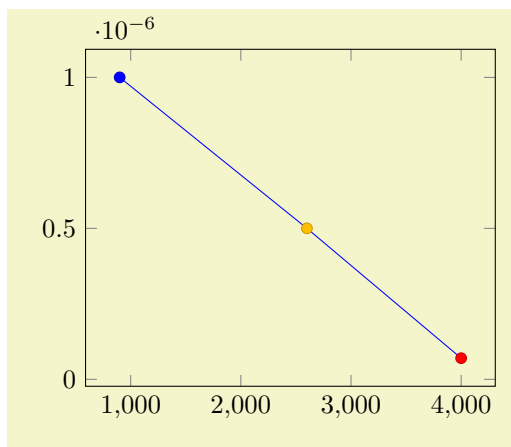

```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
\begin{axis}
\addplot+[scatter,scatter src=explicit] coordinates {
    (900,1e-6) [1]
    (2600,5e-7) [2]
    (4000,7e-8) [3]
};
\end{axis}
\end{tikzpicture}
```

Please refer to the documentation of `point meta` on page 226 for more information about per point meta data.

The coordinate stream can contain `empty line`s to tell PGFPLOTS that the function has jumps. To use it, simply insert an empty line (and ensure that you have `\pgfplotsset{compat`=1.4} or newer in your preamble). See the documentation of `empty line` for details.

/pgfplots/`plot coordinates/math parser`=true|false   (initially `true`)

Allows to turn off support for mathematical expressions in every coordinate inside of `plot coordinates`. This might be necessary if coordinates are not in numerical form (or if you'd like to improve speed).

It is necessary to disable `plot coordinates/math parser` if you use some sort of symbolic transformations (i.e. text coordinates).

4.3.2 Reading Coordinates From Tables

`\addplot table [⟨`*column selection*`⟩]{⟨`*file or inline table*`⟩};`
`\addplot[⟨`*options*`⟩] table [⟨`*column selection*`⟩]{⟨`*file or inline table*`⟩}` *⟨trailing path commands⟩*`;`
`\addplot3 ...`

This input method is the main input format for any data–based function. It accepts either a file containing data or an inline table provided in curly braces.

Given a data file like

```
dof      L2              Lmax            maxlevel
5        8.31160034e-02  1.80007647e-01  2
17       2.54685628e-02  3.75580565e-02  3
49       7.40715288e-03  1.49212716e-02  4
129      2.10192154e-03  4.23330523e-03  5
321      5.87352989e-04  1.30668515e-03  6
769      1.62269942e-04  3.88658098e-04  7
1793     4.44248889e-05  1.12651668e-04  8
4097     1.20714122e-05  3.20339285e-05  9
9217     3.26101452e-06  8.97617707e-06  10
```

one may want to plot 'dof' versus 'L2' or 'dof' versus 'Lmax'. This can be done by

```
\begin{tikzpicture}
\begin{loglogaxis}[
    xlabel=Dof,
    ylabel=$L_2$ error]
\addplot table[x=dof,y=L2] {datafile.dat};
\end{loglogaxis}
\end{tikzpicture}
```

or, for the `Lmax` column, using

```
\begin{tikzpicture}
\begin{loglogaxis}[
    xlabel=Dof,
    ylabel=$L_\infty$ error]
\addplot table[x=dof,y=Lmax] {datafile.dat};
\end{loglogaxis}
\end{tikzpicture}
```

It is also possible to provide the data inline, i.e. directly as argument in curly braces:

```
\begin{tikzpicture}
\begin{loglogaxis}[
    xlabel=Dof,
    ylabel=$L_\infty$ error]
\addplot table[x=dof,y=Lmax] {
    dof    L2              Lmax            maxlevel
    5      8.31160034e-02  1.80007647e-01  2
    17     2.54685628e-02  3.75580565e-02  3
    49     7.40715288e-03  1.49212716e-02  4
    129    2.10192154e-03  4.23330523e-03  5
    321    5.87352989e-04  1.30668515e-03  6
    769    1.62269942e-04  3.88658098e-04  7
    1793   4.44248889e-05  1.12651668e-04  8
    4097   1.20714122e-05  3.20339285e-05  9
    9217   3.26101452e-06  8.97617707e-06  10
};
\end{loglogaxis}
\end{tikzpicture}
```

Inline table may be convenient together with '\\' and row sep=\\, see below for more information.

Alternatively, you can load the table *once* into an internal structure and use it *multiple* times[3]:

```
\pgfplotstableread{datafile.dat}\loadedtable % use any custom name in place of '\loadedtable'
...
\addplot table[x=dof,y=L2] {\loadedtable};
...
\addplot table[x=dof,y=Lmax] {\loadedtable};
...
```

I am not really sure how much time can be saved, but it works anyway. The \pgfplotstableread command is documented in all detail in the manual for PGFPLOTSTABLE. As a rule of thumb, decide as follows:

1. If tables contain few rows and many columns, the $\langle\backslash macro\rangle$ framework will be more efficient.

2. If tables contain more than 200 data points (rows), you should always use file input (and reload if necessary).

Occasionally, it might be handy to load a table, apply manual preparation steps (for example \pgfplotstabletranspose) and plot the result tables afterwards.

If you do prefer to access columns by column indices instead of column names (or your tables do not have column names), you can also use

```
\addplot table[x index=2,y index=3] {datafile.dat};
\addplot table[x=dof,y index=2] {datafile.dat};
```

Summary and remarks:

- Use \addplot table[x={$\langle column\ name\rangle$},y={$\langle column\ name\rangle$}] to access column names. Those names are case sensitive and need to exist.

- Use \addplot table[x index={$\langle column\ index\rangle$},y index={$\langle column\ index\rangle$}] to access column indices. Indexing starts with 0. You may also use an index for x and a column name for y.

- Use \addplot table[x expr=\coordindex,y={$\langle column\ name\rangle$}] to plot the coordinate index versus some y data.

---

[3]In earlier versions, there was an addition keyword 'from' before the argument like \addplot table from {\loadedtable}. This keyword is still accepted, but no longer required.

- Use `\addplot table[header=false] {⟨file name⟩}` if your input file has no column names. Otherwise, the first non-comment line is checked for column names: if all entries are numbers, they are treated as numerical data; if one of them is not a number, all are treated as column names.

- It is possible to read error coordinates from tables as well. Simply add options 'x error', 'y error' or 'x error index'/'y error index' to ⟨source columns⟩. See Section 4.12 for details about error bars.

- It is possible to read per point meta data (usable in scatter src, see page 109) as has been discussed for plot coordinates and plot file above. The meta data column can be provided using the meta key (or the meta index key).

- Use `\addplot table[⟨source columns⟩] {⟨\macro⟩}` to use a pre–read table. Tables can be read using

  ```
  \pgfplotstableread{datafile.dat}\macroname.
  ```

  If you like, you can insert the optional keyword 'from' before \macroname.

- The accepted input format of tables is as follows:
  - Rows are separated by new line characters.
    Alternatively, you can use row sep=\\ which enables '\\' as row separator. This might become necessary for inline table data, more precisely: if newline characters have been converted to white spaces by TeX's character processing before PGFPLOTS had a chance to see them. This happens if inline tables are provided inside of macros. Use row sep=\\ and separate the rows by '\\' if you experience such problems.
  - Columns are usually separated by white spaces (at least one tab or space).
    If you need other column separation characters, you can use the
    col sep=space|tab|comma|colon|semicolon|braces|&|ampersand
    option documented in all detail in the manual for PGFPLOTSTABLE which is part of PGFPLOTS.
  - Any line starting with '#' or '%' is ignored.
  - The first line will be checked if it contains numerical data. If there is a column in the first line which is *no* number, the complete line is considered to be a header which contains column names. Otherwise it belongs to the numerical data and you need to access column indices instead of names.
  - There is future support for a second header line which must start with '$flags '. Currently, such a line is ignored. It may be used to provide number formatting hints like precision and number format if those tables shall be typeset using \pgfplotstabletypeset (see the manual for PGFPLOTSTABLE).
  - The accepted number format is the same as for 'plot coordinates', see above.
  - If you omit column selectors, the default is to plot the first column against the second. That means plot table does exactly the same job as plot file for this case.
  - If you need unbalanced columns, simply use nan as "empty cell" placeholder. These coordinates will be skipped in plots.

- It is also possible to use **mathematical expressions** together with 'plot table'. This is documented in all detail in Section 4.3.4, but the key idea is to use one of x expr, y expr, z expr or meta expr as in 'plot table[x expr=\thisrow{maxlevel}+3,y=L2]'.

- The PGFPLOTSTABLE package coming with PGFPLOTS has a the feature "Postprocessing Data in New Columns" (see its manual).

  This allows to compute new columns based on existing data. One of these features is create col/linear regression (described in Section 4.24).

  You can invoke all the create col/⟨key name⟩ features directly in \addplot table using

  `\addplot table[x={create col/⟨key name⟩=⟨arguments⟩}]`.

  In this case, a new column will be created using the functionality of ⟨key name⟩. This column generation is described in all detail in PGFPLOTSTABLE. Finally, the resulting data is available as x coordinate (the same holds for y= or z=).

  One application (with several examples how to use this syntax) is line fitting with create col/linear regression, see Section 4.24 for details.

- The table can contain `empty line`s to tell PGFPLOTS that the function has jumps. To use it, simply insert an empty line (and ensure that you have `\pgfplotsset{compat=1.4}` or newer in your preamble). See the documentation of `empty line` for details.

- Technical note: every opened file will be protocolled into your log file.

Keys To Configure Table Input

The following list of keys allow different methods to select input data or different input formats. Note that the common prefix 'table/' can be omitted if these keys are set after `\addplot table[⟨options⟩]`. The `/pgfplots/` prefix can always be omitted when used in a PGFPLOTS method.

`/pgfplots/table/header=true|false`   (initially `true`)

Allows to disable header identification for `plot table`. See above.

`/pgfplots/table/x={⟨column name⟩}`
`/pgfplots/table/y={⟨column name⟩}`
`/pgfplots/table/z={⟨column name⟩}`
`/pgfplots/table/x index={⟨column index⟩}`
`/pgfplots/table/y index={⟨column index⟩}`
`/pgfplots/table/z index={⟨column index⟩}`

These keys define the sources for `plot table`. If both column names and column indices are given, column names are preferred. Column indexing starts with 0. The initial setting is to use `x index`=0 and `y index`=1.

Please note that column *aliases* will be considered if unknown column names are used. Please refer to the manual of PGFPLOTSTABLE which comes with this package.

`/pgfplots/table/x expr={⟨expression⟩}`
`/pgfplots/table/y expr={⟨expression⟩}`
`/pgfplots/table/z expr={⟨expression⟩}`

These keys allow to combine the mathematical expression parser with file input. They are listed here to complete the list of table keys, but they are described in all detail in Section 4.3.4.

The key idea is to provide an ⟨expression⟩ which depends on table data (possibly on all columns in one row). Only data within the same row can be used where columns are referenced with `\thisrow{⟨column name⟩}` or `\thisrowno{⟨column index⟩}`.

Please refer to Section 4.3.4 for details.

`/pgfplots/table/x error={⟨column name⟩}`
`/pgfplots/table/y error={⟨column name⟩}`
`/pgfplots/table/z error={⟨column name⟩}`
`/pgfplots/table/x error index={⟨column index⟩}`
`/pgfplots/table/y error index={⟨column index⟩}`
`/pgfplots/table/z error index={⟨column index⟩}`
`/pgfplots/table/x error expr={⟨math expression⟩}`
`/pgfplots/table/y error expr={⟨math expression⟩}`
`/pgfplots/table/z error expr={⟨math expression⟩}`

These keys define input sources for error bars with explicit error values.

The `x error` method provides an input column name (or alias), the `x error index` method provides input column *indices* and `x error expr` works just as `table/x expr`: it allows arbitrary mathematical expressions which may depend on any number of table columns using `\thisrow{⟨col name⟩}`.

Please see Section 4.12 for details about the usage of error bars.

`/pgfplots/table/x error plus={⟨column name⟩}`
`/pgfplots/table/y error plus={⟨column name⟩}`
`/pgfplots/table/z error plus={⟨column name⟩}`
`/pgfplots/table/x error plus index={⟨column index⟩}`
`/pgfplots/table/y error plus index={⟨column index⟩}`
`/pgfplots/table/z error plus index={⟨column index⟩}`

/pgfplots/**table/x error plus expr**={⟨*math expression*⟩}
/pgfplots/**table/y error plus expr**={⟨*math expression*⟩}
/pgfplots/**table/z error plus expr**={⟨*math expression*⟩}
/pgfplots/**table/x error minus**={⟨*column name*⟩}
/pgfplots/**table/y error minus**={⟨*column name*⟩}
/pgfplots/**table/z error minus**={⟨*column name*⟩}
/pgfplots/**table/x error minus index**={⟨*column index*⟩}
/pgfplots/**table/y error minus index**={⟨*column index*⟩}
/pgfplots/**table/z error minus index**={⟨*column index*⟩}
/pgfplots/**table/x error minus expr**={⟨*math expression*⟩}
/pgfplots/**table/y error minus expr**={⟨*math expression*⟩}
/pgfplots/**table/z error minus expr**={⟨*math expression*⟩}

These keys define input sources for error bars with *asymmetric* error values, i.e. different values for upper and lower bounds.

They are to be used in the same way as `x error`. In fact, `x error` is just a style which sets both `x error plus` and `x error minus` to the same value.

Please see Section 4.12 for details about the usage of error bars.

/pgfplots/**table/meta**={⟨*column name*⟩}
/pgfplots/**table/meta index**={⟨*column index*⟩}
/pgfplots/**table/meta expr**={⟨*expression*⟩}

These keys define input sources for per point meta data. Please see page 109 for details about meta data or the documentation for `plot coordinates` and `plot file` for further information.

These keys are *only* useful in conjunction with `point meta`=explicit or `point meta`=explicit symbolic. Note that

```
\addplot[point meta=explicit] table[meta=colname] .... ;
```

is *equivalent* to

```
\addplot[point meta=\thisrow{colname}] table[] .... ;
```

If the value of `point meta` is neither `explicit` nor `explicit symbolic`, the choice `table/meta` (and its friends) are ignored.

However, if `point meta` is one of `explicit` or `explicit symbolic`, the choice `table/meta` (or one of its friends) is mandatory.

/pgfplots/**table/row sep**=newline|\\ (initially `newline`)

Configures the character to separate rows.

The choice `newline` uses the end of line as it appears in the table data (i.e. the input file or any inline table data).

The choice `\\` uses '\\' to indicate the end of a row.

Note that `newline` for inline table data is "fragile": you can't provide such data inside of TEX macros (this does not apply to input files). Whenever you experience problems, proceed as follows:

1. First possibility: call `\pgfplotstableread`{⟨*data*⟩}\yourmacro *outside* of any macro declaration.
2. Use `row sep`=\\.

The same applies if you experience problems with inline data and special `col sep` choices (like `col sep`=tab).

The reasons for such problems is that TEX scans the macro bodies and replaces newlines by white spaces. It does other substitutions of this sort as well, and these substitutions can't be undone (maybe not even found).

/pgfplots/**table/col sep**=space|tab|comma|semicolon|colon|braces|&|ampersand (initially `space`)

Allows to choose column separators for `plot table`. Please refer to the manual of PGFPLOTSTABLE which comes with this package for details about `col sep`.

/pgfplots/table/read completely={⟨*auto,true,false*⟩}   (initially `auto`)

Allows to customize \addplot table{⟨*file name*⟩} such that it always reads the entire table into memory.

This key has just one purpose, namely to create postprocessing columns on-the-fly and to plot those columns afterwards. This "lazy evaluation" which creates missing columns on-the-fly is documented in the PGFPLOTSTABLE manual (in section "Postprocessing Data in New Columns").

The initial configuration `auto` checks whether one of the keys table/x, table/y, table/z or table/meta contains a `create on use` column. If so, it enables `read completely`, otherwise it prefers to load the file in the normal way.

Attention: Usually, \addplot table only picks required entries, requiring linear runtime complexity. As soon as `read completely` is activated, tables are loaded completely into memory. Due to datastructures issues ("macro append runtime"), the runtime complexity for `read completely` is $O(N^2)$ where N is the number of rows. Thus: use this feature only for "small" tables[4].

/pgfplots/table/ignore chars={⟨*comma-separated-list*⟩}   (initially `empty`)

Allows to silently remove a set of single characters from input files. The characters are separated by commas. The documentation for this command, including cases like '`\%,\#,\ `' or binary character codes like '`\^^ff`' can be found in the manual for PGFPLOTSTABLE.

This setting applies to \addplot file as well.

/pgfplots/table/white space chars={⟨*comma-separated-list*⟩}   (initially `empty`)

Allows to define a list of single characters which are actually treated like white spaces (in addition to tabs and spaces). Please refer to the manual of PGFPLOTSTABLE for details.

This setting applies to \addplot file as well.

/pgfplots/table/comment chars={⟨*comma-separated-list*⟩}   (initially `empty`)

Allows to add one or more *additional* comment characters. Each of these characters has a similar effect as the `#` character, i.e. all following characters of that particular input line are skipped.

For example, comment chars=! uses '!' as additional comment character (which allows to parse Touchstone files).

Please refer to the manual of PGFPLOTSTABLE for details.

/pgfplots/table/skip first n={⟨*integer*⟩}   (initially `0`)

Allows to skip the first ⟨*integer*⟩ lines of an input file. The lines will not be processed.

Please refer to the manual of PGFPLOTSTABLE for details.

/pgfplots/table/search path={⟨*comma-separated-list*⟩}   (initially `.`)

Allows to provide a search path for input tables. This variable is evaluated whenever PGFPLOTS attempts to read a data file. This includes both \pgfplotstableread and \addplot table; its value resembles a comma-separated list of path names. The requested file will be read from the first matching location in that list.

Use '.' to search using the normal TeX file searching procedure. This standard search procedure will typically use the current working directory and the environment variable TEXINPUTS as for any other \input or \include statements.

An entry in ⟨*comma-separated-list*⟩ can be relative to the current working directory, i.e. something like search path={.,../datafiles} is accepted.

/pgfplots/table/search path/implicit .=true|false   (initially `true`)

PGFPLOTSTABLE allows to add '.' to the value of search path implicitly as this is typically assumed in many applications of search paths.

The initial configuration search path/implicit .=true will ensure that '.' is added in front of the search path if the user value does not contain a '.'.

---

[4]This remark might be deprecated; many of the slow routines have been optimized in the meantime to have at least pseudo-linear runtime.

The value search path/implicit .=false will not add '.'.

Keep in mind that '.' means "let TEX search for the file on its own". This will typically find files in the current working directory, but it will also include processing of the environment variable TEXINPUTS.

4.3.3 Computing Coordinates with Mathematical Expressions

\addplot {⟨math expression⟩} ;
\addplot[⟨options⟩] {⟨math expression⟩} ⟨trailing path commands⟩;
\addplot3 ...

This input method allows to provide mathematical expressions which will be sampled. But unlike plot gnuplot, the expressions are evaluated using the math parser of PGF, no external program is required.

Plot expression samples x from the interval $[a, b]$ where a and b are specified with the domain key. The number of samples can be configured with samples=⟨N⟩ as for plot gnuplot.
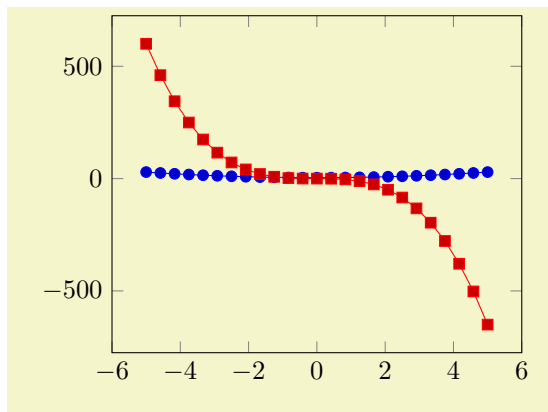
```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
\begin{axis}
    \addplot {x^2 + 4};
    \addplot {-5*x^3 - x^2};
\end{axis}
\end{tikzpicture}
```

Please note that PGF's math parser is configured to use trig format=degrees by default whenever trigonometric functions are involved:
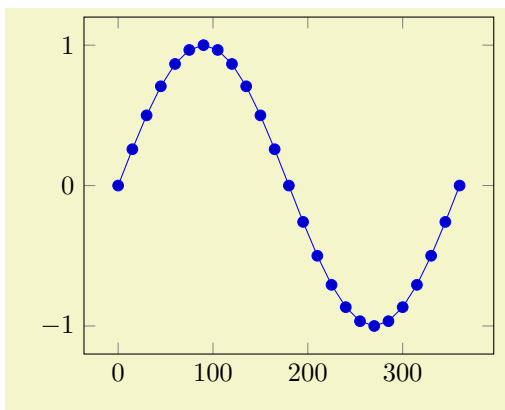
```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
\begin{axis}
    \addplot+[domain=0:360]
        {sin(x)};
\end{axis}
\end{tikzpicture}
```

If you want to use radians, use
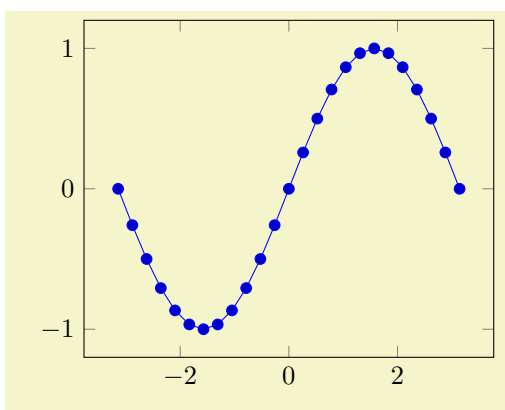
```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
\begin{axis}
    \addplot+[domain=-pi:pi]
        {sin(deg(x))};
\end{axis}
\end{tikzpicture}
```

to convert the radians to degrees (also see `trig format` and `trig format plots`).

The plot expression parser also accepts some more options like `samples at`={⟨*coordinate list*⟩} or `domain`=⟨*first*⟩:⟨*last*⟩ which are described below.

Remarks

1. What really goes on is a loop which assigns the current sample coordinate to the macro `\x`. PGFPLOTS defines a math constant `x` which always has the same value as `\x`.

   In short: it is the same whether you write `\x` or just `x` inside of math expressions.

   The variable name can be customized using `variable`=t. Then, `t` will be the same as `\t`.

2. The complete set of math expressions can be found in the PGF manual. The most important mathematical operations are `+`, `-`, `*`, `/`, `abs`, `round`, `floor`, `mod`, `<`, `>`, `max`, `min`, `sin`, `cos`, `tan`, `deg` (conversion from radians to degrees), `rad` (conversion from degrees to radians), `atan`, `asin`, `acos`, `cot`, `sec`, `cosec`, `exp`, `ln`, `sqrt`, the constants `pi` and `e`, `^` (power operation), `factorial`[5], `rand` (random between −1 and 1), `rnd` (random between 0 and 1), number format conversions `hex`, `Hex`, `oct`, `bin` and some more. The math parser has been written by Mark Wibrow and Till Tantau [7], the FPU routines have been developed as part of PGFPLOTS. The documentation for both parts can be found in [7].

   Please note, however, that trigonometric functions are defined in degrees (see `trig format`). The character '`^`' is used for exponentiation (not '`**`' as in gnuplot).

3. If the x axis is logarithmic, samples will be drawn logarithmically.

4. Plot expression also allows to define per `point meta` data (color data) using `point meta`=⟨*math expression*⟩.

About the precision and number range: Starting with version 1.2, `plot expression` uses a floating point unit. The FPU provides the full data range of scientific computing with a relative precision between 10^{-4} and 10^{-6}. The `/pgf/fpu` key provides some more details.

Note that PGFPLOTS makes use of `lualatex`'s features: if you use `lualatex` instead of `pdflatex`, PGFPLOTS will use lua's math engine which is both faster and more accurate (`compat`=1.12 or higher).
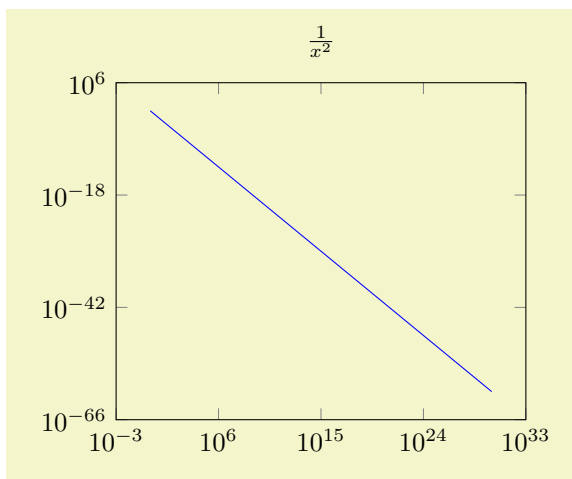

```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
    \begin{loglogaxis}[
        title={$\frac{1}{x^2}$}]
    \addplot[blue,domain=1:1e30]
        {x^-2};
    \end{loglogaxis}
\end{tikzpicture}
```

---

[5]Starting with PGF versions newer than 2.00, you can use the postfix operator `!` instead of `factorial`.
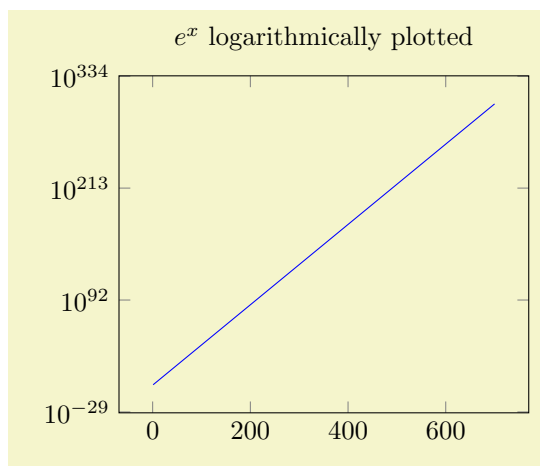
```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
    \begin{semilogyaxis}[
        title={$e^x$ logarithmically plotted}]
    \addplot[blue,domain=1:700]
        {exp(x)};
    \end{semilogyaxis}
\end{tikzpicture}
```

\addplot expression {⟨*math expr*⟩};
\addplot[⟨*options*⟩] expression {⟨*math expr*⟩} ⟨*trailing path commands*⟩;
\addplot3 ...

The syntax

\addplot {⟨*math expression*⟩};

as short-hand equivalent for

\addplot expression {⟨*math expression*⟩};

\addplot (⟨*x expression*⟩,⟨*y expression*⟩) ;
\addplot[⟨*options*⟩] (⟨*x expression*⟩,⟨*y expression*⟩) ⟨*trailing path commands*⟩;
\addplot3 ...

A variant of \addplot expression which allows to provide different coordinate expressions for the x and y coordinates. This can be used to generate parametrized plots.

Please note that \addplot (x,x^2) is equivalent to \addplot expression {x^2}.

Note further that since the complete point expression is surrounded by round braces, round braces for either ⟨*x expression*⟩ or ⟨*y expression*⟩ need special attention. You will need to introduce curly braces additionally to allow round braces:

\addplot ({⟨*x expr*⟩}, {⟨*y expr*⟩}, {⟨*z expr*⟩});

/pgfplots/domain=⟨x_1⟩:⟨x_2⟩   (initially [-5:5])
/pgfplots/y domain=⟨y_1⟩:⟨y_2⟩
/pgfplots/domain y=⟨y_1⟩:⟨y_2⟩

Sets the function's domain(s) for plot expression and plot gnuplot. Two dimensional plot expressions are defined as functions $f: [x_1, x_2] \to \mathbb{R}$ and ⟨x_1⟩ and ⟨x_2⟩ are set with domain. Three dimensional plot expressions use functions $f: [x_1, x_2] \times [y_1, y_2] \to \mathbb{R}$ and ⟨y_1⟩ and ⟨y_2⟩ are set with y domain. If y domain is empty, $[y_1, y_2] = [x_1, x_2]$ is assumed for three dimensional plots (see page 127 for details about three dimensional plot expressions).

The keys y domain and domain y are the same.

The domain key will be ignored if samples at is specified; samples at has higher precedence.

Please note that domain is not necessarily the same as the axis limits (which are configured with the xmin/xmax options).

The domain keys are *only* relevant for gnuplot and plot expression. In case you'd like to plot only a subset of other coordinate input routines, consider using the coordinate filter restrict x to domain.

Remark for TikZ-users: /pgfplots/domain and /tikz/domain are independent options. Please prefer the PGFPLOTS variant (i.e. provide domain to an axis, \pgfplotsset or a plot command). Since older versions also accepted something like \begin{tikzpicture}[domain=...], this syntax is also accepted as long as no PGFPLOTS domain key is set.

/pgfplots/samples={⟨*number*⟩}   (initially 25)

/pgfplots/samples y={⟨*number*⟩}

> Sets the number of sample points for `plot expression` and `plot gnuplot`. The `samples` key defines the number of samples used for line plots while the `samples y` key is used for mesh plots (three dimensional visualisation, see page 127 for details). If `samples y` is not set explicitly, it uses the value of `samples`.
>
> The `samples` key won't be used if `samples at` is specified; `samples at` has higher precedence.
>
> The same special treatment of `/tikz/samples` and `/pgfplots/samples` as for the `domain` key applies here. See above for details.

/pgfplots/samples at={⟨*coordinate list*⟩}

> Sets the x coordinates for `plot expression` explicitly. This overrides `domain` and `samples`.
>
> The ⟨*coordinate list*⟩ is a `\foreach` expression, that means it can contain a simple list of coordinates (comma–separated), but also complex ... expressions like[6]

```
\pgfplotsset{samples at={5e-5,7e-5,10e-5,12e-5}}
\pgfplotsset{samples at={-5,-4.5,...,5}}
\pgfplotsset{samples at={-5,-3,-1,-0.5,0,...,5}}
```

> The same special treatment of `/tikz/samples at` and `/pgfplots/samples at` as for the `domain` key applies here. See above for details.
>
> **Attention:** `samples at` overrides `domain`, even if `domain` has been set *after* `samples at`! Use `samples at={}` to clear ⟨*coordinate list*⟩ and re-activate `domain`.

/pgfplots/variable={⟨*variable name*⟩}   (initially x)
/pgfplots/variable y={⟨*variable name*⟩}   (initially y)

> Defines the variables names which will be sampled in `domain` (with `variable`) and in `domain y` (with `variable y`).
>
> The same variables are used for parametric and for non-parametric plots. Use `variable=t` to change them if you like (for `gnuplot`, there is such a distinction; see `parametric/var 1d`).
>
> Technical remark: TikZ also uses the `variable` key. However, it expects a *macro* name, i.e. `\x` instead of just `x`. Both possibilities are accepted here.

/pgfplots/trig format plots=default|deg|rad   (initially default)

> Allows to reconfigure the input format for trigonometric functions like `sin`, `cos`, `tan`, and their friends.
>
> This key reconfigures trigonometric functions inside of plot expressions, `point meta` arguments, and other items which are directly related to the evaluation of plot coordinates.
>
> Note that this does *not* apply to TikZ drawing instructions like `\node`, `\draw`, `\fill`, etc.


```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
    \begin{axis}[view={60}{30},trig format plots=rad,
        title=plots in radians]
    \addplot3+[domain=0:4*pi,samples=19,samples y=0]
        ({sin(x)},
         {cos(x)},
         {2*x/(4*pi)});

    % drawing instructions still use PGF's default
    \node[fill=white,draw=black,anchor=center] at
        ({sin(90)},{cos(90)},1) {X};
    \end{axis}
\end{tikzpicture}
```
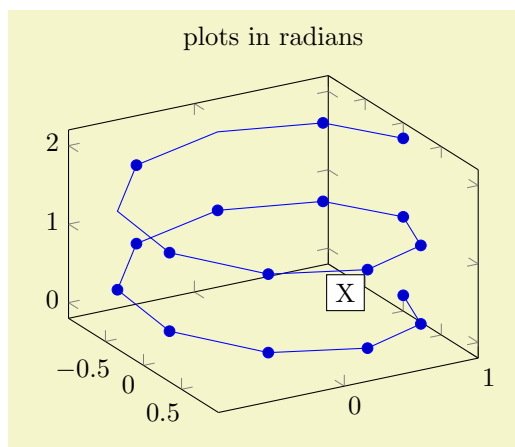
---

[6]Unfortunately, the ... is somewhat restrictive when it comes to extended accuracy. So, if you have particularly small or large numbers (or a small distance), you have to provide a comma–separated list (or use the `domain` key).

Limitations: this feature is currently unavailable for `polaraxis` and `smithchart`.

`/pgf/trig format=deg|red` (initially `deg`)

Allows to reconfigure the trigonometric format for *all* user arguments.
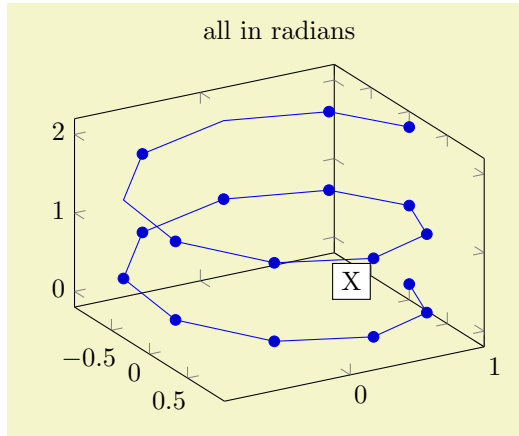
This affects *all* user arguments including `view`, TikZ polar coordinates, `pins` of `\node`s, start/end angles for edges, etc.

At the time of this writing, this feature is in experimental state: it can happen that it breaks TikZ internals. Please handle with care and report any bugs.


```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
    \begin{axis}[view={rad(60)}{rad(30)},
        trig format=rad,
        title=all in radians]
    \addplot3+[domain=0:4*pi,samples=19,samples y=0]
        ({sin(x)},
         {cos(x)},
         {2*x/(4*pi)});

    % drawing instructions now also use radians
    \node[fill=white,draw=black,anchor=center] at
        ({sin(pi/2)},{cos(pi/2)},1) {X};
    \end{axis}
\end{tikzpicture}
```

4.3.4 Mathematical Expressions And File Data

PGFPLOTS allows to combine '`plot table`' and '`plot expression`' to get both file input and modifications by means of mathematical expressions.

`\addplot table [⟨column selection and expressions⟩]{⟨file⟩};`
`\addplot[⟨options⟩] table [⟨column selection and expressions⟩]{⟨file⟩} ⟨trailing path commands⟩;`
`\addplot3 ...`

Besides the already discussed possibility to provide a column selection by means of column names (`x=`⟨*name*⟩ or `x index=`⟨*index*⟩, see Section 4.3.2), it is also possible to provide mathematical expressions as arguments.

Mathematical expressions are specified with `x expr=`⟨*expression*⟩ inside of ⟨*column selection and expressions*⟩. They can depend on zero, one or more columns of the input file. A column is referenced using the special command '`\thisrow{`⟨*column name*⟩`}`' within ⟨*expression*⟩ (or `\thisrowno`⟨*column index*⟩).

maxlevel	L2
2	$2.97 \cdot 10^{-2}$
2	$2.97 \cdot 10^{-2}$
4	$5.27 \cdot 10^{-3}$
5	$3.8 \cdot 10^{-3}$
6	$8.41 \cdot 10^{-4}$
6	$5.01 \cdot 10^{-4}$
7	$1.11 \cdot 10^{-4}$
8	$5.41 \cdot 10^{-5}$
9	$1.25 \cdot 10^{-5}$
10	$6.01 \cdot 10^{-6}$
11	$1.11 \cdot 10^{-6}$
11	$5.9 \cdot 10^{-7}$
12	$1.03 \cdot 10^{-7}$
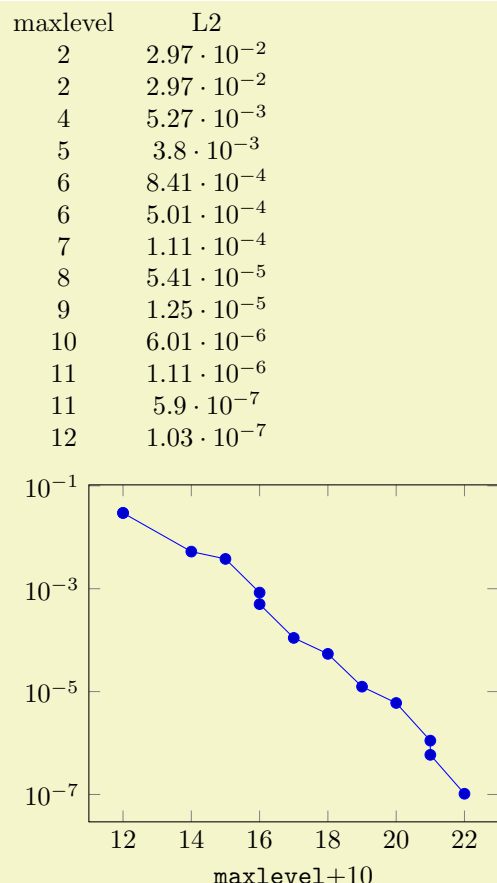

```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\pgfplotstabletypeset[columns={maxlevel,L2}]{plotdata/newexperiment1.dat}

\begin{tikzpicture}
    \begin{semilogyaxis}[
        xlabel=\texttt{maxlevel}$ + 10$
    ]
    \addplot table
        [x expr=\thisrow{maxlevel}+10, y=L2]
        {plotdata/newexperiment1.dat};
    \end{semilogyaxis}
\end{tikzpicture}
```

Besides `x expr`, there are keys `y expr`, `z expr` and `meta expr` where the latter allows to provide point meta data (which is used as `scatter src` or color data for surface plots etc.).

Inside of ⟨*expression*⟩, the following macros can be used to access numerical data cells inside of the input file:

\thisrow{⟨*column name*⟩}

Yields the value of the column designated by ⟨*column name*⟩. There is no limit on the number of columns which can be part of a mathematical expression, but only values inside of the currently processed *table row* can be used.

It is possible to provide column aliases for ⟨*column name*⟩ as described in the manual of PGFPLOT-STABLE.

The argument ⟨*column name*⟩ has to denote either an existing column or one for which a column alias exists (see the manual of PGFPLOTSTABLE). If it can't be resolved, the math parser yields an "Unknown function" error message.

\thisrowno{⟨*column index*⟩}

Similar to **\thisrow**, this command yields the value of the column with index ⟨*column index*⟩ (starting with 0).

\coordindex

> Yields the current index of the table row (starting with 0). This does *not* count header or comment lines.

\lineno

> Yields the current line number (starting with 0). This does also count header and comment lines.

If `x index`, `x` and `x expr` (or the corresponding keys for `y`, `z` or `meta`) are combined, this is how they interact:

1. Column access via `x` has higher precedence than index access via `x index`.

2. Even if `x expr` is provided, the values of `x index` and `x` are still checked. Any value found using column name access or column index access is made available as `\columnx` (or `\columny`, `\columnz`, `\columnmeta`, resp.). However, the result of `x expr` is used as plot coordinate.

   This allows to access the cell values identified by `x` or `x index` using the "pointer" `\columnx`. I am not sure if this yields any advantage, but it is possible nevertheless. If in doubt, prefer using `\thisrow{⟨column name⟩}`.

Attention: If your table has less than two rows, you may need to set `x index={}`,`y index={}` explicitly. This is a consequence of the fact that column name/index access is still applied even if an expression is provided.

4.3.5 Computing Coordinates with Mathematical Expressions (gnuplot)

\addplot **gnuplot** [⟨*further options*⟩]{⟨*gnuplot code*⟩};
\addplot[⟨*options*⟩] **gnuplot** [⟨*further options*⟩]{⟨*gnuplot code*⟩} ⟨*trailing path commands*⟩;
\addplot3 ...

> In contrast to `plot expression`, the `plot gnuplot` command[7] employs the external program `gnuplot` to compute coordinates. The resulting coordinates are written to a text file which will be plotted with `plot file`. PGF checks whether coordinates need to be re-generated and calls `gnuplot` whenever necessary (this is usually the case if you change the number of samples, the argument to `plot gnuplot` or the plotted domain[8]).

> The differences between `plot expression` and `plot gnuplot` are:

> - `plot expression` does not require any external programs and requires no additional command line options.

> - `plot expression` does not produce a lot of temporary files.

> - `plot gnuplot` uses radians for trigonometric functions while `plot expression` has degrees (unless PGF is configured for `trig format`=rad).

> - `plot gnuplot` is faster than `pdflatex`. Using `lualatex` and `compat`=1.12 (or higher) can reach a similar speed.

> - `plot gnuplot` has a larger mathematical library.

> - `plot gnuplot` has a higher accuracy. Note that `lualatex` and `compat`=1.12 (or higher) come with the same precision.

> Since system calls are a potential danger, they need to be enabled explicitly using command line options, for example

```
pdflatex -shell-escape filename.tex.
```

> Sometimes it is called `shell-escape` or `enable-write18`. Sometimes one needs two hyphens – that all depends on your TeX distribution.

---

[7]Note that `plot gnuplot` is actually a re-implementation of the `plotfunction` method known from PGF. It also invokes PGF basic layer commands.

[8]Please note that PGFPLOTS produces slightly different files than TikZ when used with `plot gnuplot` (it configures high precision output). You should use different `id` for PGFPLOTS and TikZ to avoid conflicts in such a case.
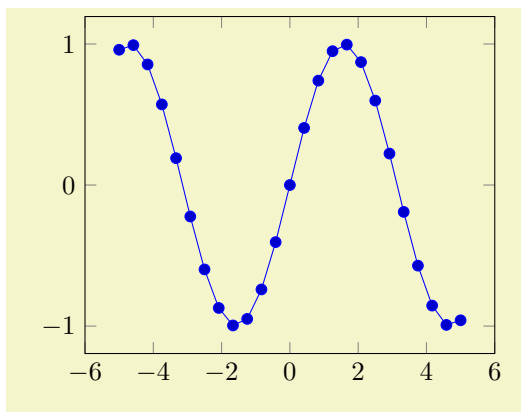
```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
\begin{axis}
\addplot
    gnuplot[id=sin]{sin(x)};
\end{axis}
\end{tikzpicture}
```
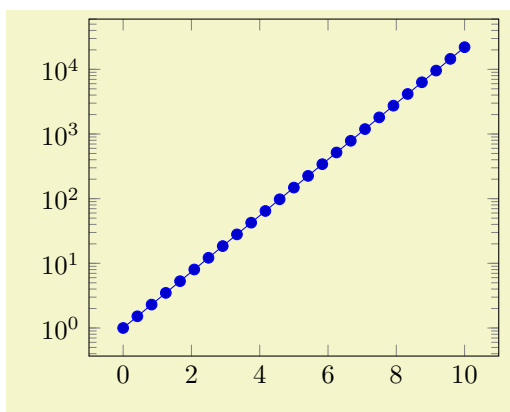
```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
\begin{semilogyaxis}
\addplot gnuplot
    [id=exp,domain=0:10]{exp(x)};
\end{semilogyaxis}
\end{tikzpicture}
```

The ⟨*options*⟩ determine the appearance of the plotted function; these parameters also affect the legend. There is also a set of options which are specific to the gnuplot interface. These options are described in all detail in [7, section 18.6]. A short summary is shown below.

Some remarks:

- The independent variable for one-dimensional plots can be changed with the `variable` option, just as for `plot expression`. Similarly, the second variable for two dimensional plots can be changed with `variable y`.

  For `parametric` plots, the variable names need to be adjusted with `parametric/var 1d` and `parametric/var 2d` (since gnuplot uses `t` and `u,v` as initial values for `parametric` plots).

- Please note that `plot gnuplot` does not allow separate per point meta data (color data for each coordinate). You can, however, use `point meta=f(x)` or `point meta=x`.

- The generated output file name can be customized with `id`, see below.

Please refer to [7, section 18.6] for more details about `plot function` and the `gnuplot` interaction.

`\addplot function {⟨gnuplot code⟩};`
`\addplot[⟨options⟩] function {⟨gnuplot code⟩} ⟨trailing path commands⟩;`
`\addplot3 ...`

Use

`\addplot function {⟨gnuplot code⟩};`

as alias for

`\addplot gnuplot {⟨gnuplot code⟩};`

`/pgfplots/translate gnuplot=true|false`   (initially `true`)

Enables or disables automatic translation of the exponentiation operator '`^`' to '`**`'.

This features allows to use `^` in `plot gnuplot` instead of gnuplot's `**`.

`/pgfplots/parametric=true|false`   (initially `false`)

Set this to `true` if you'd like to use parametric plots with `gnuplot`. Parametric plots use a comma separated list of expressions to make up $x(t)$, $y(t)$ for a line plot or $x(u,v)$, $y(u,v)$ $z(u,v)$ for a mesh plot (refer to the gnuplot manual for more information about its input methods for parametric plots).

/pgfplots/**parametric/var 1d**={⟨*variable name*⟩}   (initially `t`)
/pgfplots/**parametric/var 2d**={⟨*variable name,variable name*⟩}   (initially `u,v`)

Allows to change the dummy variables used by `parametric gnuplot` plots. The initial setting is the one of `gnuplot`: to use the dummy varialbe '`t`' for parametric line plots and '`u,v`' for parametric mesh plots.

These keys are quite the same as `variable` and `variable y`, only for parametric plots. If you like to change variables for non-parametric plots, use `variable` and/or `variable y`.

In case you don't want the distinction between parametric and non-parametric plots, use

`\pgfplotsset{parametric/var 1d=,parametric/var 2d=}`.

/tikz/**id**={⟨*unique string identifier*⟩}

A unique identifier for the current plot. It is used to generate temporary filenames for `gnuplot` output.

/tikz/**prefix**={⟨*file name prefix*⟩}

A common path prefix for temporary filenames (see [7, section 18.6] for details).

/tikz/**raw gnuplot**   (no value)

Disables the use of `samples` and `domain`.

4.3.6 Computing Coordinates with External Programs (shell)

`\addplot` **shell** [⟨*further options*⟩]{⟨*shell commands*⟩};
`\addplot`[⟨*options*⟩] **shell** [⟨*further options*⟩]{⟨*shell commands*⟩} ⟨*trailing path commands*⟩;
`\addplot3` ...

An extension by Stefan Tibus

In contrast to `plot gnuplot`, the `plot shell` command allows execution of arbitrary shell commands to compute coordinates. The resulting coordinates are written to a text file which will be plotted with `plot file`. PGF checks whether coordinates need to be re-generated and executes the ⟨*shell commands*⟩ whenever necessary.

Since system calls are a potential danger, they need to be enabled explicitly using command line options, for example

```
pdflatex -shell-escape filename.tex.
```

Sometimes it is called `shell-escape` or `enable-write18`. Sometimes one needs two slashes – that all depends on your TeX distribution.
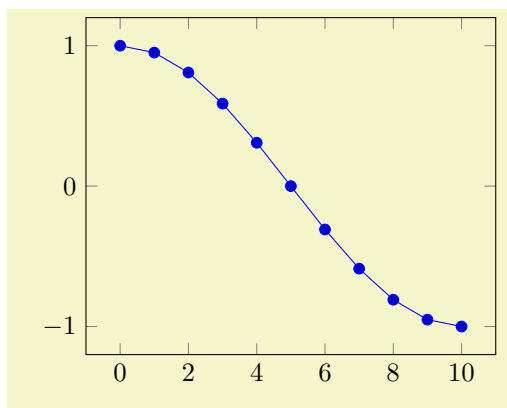

```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
\begin{axis}
\addplot
    shell[prefix=pgfshell_,id=cos]{awk 'BEGIN{
        pi=3.14159; N=10;
        for(i=0;i<=N;i++) print i,cos(i/N*pi);}'};
\end{axis}
\end{tikzpicture}
```
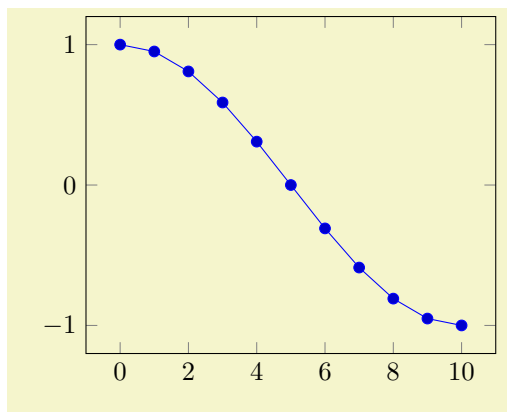
```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
\begin{axis}
\addplot+[prefix=pgfshell_,id=replot]
    shell{cat pgfshell_cos.out};
    % just reprint the result from above
\end{axis}
\end{tikzpicture}
```

The ⟨*options*⟩ determine the appearance of the plotted function; these parameters also affect the legend. There is also a set of options which are specific to the gnuplot and the shell interface. These options are described in all detail in [7, section 19.6]. A short summary is shown below.

/tikz/**id**={⟨*unique string identifier*⟩}

A unique identifier for the current plot. It is used to generate temporary filenames for **shell** output.

/tikz/**prefix**={⟨*file name prefix*⟩}

A common path prefix for temporary filenames (see [7, section 19.6] for details).

4.3.7   Using External Graphics as Plot Sources

\addplot **graphics** {⟨*file name*⟩};
\addplot[⟨*options*⟩] **graphics** {⟨*file name*⟩} ⟨*trailing path commands*⟩;
\addplot3 ...

This plot type allows to extend the plotting capabilities of PGFPLOTS beyond its own limitations. The idea is to generate the graphics as such (for example, a contour plot, a complicated shaded surface[9] or a large point cluster) with an external program like Matlab (Ⓡ) or gnuplot. The graphics, however, should *not* contain an axis or descriptions. Then, we use \includegraphics and a PGFPLOTS axis which fits exactly on top of the imported graphics.

Of course, one could do this manually by providing proper scales and such. The operation plot graphics is intended so simplify this process. However the *main difficulty* is to get images with correct bounding box. Typically, you will have to adjust bounding boxes manually.

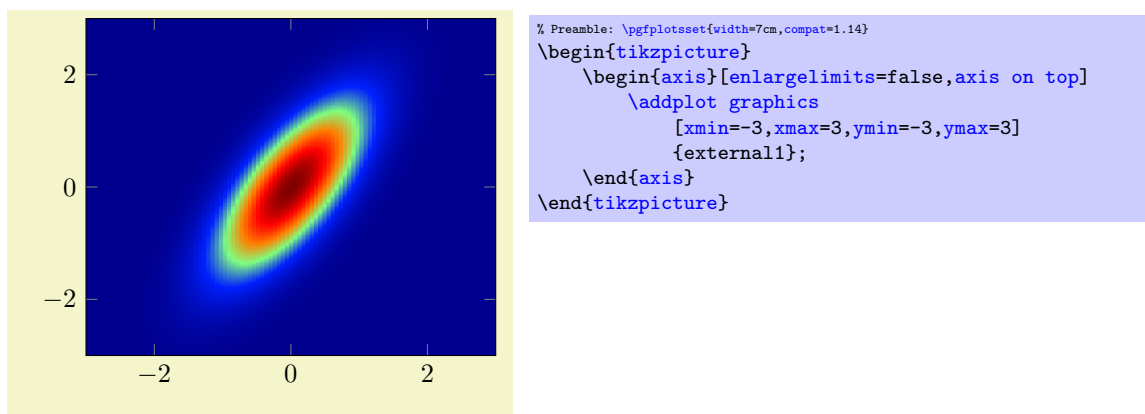Let's start with an example: Suppose we use, for example, matlab to generate a surface plot like

```
[X,Y] = meshgrid( linspace(-3,3,500) );
surf( X,Y, exp(-(X - Y).^2 - X.^2 ) );
shading flat; view(0,90); axis off;
print -dpng external1
```

which is then found in external1.png. The surf command of Matlab generates the surface, the following commands disable the axis descriptions, initialise the desired view and export it. Viewing the image in any image tool, we see a lot of white space around the surface – Matlab has a particular weakness in producing tight bounding boxes, as far as I know. Well, no problem: use your favorite image editor and crop the image (most image editors can do this automatically). We could use the free ImageMagick command

convert -trim external1.png external1.png

to get a tight bounding box. Then, we use

---

[9]See also Section 4.6.6 for an overview of PGFPLOTS methods to draw shaded surfaces.

```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
    \begin{axis}[enlargelimits=false,axis on top]
        \addplot graphics
            [xmin=-3,xmax=3,ymin=-3,ymax=3]
            {external1};
    \end{axis}
\end{tikzpicture}
```

to load the graphics[10] just as if we would have drawn it with PGFPLOTS. The `axis on top` simply tells PGFPLOTS to draw the axis on top of any plots (see its description).

Please note that PGFPLOTS offers support for smaller surface plots as well which might be an option – unless the number of samples is too large. See Section 4.6.6 for details.

However, external programs have the following advantages here: they are faster, allow more complexity and provide real z buffering which is currently only simulated by PGFPLOTS. Thus, it may help to consider `plot graphics` for complicated surface plots.

Our first test was successful – and not difficult at all because graphics programs can automatically compute the bounding box. There are a couple of free tools available which can compute tight bounding boxes for `.eps` or `.pdf` graphics:

1. The free vector graphics program `inkscape` can help here. Its feature "File ≫ Document Properties: Fit page to selection" computes a tight bounding box around every picture element.

   However, some images may contain a rectangular path which is as large as the bounding box (Matlab (Ⓡ) computes such `.eps` images). In this case, use the "Ungroup" method (context menu of `inkscape`) as often as necessary and remove such a path.

   Finally, save as `.eps`.

   However, `inkscape` appears to have problems with postscript fonts – it substitutes them. This doesn't pose problems in this application because fonts shouldn't be part of such images – the descriptions will be drawn by PGFPLOTS.

2. The tool `pdfcrop` removes surrounding whitespace in `.pdf` images and produces quite good bounding boxes.

Adjusting bounding boxes manually

In case you don't have tools at hand to provide correct bounding boxes, you can still use TEX to set the bounding box manually. Some viewers like `gv` provide access to low–level image coordinates. The idea is to determine the number of units which need to be removed and communicate these units to `\includegraphics`.

I am aware of the following methods to determine bounding boxes manually:

inkscape I am pretty sure that `inkscape` can do it.

gv The ghost script viewer `gv` always shows the postscript units under the mouse cursor.

gimp The graphics program `gimp` usually shows the cursor position in pixels, but it can be configured to display postscript points (`pt`) instead.

Let's follow this approach in a further example.

We use gnuplot to draw a (relatively stupid) example data set. The gnuplot script

---

[10]Please note that I don't have a Matlab license, so I used `gnuplot` to produce an equivalent replacement graphics.

```
set samples 30000
set parametric
unset border
unset xtics
unset ytics
set output "external2.eps"
set terminal postscript eps color
plot [t=0:1] rand(0),rand(0) with dots notitle lw 5
```

generates `external2.eps` with a uniform random sample of size 30000. As before, we import this scatter plot into PGFPLOTS using `plot graphics`. Again, the bounding box is too large, so we need to adjust it (`gnuplot` can do this automatically, but we do it anyway to explain the mechanisms):

Using `gv`, I determined that the bounding box needs to be shifted `12` units to the left and `9` down. Furthermore, the right end is `12` units too far off and the top area has about `8` units space wasted. This can be provided to the `trim` option of `\includegraphics`, and we use `clip` to clip the rest away:
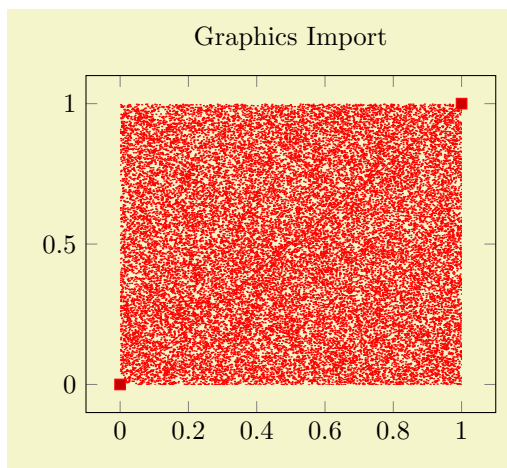

```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
    \begin{axis}[axis on top,title=Graphics Import]
        \addplot graphics
            [xmin=0,xmax=1,ymin=0,ymax=1,
            % trim=left bottom right top
            includegraphics={trim=12 9 12 8,clip}]
            {external2};
        \addplot coordinates {(0,0) (1,1)};
    \end{axis}
\end{tikzpicture}
```

So, `plot graphics` takes a graphics file along with options which can be passed to `\includegraphics`. Furthermore, it provides the information how to embed the graphics into an axis. The axis can contain any other `\addplot` command as well and will be resized properly.

Details about `plot graphics`:

The loaded graphics file is drawn with

`\node[/pgfplots/plot graphics/node] {\includegraphics[⟨options⟩]{⟨file name⟩}};`

where the `node` style is a configurable style. The node is placed at the coordinate designated by `xmin`, `ymin`.

The ⟨options⟩ are any arguments provided to the `includegraphics` key (see below) and `width` and `height` determined such that the graphics fits exactly into the rectangle denoted by the `xmin`, `ymin` and `xmax`, `ymax` coordinates.

The scaling will thus ignore the aspect ratio of the external image and prefer the one used by PGFPLOTS. You will need to provide `width` and `height` to the PGFPLOTS axis to change its scaling. Use the `scale only axis` key in such a case.

Legends in `plot graphics`:

A legend for `plot graphics` uses the current plot handler and the current plot `mark`:
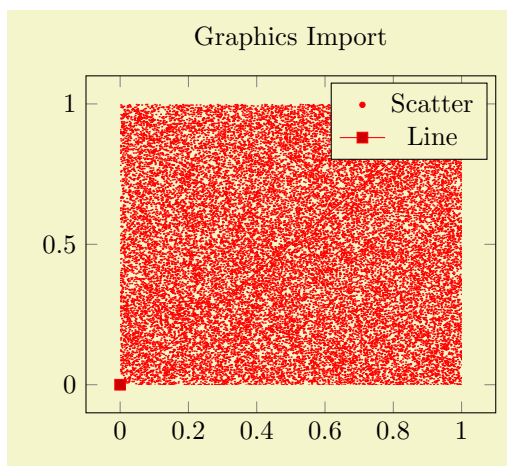
```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
\begin{axis}[axis on top,title=Graphics Import]
    % provide options for the legend:
    \addplot[red,only marks,mark=*,mark size=1pt]
    graphics
        [xmin=0,xmax=1,ymin=0,ymax=1,
        % trim=left bottom right top
        includegraphics={trim=12 9 12 8,clip}]
        {external2};

    \addplot coordinates {(0,0) (1,1)};

    \legend{Scatter,Line}
\end{axis}
\end{tikzpicture}
```

4.3.8   Keys To Configure Plot Graphics

The following list of keys configure `\addplot graphics`. Note that the common prefix 'plot graphics/' can be omitted if these keys are set after `\addplot graphics`[⟨*options*⟩]. The /pgfplots/ prefix can always be omitted when used in a PGFPLOTS method.

/pgfplots/**plot graphics/xmin**={⟨*coordinate*⟩}
/pgfplots/**plot graphics/ymin**={⟨*coordinate*⟩}
/pgfplots/**plot graphics/zmin**={⟨*coordinate*⟩}
/pgfplots/**plot graphics/xmax**={⟨*coordinate*⟩}
/pgfplots/**plot graphics/ymax**={⟨*coordinate*⟩}
/pgfplots/**plot graphics/zmax**={⟨*coordinate*⟩}

These keys are required for `plot graphics` and provide information about the external data range. The graphics will be squeezed between these coordinates. The arguments are axis coordinates; they are only useful if you provide each of them.

Alternatively, you can also use the `plot graphics/points` feature to provide the external data range, see below.

/pgfplots/**plot graphics/points**={⟨*list of coordinates*⟩}   (initially `empty`)

This key also allows to provide the external data range. It constitutes an alternative to `plot graphics/xmin` (and its variants): simply provide at least two coordinates in ⟨*list of coordinates*⟩. Their bounding box is used to determine the external data range, and the graphics is squeezed between these coordinates.

The example from above can be written equivalently as
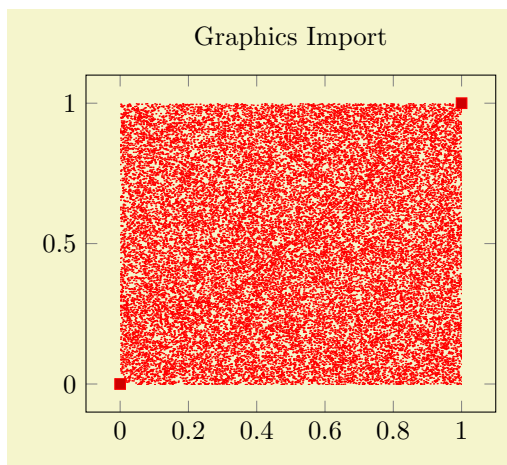

```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
    \begin{axis}[axis on top,title=Graphics Import]
        \addplot graphics
            % instead of the min/max things:
            [points={(0,1) (1,0)},
            % trim=left bottom right top
            includegraphics={trim=12 9 12 8,clip}]
            {external2};
        \addplot coordinates {(0,0) (1,1)};
    \end{axis}
\end{tikzpicture}
```

The ⟨*list of coordinates*⟩ is a sequence of the form (x,y) for two–dimensional plots and (x,y,z) for three–dimensional ones, the ordering is irrelevant. The single elements are separated by white space.

It is possible to mix `plot graphics/xmin` and variants with `plot graphics/points`.

The `plot graphics/points` key has further functionality for inclusion of three–dimensional graphics which is discussed at the end of this section (on page 66). Here is a short reference on the accepted syntax for three–dimensional plot graphics: in addition to the `(x,y,z)` syntax, you can provide arguments of the form `(x,y,z) => (X,Y)`. Here, the first (three–dimensional) coordinate is a logical coordinate and the second (two–dimensional) coordinate denotes the coordinates of the very same point, but inside of the included image (relative to the lower left corner of the image). Applications and examples for this syntax can be found in the section for three–dimensional plot graphics (see page 66).

/pgfplots/plot graphics/includegraphics={⟨*options*⟩}

A list of options which will be passed as–is to `\includegraphics`. Interesting options include the `trim`=⟨*left*⟩ ⟨*bottom*⟩ ⟨*right*⟩ ⟨*top*⟩ key which reduces the bounding box and `clip` which discards everything outside of the bounding box. The scaling options won't have any effect, they will be overwritten by PGFPLOTS.

/pgfplots/plot graphics/includegraphics cmd={⟨*macro*⟩}   (initially `\includegraphics`)

Allows to use a different graphics routine. A possible choice could be `\pgfimage`. The macro should accept the `width` and `height` arguments (in brackets) and the file name as first argument.

/pgfplots/plot graphics/node   (style, no value)

A predefined style used for the TikZ node containing the graphics. The predefined value is

```
\pgfplotsset{
    plot graphics/node/.style={
        transform shape,
        inner sep=0pt,
        outer sep=0pt,
        every node/.style={},
        anchor=south west,
        at={(0pt,0pt)},
        rectangle
    }
}
```

/pgfplots/plot graphics   (no value)

This key belongs to the public low–level plotting interface. You won't need it in most cases.

This key is similar to `sharp plot` or `smooth` or `const plot`: it installs a low–level plot–handler which expects exactly two points: the lower left corner and the upper right one. The graphics will be drawn between them. The graphics file name is expected as value of the **/pgfplots/plot graphics/src** key. The other keys described above need to be set correctly (excluding the limits, these are ignored at this level of abstraction). This key can be used independently of an axis.

/pgfplots/plot graphics/lowlevel draw={⟨*width*⟩}{⟨*height*⟩}

A low–level interface for `plot graphics` which actually invokes `\includegraphics`. But there is no magic involved: the command is simply expected to draw a box of dimensions ⟨*width*⟩ × ⟨*height*⟩. The coordinate system has already been shifted correctly.

The initial configuration is

`\includegraphics[`⟨*value of "*`plot graphics/includegraphics`*"*⟩`,width=#1,height=#2]`

   {⟨*value of "*`plot graphics/src`*"*⟩}.

Thus, you can tweak `plot graphics` to place any TEX box of the desired dimensions into an axis between the provided minimum and maximum coordinates. It is not necessary to make use of the graphics file name or the options in the '`includegraphics`' key if you overwrite this lowlevel interface with

`plot graphics/lowlevel draw/.code 2 args=`{⟨*code which depends on* `#1` *and* `#2`⟩}.

Support for External Three-Dimensional Graphics

PGFPLOTS offers several visualization techniques for three dimensional graphics. Nevertheless, complex visualizations or specialized applications are beyond the scope of PGFPLOTS and you might want to use other tools to generate such figures.
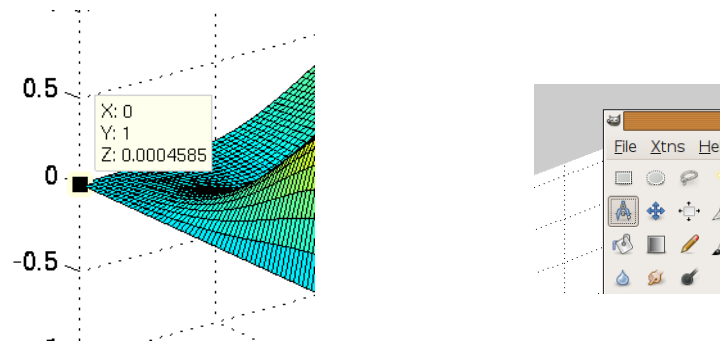
Figure 4.1: Using Matlab to extract image coordinates (left) and Gimp to measure distances (right).

The `plot graphics` tool of PGFPLOTS allows to include three–dimensional external graphics: it generates a three–dimensional axis on its own. The idea is to provide a graphics (without descriptions) and use PGFPLOTS to overlay a three–dimensional axis automatically. This allows to maintain document consistency (making it unnecessary to use different programs within the same document).

You are probably wondering how this is possible. Well, it needs more user input than two–dimensional external graphics. The cost to include external three dimensional images into PGFPLOTS is essentially control of a graphics program like `gimp`: you need to identify the 3D coordinates of a couple of points in your image. PGFPLOTS will then squeeze the graphics correctly, and it reconfigures the axis to ensure a correct display of the result.

Matlab versus other tools: Although this section is based on Matlab images, the technique to import three–dimensional graphics is independent of Matlab. Thus, if you have a different tool, you need to read all that follows. However, users of Matlab *can use a simplified export mechanism* which has been contributed by Jürnjakob Dugge. Please skip to section 4.3.8 on page 71 if you use Matlab to generate the graphics files (although you may want to take a brief look at the examples on the following pages to learn about flexibility or legends).

Let's start with two examples. Suppose you generate a surface plot with Matlab and want to include it in PGFPLOTS. We have the matlab script

```
[x,y]=meshgrid(linspace(0,1,120));
surf(x,y,sin(8*pi*x).* exp(-20*(y-0.5).^2) + exp(-(x-0.5).^2*30 - (y-0.25).^2 - (x-0.5).*(y-0.25)))
xlabel('x'), ylabel('y')
axis off
print -dpng plotgraphics3dsurf
```

which generates the figure in question.

After automatically computing a tight bounding box for `plotgraphics3dsurf.png` (I used `gimp`'s Image≫Autocrop feature), and making the background color transparent (`gimp`: select the outer white space with the magic wand, then use[11] Layer≫Transparency≫Color to Transparency) we get:
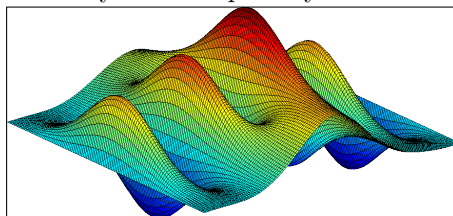
The key idea is now to identify several points in the image, and assign *both* their logical three–dimensional coordinates *and* the corresponding two–dimensional canvas coordinates in image coordinates. How? Well, the three–dimensional coordinates are known to Matlab, it can display them for you if you click somewhere into the image, compare Figure 4.1 (left).

The two–dimensional canvas coordinates need work; they need to be provided relative to the *lower left corner* of the image. I used `gimp` and activated "Points" as units (lower left corner). The lower left corner now displays the image coordinates in `pt` which is compatible with PGFPLOTS. An alternative to pointing onto coordinates is a measurement tool; compare Figure 4.1 (right) for the "Measure" tool in `gimp` which allows to compute the length of a line (in our case, the length of the lower left corner to the point of interest).

[11]I have a german version, I am not sure if the translation is correct.

I selected four points in the graphics and noted their 2d image coordinates and their 3d logical coordinates as follows:
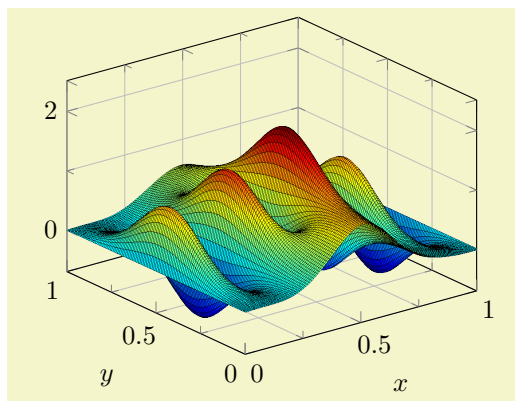
```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
\begin{axis}[
    grid=both,minor tick num=1,
    xlabel=$x$,ylabel=$y$,
    ]
\addplot3 graphics[
    points={% important
        (0,1,0) => (0,207-112)
        (1,0,0) => (446,207-133)
        (0.5546,0.5042,1.825) => (236,207)
        (0,0,0) => (194,207-202)
    }] {plotdata/plotgraphics3dsurf.png};
\end{axis}
\end{tikzpicture}
```

Here, the `points` key gets our collected coordinates as argument. It accepts a sequence of maps of the form ⟨*3d logical coordinate*⟩ => ⟨*2d canvas coordinate*⟩. In our case, `(0,1,0)` has been found in the `.png` file at `(0,207-112)`. Note that I introduced the difference since `gimp` counts from the upper left, but PGFPLOTS counts from the lower left.

Once these four point coordinates are gathered, we find Matlab's surface plot in a PGFPLOTS axis. You can modify any appearance options, including different axis limits or further `\addplot` commands:
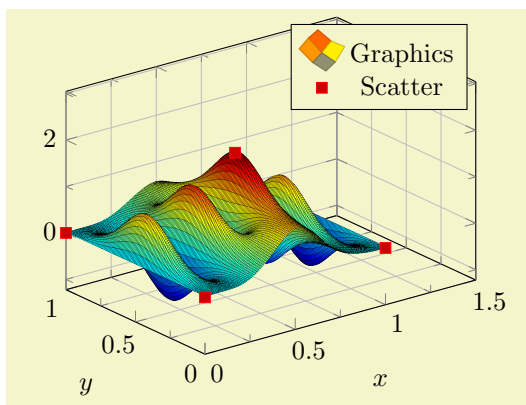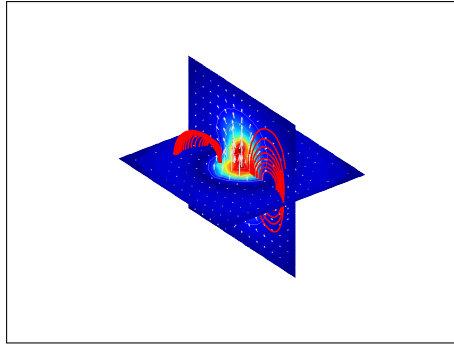
```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
\begin{axis}[
    xmax=1.5,% extra limits
    grid=both,minor tick num=1,
    xlabel=$x$,ylabel=$y$,
    ]
\addplot3[surf] % 'surf' is only used for the legend.
    graphics[
        points={
            (0,1,0) => (0,207-112)
            (1,0,0) => (446,207-133)
            (0.5546,0.5042,1.825) => (236,207)
            (0,0,0) => (194,207-202)
    }]
    {plotdata/plotgraphics3dsurf.png};
\addlegendentry{Graphics}

\addplot3+[only marks] coordinates {
    (0,1,0) (1,0,0)
    (0.5546,0.5042,1.825) (0,0,0)
};
\addlegendentry{Scatter}
\end{axis}
\end{tikzpicture}
```

PGFPLOTS uses the four input points to compute appropriate `x`, `y` and `z` unit vectors (and the origin in graphics coordinates). These four vectors (with two components each) can be computed as a result of a linear system of size 8×8, that is why you need to provide four input points (each has two coordinates). PGFPLOTS computes the unit vectors of the imported graphics, and afterwards it rescales the result such that it fits into the specified `width` and `height`. This rescaling respects the `unit vector ratio` (more precisely, it uses `scale mode`=scale uniformly instead of `scale mode`=stretch to fill). Consequently, the freedom to change the view of a three–dimensional axis which contains a projected graphics is considerably smaller than before. Surprisingly, you can still change axis limits and `width` and `height` – PGFPLOTS will take care of a correct display of your imported graphics. Since version 1.6, you can also change `zmin` and/or `zmax` – PGFPLOTS will respect your changes as good as it can.

Here is a further example. Suppose we are given the three–dimensional visualization

It has been generated by matlab (I only added transparency to the background with `gimp`). Besides advanced visualization techniques, it uses `axis equal`, i.e. `unit vector ratio=1 1 1`. As before, we need to identify four points, each with its 3d logical coordinates (from matlab) and the associated 2d canvas coordinates relative to the lower left corner of the graphics (note that there is a lot of white space around the graphics). Here is the output of PGFPLOTS when you import the resulting graphics:
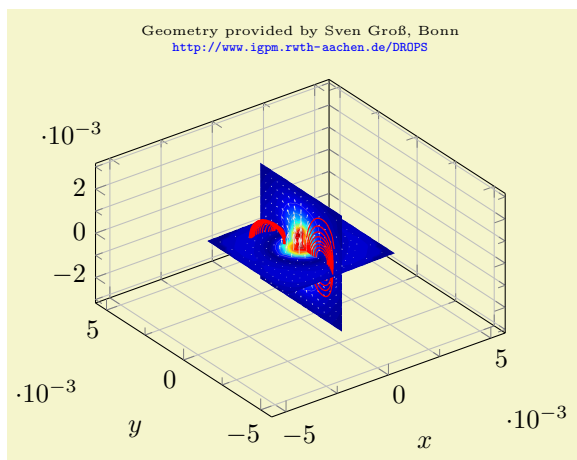

```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
\begin{axis}[
    grid=both,minor tick num=1,
    xlabel=$x$,ylabel=$y$,
    title={\centering
      Geometry provided by Sven Gro\ss, Bonn\\
      \url{http://www.igpm.rwth-aachen.de/DROPS}\\},
    title style={text width=6cm,font=\tiny},
]
    \addplot3 graphics[
        points={
            (-0.002625,0.002625,0) => (140,234)
            (0,0.00263,0.00263)   => (230,364)
            (0,-0.00263,-0.00263)  => (366,81)
            (0,-0.00263,0.00263)   => (366,276)
            (0.002625,0.002625,0.002625)
        }
    ]
    {plotdata/risingdrop3d.png};
\end{axis}
\end{tikzpicture}
```

Note that I provided *five* three–dimensional coordinates here, but the last entry has no `=>` mapping to two–dimensional canvas coordinates. Thus, it is only used to update the bounding box (see the reference manual for the `points` key for details).

The example above leads to a relatively small image and much "empty space". This is due to the `scale mode=scale uniformly` implementation of PGFPLOTS: it decided that the best way is to enlarge the involved axis limits. Here, "best way" means to satisfy `width`/`height` constraints combined with minimally enlarged (never shrinked) axis limits. The remaining degrees of freedom are `width`, `height`, and the axis limits. In our case, changing the ratio between `width` and `height` improves the display:
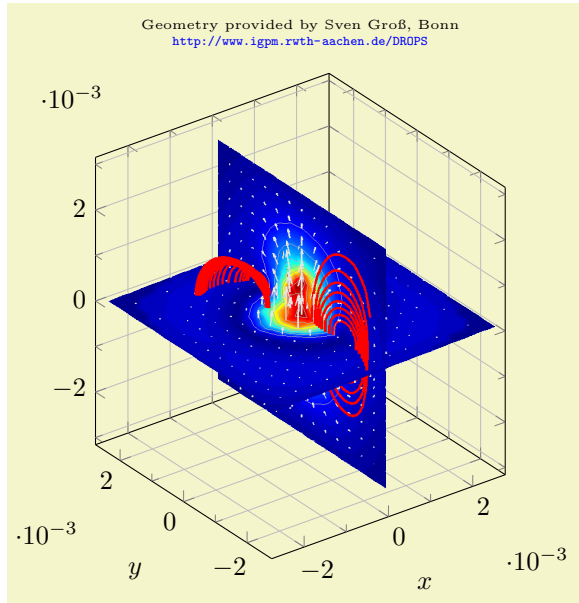
```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
\begin{axis}[
    height=8cm,width=7cm,% improve scaling manually
    grid=both,minor tick num=1,
    xlabel=$x$,ylabel=$y$,
    title={\centering
      Geometry provided by Sven Gro\ss, Bonn\\
      \url{http://www.igpm.rwth-aachen.de/DROPS}\\},
    title style={text width=6cm,font=\tiny},
]
    \addplot3 graphics[
        points={
            (-0.002625,0.002625,0) => (140,234)
            (0,0.00263,0.00263)    => (230,364)
            (0,-0.00263,-0.00263)  => (366,81)
            (0,-0.00263,0.00263)   => (366,276)
            (0.002625,0.002625,0.002625)
        }
    ]
    {plotdata/risingdrop3d.png};
\end{axis}
\end{tikzpicture}
```

What happens is that PGFPLOTS selects a *single* scaling factor which is applied to all units as they have been deduced from the `points` key. This ensures that the imported graphics fits correctly into the axis. In addition, PGFPLOTS does its best to satisfy the remaining constraints.

The complete description of how PGFPLOTS scales the axis can be found in the documentation for `scale mode`=scale uniformly. Here is just a brief summary: PGFPLOTS assumes that the prescribed `width` and `height` have to be satisfied. To this end, it rescales the projected unit vectors (i.e. the space which is taken up for each unit in x, y, and z) and it can modify the axis limits. In the default configuration `scale uniformly strategy`=auto, PGFPLOTS will *never* shrink axis limits.

Compatibility remark: Note that the scaling capabilities have been improved for PGFPLOTS version 1.6. In previous versions, only `scale uniformly strategy`=change vertical limits was available which lead to clipped axes. In short: please consider writing `\pgfplotsset{compat`=1.6} or newer into your document to benefit from the improved scaling. If you have `\pgfplotsset{compat`=1.5} or older, the outcome for `\addplot3 graphics` will be different.

We consider a third example which has been generated by the Matlab code

```
clear all
close all
seed = sum(clock)
rand('seed',seed);
X = rand(10,10,10);
data = smooth3(X,'box',5);
p1 = patch(isosurface(data,.5), ...
   'FaceColor','blue','EdgeColor','none');
p2 = patch(isocaps(data,.5), ...
    'FaceColor','interp','EdgeColor','none');
isonormals(data,p1)
daspect([1 2 2])
view(3); axis vis3d tight
camlight; lighting phong
% print -dpng plotgraphics3withaxis
axis off
print -dpng plotgraphics3
save  plotgraphics3.seed seed -ASCII % to reproduce the result
```

I only added background transparency with `gimp` and got the following graphics:
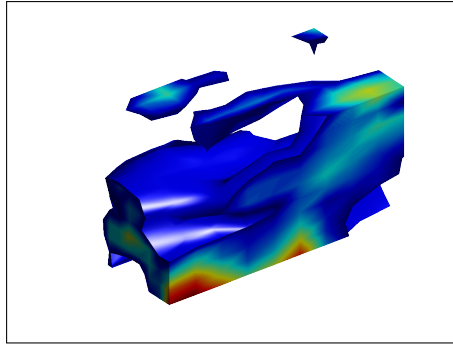
We proceed as before and collect four points, each with 3d logical coordinates (by clicking into the matlab figure) and their associated 2d canvas (graphics) coordinates using the measure tool of gimp. The result is shown in the code example below.
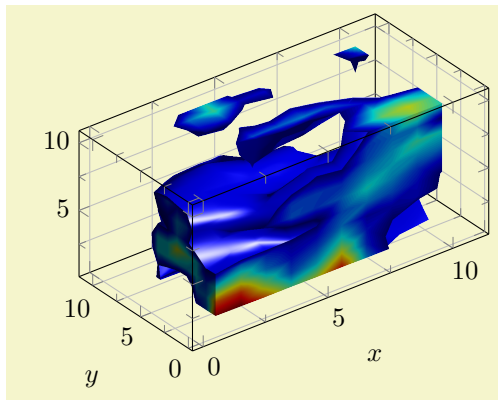

```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
\begin{axis}[
    grid=both,minor tick num=1,
    xlabel=$x$,ylabel=$y$,
    3d box,
]
    \addplot3 graphics[
        points={
            (1,1,1)     => (205,48)
            (10,1,10)   => (503,324)
            (1,1,4.044) => (206,102)
            (10,10,10)  => (390,398)
        }
    ]
    {plotdata/plotgraphics3.png};
\end{axis}
\end{tikzpicture}
```

Note that it has non-standard data aspect ratio which is respected by PGFPLOTS automatically.

External Three-Dimensional Graphics and Matlab

An extension by Jürnjakob Dugge

The procedure to map three–dimensional logical coordinates to two–dimensional canvas coordinates is tedious.

Jürnjakob Dugge contributed a script which does most of the logic and your work is reduced to a copy–paste job. With his permission, I post the contribution here.

The idea is to start a simple script which *records* mappings for any coordinates which have been clicked by the user. It works as follows:

1. Create the Matlab plot, say, using

```
hist3(randn(10000,2)) % some random data
set(get(gca,'child'),'FaceColor','interp','CDataMode','auto'); % colors
% make sure the "print" paper format is the same as the screen paper format:
set(gcf,'PaperPositionMode','auto')
```

2. Save the following code as `pgfplotscsconversion.m`:

```
function pgfplotscsconversion

% Hook into the Data Cursor "click" event
h = datacursormode(gcf);
set(h,'UpdateFcn',@myupdatefcn,'SnapToDataVertex','off');
datacursormode on

% select four points in plot using mouse

% The function that gets called on each Data Cursor click
function [txt] = myupdatefcn(obj,event_obj)

% Get the screen resolution, in dots per inch
dpi = get(0,'ScreenPixelsPerInch');

% Get the click position in pixels, relative to the lower left of the
% screen
screen_location=get(0,'PointerLocation');

% Get the position of the plot window, relative to the lower left of
% the screen
figurePos = get(gcf,'Position');

% Get the data coordinates of the cursor
pos = get(event_obj,'Position');

% Format the data and figure coordinates. The factor "72.27/dpi" is
% necessary to convert from pixels to TeX points (72.27 poins per inch)
display(['(',num2str(pos(1)),',',num2str(pos(2)),',',num2str(pos(3)),') => (', ...
    num2str((screen_location(1)-figurePos(1))*72.27/dpi),',', ...
    num2str((screen_location(2)-figurePos(2))*72.27/dpi),')'])

% Format the tooltip display
txt = {['X: ',num2str(pos(1))],['Y: ',num2str(pos(2))],['Z: ',num2str(pos(3))]};
```

Run `pgfplotscsconversion`, click on four points in your plot. Preferably select non-colinear points near the edges of the plot. Copy and paste the four lines that were written to the Matlab command window.

Make sure that the first two points have different X and Y values on screen (i.e. image canvas coordinates).

3. Export the plot as an image

```
axis off
print -dpng matlabout -r400 % PNG called "matlabout.png" with 400 dpi resolution
```

If you want to export vectors graphics, you should note that `pdf` output of Matlab is clumsy. It might be best to export to `eps` first, followed by a conversion from `eps` to `pdf`.

If you really want to use `pdf` output of Matlab, you may need to set the paper size to match the figure size by yourself, since the PDF driver does not automatically adjust the size:

```
% It might be better to use print -depsc  followed by epstopdf.
% Use this if you (really) want to use print -dpdf:
currentScreenUnits=get(gcf,'Units')      % Get current screen units
currentPaperUnits=get(gcf,'PaperUnits') % Get current paper units
set(gcf,'Units',currentPaperUnits)       % Set screen units to paper units
plotPosition=get(gcf,'Position')         % Get the figure position and size
set(gcf,'PaperSize',plotPosition(3:4))   % Set the paper size to the figure size
set(gcf,'Units',currentScreenUnits)      % Restore the screen units

print -dpdf matlabout        % PDF called "matlabout.pdf"
```

4. Include the image in your PGFPLOTS axis. If you selected points on the plot corners, your `xmin`, `xmax`, `ymin` and `ymax` should be set automatically, otherwise you may want to provide those yourself. Also, adjustments of `width` and `height` might be of interest to get the right vertical placement of the plot. Consider changing `zmin` and/or `zmax` to fit your needs (preferrably only one of them; otherwise PGFPLOTS may be unable to fix the `height`).

This contribution is from
http://tex.stackexchange.com/questions/52987/3-dimensional-histogram-in-pgfplots .

Summary: External Three-Dimensional Graphics

As has been shown in the previous sections, `\addplot3 graphics` allows to include three-dimensional graphics and PGFPLOTS overlays a flexible axis with all its power. The cost to do so is

1. collect both logical three–dimensional coordinates *and* image–internal two–dimensional coordinates for *four points* of your graphics.

   In Matlab, this can be simplified by the tool mentioned on page 71.

2. If your axes form a right–handed–coordinate system, that is all. If not, also add `x dir`=reverse for any reversed axes.

Consider the following list of you encounter problems while working with `\addplot3 graphics`:

- It must be possible to deduce the origin and the three (two–dimensional) unit vectors from the four provide `points`; otherwise the algorithm will fail.

  The algorithm should detect any deficiancies. However, if you encounter strange "Dimension too large" messages here, you can try other arguments in `points`. Take a look into your log file, it will probably indicate the source of problems (or use the `debug` key).

- Ensure that the external graphics has an orthogonal axis. In fact, the axis may be skewed (just like a PGFPLOTS axis can be created by means of custom `x`, `y`, and `z` vectors). However, the external image must not have perspective projection as this is unsupported by PGFPLOTS. The `points` command needs to receive four points which belong to linearly independent position vectors.

- PGFPLOTS uses the first two points to squeeze the graphics into the desired coordinates (which implies that they should not have the same canvas X or Y coordinates). It verifies that the remaining `points` arguments are projected correctly.

- The resulting scaling by means of `scale mode`=scale uniformly will try to satisfy all scaling constraints. You can change these constraints by modifying `width`, `height`, `xmin`, `xmax`, `ymin`, `ymax`, `zmin`, `zmax` and/or any combination of these parameters. See also `unit rescale keep size` which controls the flexibility of limit changes. There is also a key `scale uniformly strategy` which allows to select a different scaling strategy.

- The image should have a "right–handed–coordinate system": you should be able to take your right hand, point your thumb in direction of the x axis, your first finger in direction of y, and your second finger in direction of the z axis. If that is impossible, once of your axes is reversed and you need to communicate that to PGFPLOTS explicitly by means of the `x dir`=reverse key (and its variants).

- Note that this feature has been verified with standard cartesian axes only.

- There is a `debug` key to investigate what the algorithm is doing:

  /pgfplots/`plot graphics/debug`=true|false|visual   (initially `false`)

  > If you provide `\addplot3 graphics[debug,points={...}]`, PGFPLOTS will provide debug information onto your terminal and into the logfile. It will also generate extra files containing the determined unit vectors and the linear system used to derive them (one such file for every `\addplot3 graphics` statement, the filename will be the graphics file name and `.dat` appended).
  >
  > Without the `debug` key, only the log file will contain brief information what PGFPLOTS is doing behind the scenes.
  >
  > The choice `true` activates log messages. The choice `visual` activates log messages *and* places some filled circles at the provided `points`. The choice `false` disables all `debug` features.

4.3.9 Reading Coordinates From Files

```
\addplot file {⟨name⟩};
\addplot[⟨options⟩] file {⟨name⟩} ⟨trailing path commands⟩;
\addplot3 ...
```

Deprecation note: If you have data files, you should generally use `\addplot table`. The input type `\addplot file` is almost the same, but considerably less powerful. It is only kept for backwards compatibility.

The `\addplot file` input mechanism is similar to the TikZ-command '`plot file`'. It is to be used like

```
\addplot file {datafile.dat};
```

where ⟨*name*⟩ is a text file with at least two columns which will be used as x and y coordinates. Lines starting with '`%`' or '`#`' are ignored. Such files are often generated by GNUPLOT:

```
#Curve 0, 20 points
#x y type
0.00000 0.00000 i
0.52632 0.50235 i
1.05263 0.86873 i
1.57895 0.99997 i
...
9.47368 -0.04889 i
10.00000 -0.54402 i
```

This listing has been copied from [7, section 16.4].

Plot file accepts one optional argument,

```
\addplot file[skip first] {datafile.dat};
```

which allows to skip over a non-comment header line. This allows to read the same input files as `plot table` by skipping over column names. Please note that comment lines do not count as lines here.

The input method `plot file` can also read meta data for every coordinate. As already explained for `plot coordinates` (see above), meta data can be used to change colors or other style parameters for every marker separately. Now, if `point meta` is set to `explicit` or to `explicit symbolic` and the input method is `plot file`, one further element will be read from disk – for every line. Meta data is always the last element which is read. See page 109 for information and examples about per point meta data and page 112 for an application example using `scatter/classes`.

Plot file is very similar to `plot table`: you can achieve the same effect with

```
\addplot table[x index=0,y index=1,header=false] {datafile.dat};
```

Due to its simplicity, `plot file` is slightly faster while `plot table` allows higher flexibility.

Technical note: every opened file will be protocolled into your log file.

The file can contain `empty line`s to tell PGFPLOTS that the function has jumps. To use it, simply insert an empty line (and ensure that you have `\pgfplotsset{compat=1.4}` or newer in your preamble). See the documentation of `empty line` for details.

/pgfplots/**plot file/skip first**=true|false   (initially **false**)
/pgfplots/**plot file/ignore first**=true|false   (initially **false**)

The two keys can be provided as arguments to `\addplot` file[⟨*options*⟩] {⟨*filename*⟩}; to skip the first non-comment entry in the file. They are equivalent. If you provide them in this context, the prefix `/pgfplots/plot file` can be omitted.

4.4   About Options: Preliminaries

PGFPLOTS knows a whole lot of key–value options which can be (re)defined to activate desired features or modified to apply some fine-tuning.

A key usually has a value (like a number, a string, or perhaps some macro code). You can assign values to keys ("set keys") in many places in a LATEX document. The value will remain effective until it is changed or until the current TEX scope ends (which happens after a closing curly brace '}', after `\end{`⟨*name*⟩`}` or, for example, after `\addplot`).

Most keys can be used like

```
\begin{tikzpicture}
\begin{axis}[key=value,key2=value2] % axis-wide keys
...
\end{axis}
\end{tikzpicture}
```

which changes them for the complete axis. A `key` in this context can be any option defined in this manual, no matter if it has the `/pgfplots/` or the `/tikz/` key prefix. Note that key prefixes can be omitted in almost all cases.

A value can usually be provided without curly braces. For example, if the manual contains something like '`xmin={⟨x coordinate⟩}`', you can safely skip the curly braces. The curly braces are mandatory if values contain something which would otherwise confuse the key setup (for example an equal sign '`=`' or a comma '`,`').

Some keys can be changed individually for each plot:

```
\begin{tikzpicture}
\begin{axis}
% keys valid for single plots:
\addplot ...;                          % uses the "cycle list" to determine keys
\addplot[key=value,key2=value2] ... ;  % uses the provided keys (not the "cycle list")
\addplot+[key=value,key2=value2] ... ; % appends something to the "cycle list"
\end{axis}
\end{tikzpicture}
```

Besides these two possibilities, it is also possible to work with document-wide keys:

```
\chapter{My Section}
\pgfplotsset{
    key=value,
    key2=value2,
}
This section has a common key configuration:
\begin{tikzpicture}
    \begin{axis}% uses the key config from above
    ...
    \end{axis}
\end{tikzpicture}
```

In the example above, the `\pgfplotsset` command changes keys. The changes are permanent and will be used until

- you redefine them or

- the current environment (like `\end{figure}`) is ended or

- T_EX encounters a closing brace '`}`'.

This includes document–wide preamble configurations like

```
\documentclass{article}

\usepackage{pgfplots}
\pgfplotsset{
    xticklabel={$\mathsf{\pgfmathprintnumber{\tick}}$},
    every axis/.append style={
        font=\sffamily,
    },
}
...
```

The basic engine to manage key–value pairs is `pgfkeys` which is part of PGF. This engine always has a key name and a key "path", which is somehow similar to file name and directory of files. The common "directory" (key path) of PGFPLOTS is '`/pgfplots/`'. Although the key definitions below provide this full path, it is always (well, almost always) safe to skip this prefix – PGFPLOTS uses it automatically. The same holds for the prefixes '`/tikz/`' which are common for all Ti*k*Z drawing options and '`/pgf/`' which are for the (more or less) low–level commands of PGF. All these prefixes can be omitted.

One important concept is the concept of *styles*. A style is a key which contains one or more other keys. It can be redefined or modified until it is actually used by the internal routines. Each single component of Ti*k*Z and PGFPLOTS can be configured with styles.

For example,

```
\pgfplotsset{legend style={line width=1pt}}
```

sets the line width for every legend to `1pt` by appending '`line width`=1pt' to the existing style for legends.

There are keys like `legend style`, `ticklabel style`, and `label style` which allow to modify the predefined styles (in this case the styles for legends, ticklabels and axis labels, respectively). They are, in general, equivalent to a ⟨*style name*⟩/`.append style`={} command (the only difference is that the /`.append style` thing is a little bit longer). There is also the possibility to define a new style (or to overwrite an already existing one) using /`.style`={}.

There are several other styles predefined to modify the appearance, see Section 4.18.

\pgfplotsset{⟨*key-value-list*⟩}

Defines or sets all options in ⟨*key-value-list*⟩. The ⟨*key-value-list*⟩ can contain any of the options in this manual which have the prefix /`pgfplots/` (however, you do not need to type that prefix).

Inside of ⟨*key-value-list*⟩, the prefixes '/`pgfplots/`' which are commonly presented in this manual can be omitted (they are checked automatically).

This command can be used to define default options for the complete document or a part of the document. For example,

```
\pgfplotsset{
    cycle list={%
        {red, mark=*}, {blue,mark=*},
        {red, mark=x}, {blue,mark=x},
        {red, mark=square*}, {blue,mark=square*},
        {red, mark=triangle*}, {blue,mark=triangle*},
        {red, mark=diamond*}, {blue,mark=diamond*},
        {red, mark=pentagon*}, {blue,mark=pentagon*}
    },
    legend style={
        at={(0.5,-0.2)},
        anchor=north,
        legend columns=2,
        cells={anchor=west},
        font=\footnotesize,
        rounded corners=2pt,
    },
    xlabel=$x$,ylabel=$f(x)$
}
```

can be used to set document-wise styles for line specifications, the legends' style and axis labels. The settings remain in effect until the end of the current environment (like `\end{figure}`) or until you redefine them or until the next closing curly brace '}' (whatever comes first).

You can also define new styles (collections of key–value–pairs) with /`.style` and /`.append style`.

```
\pgfplotsset{
    My Style 1/.style={xlabel=$x$, legend entries={1,2,3} },
    My Style 2/.style={xlabel=$X$, legend entries={4,5,6} }
}
```

The /`.style` and /`.append style` key handlers are described in Section 4.18 in more detail.

Key handler ⟨*key*⟩/`.code`={⟨*TₑX code*⟩}

Occasionally, the PGFPLOTS user interface offers to replace parts of its routines. This is accomplished using so called "code keys". What it means is to replace the original key and its behavior with new ⟨*TₑX code*⟩. Inside of ⟨*TₑX code*⟩, any command can be used. Furthermore, the `#1` pattern will be the argument provided to the key.

> I've been invoked with 'this here'
```
\pgfplotsset{
    My Code/.code={I've been invoked with '#1'}}
\pgfplotsset{My Code={this here}}
```

The example defines a (new) key named `My Code`. Essentially, it is nothing else but a `\newcommand`, plugged into the key-value interface. The second statement "invokes" the code key.

Key handler ⟨*key*⟩/`.code 2 args`={⟨*TₑX code*⟩}

As /`.code`, but this handler defines a key which accepts two arguments. When the so defined key is used, the two arguments are available as `#1` and `#2`.

Key handler ⟨*key*⟩/`.cd`

Each key has a fully qualified name with a (long) prefix, like `/pgfplots/xmin`. However, if the "current directory" is `/pgfplots`, it suffices to write just `xmin`. The `/.cd` key handler changes the "current directory" in this way.

The prefixes `/tikz/` and `/pgfplots/` are checked automatically for any argument provided to `\begin{axis}[`⟨*options*⟩`]` or `\addplot`. So, you won't need to worry about them, just omit them – and look closer in case the package doesn't identify the option.

4.4.1 Pgfplots and Ti*k*Z Options

This section is more or less technical and can be skipped unless one really wants to know more about this topic.

Ti*k*Z options and PGFPLOTS options can be mixed inside of the axis arguments and in any of the associated styles. For example,

```
\pgfplotsset{every axis legend/.append style={
    legend columns=3,font=\Large}}
```

assigns the '`legend columns`' option (a PGFPLOTS option) and uses '`font`' for drawing the legend (a Ti*k*Z option). The point is: `legend columns` needs to be known *before* the legend is typeset whereas `font` needs to be active when the legend is typeset. PGFPLOTS sorts out any key dependencies automatically:

The axis environments will process any known PGFPLOTS options, and all '**every**'–styles will be parsed for PGFPLOTS options. Every unknown option is assumed to be a Ti*k*Z option and will be forwarded to the associated Ti*k*Z drawing commands. For example, the '`font`=`\Large`' above will be used as argument to the legend matrix, and the '`font`=`\Large`' argument in

```
\pgfplotsset{every axis label/.append style={
    ylabel=Error,xlabel=Dof,font=\Large}}
```

will be used in the nodes for axis labels (but not the axis title, for example).

It is an error if you assign incompatible options to axis labels, for example '`xmin`' and '`xmax`' can't be set inside of '`every axis label`'.

4.5 Two Dimensional Plot Types

PGFPLOTS supports several two-dimensional line plots like piecewise linear line plots, piecewise constant plots, smoothed plots, bar plots and comb plots. Most of them use the PGF plot handler library directly, see [7, section 18.8].

Plot types are part of the plot style, so they are set with options. Most of the basic 2d plot types are part of Ti*k*Z, see [7, section 18.8], and are probably known to users of Ti*k*Z. They are documented here as well.
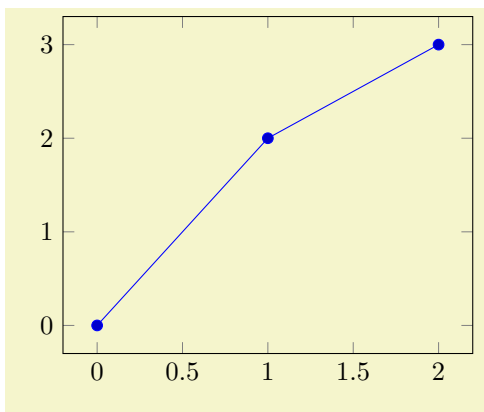
4.5.1 Linear Plots

`/tikz/`**sharp plot**   (no value)

`\addplot+[`**sharp plot**`]`

Linear ('sharp') plots are the default. Point coordinates are simply connected by straight lines.

```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
\begin{axis}
    \addplot+[sharp plot] coordinates
        {(0,0) (1,2) (2,3)};
\end{axis}
\end{tikzpicture}
```

The '+' here means to use the normal plot cycle list and append 'sharp plot' to its option list.

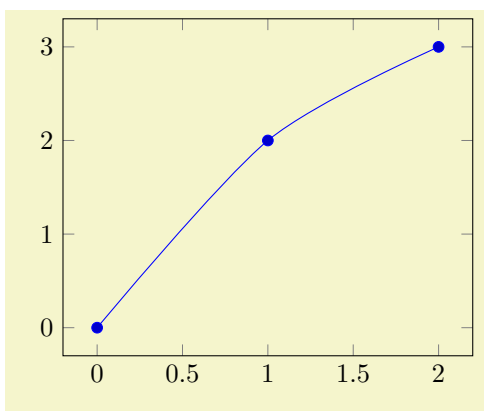### 4.5.2   Smooth Plots

/tikz/smooth   (no value)

\addplot+[smooth]

Smooth plots interpolate smoothly between successive points.


```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
\begin{axis}
    \addplot+[smooth] coordinates
        {(0,0) (1,2) (2,3)};
\end{axis}
\end{tikzpicture}
```

As described in [7] in all detail, this plot handler results in a "smooth" outline. However, it "not very intelligent" (compare [7]) and is unrelated to common plot-based interpolation schemes.

/tikz/tension={⟨tension⟩}   (initially 0.55)

A parameter which controls how the remaining degrees of freedom are fixed: it controls the smoothing effect. Higher values results in more "rounded" corners whereas low values result in sharp corners.

Please refer to [7] for details.

4.5.3   Constant Plots

Constant plots draw lines parallel to the x-axis to connect coordinates. The discontinuous edges may be drawn or not, and marks may be placed on left or right ends.

/tikz/const plot   (no value)

\addplot+[const plot]

Connects all points with horizontal and vertical lines. Marks are placed left-handed on horizontal line segments, causing the plot to be right-sided continuous at all data points.
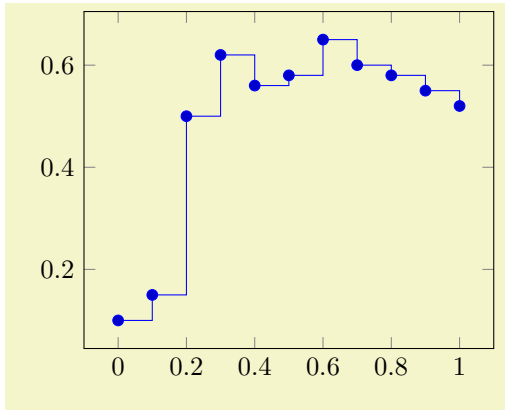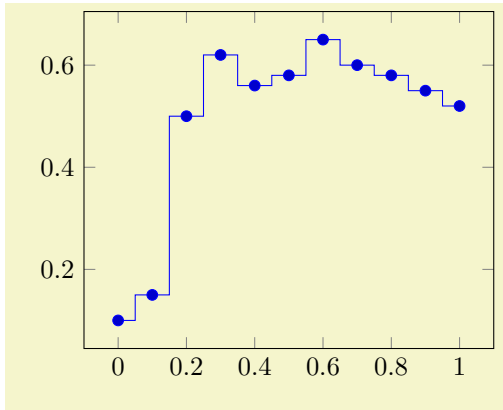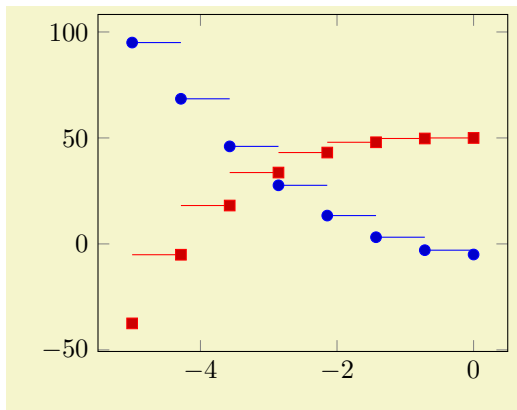
```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
\begin{axis}
\addplot+[const plot]
coordinates
{(0,0.1)    (0.1,0.15) (0.2,0.5)   (0.3,0.62)
 (0.4,0.56) (0.5,0.58) (0.6,0.65)  (0.7,0.6)
 (0.8,0.58) (0.9,0.55) (1,0.52)};
\end{axis}
\end{tikzpicture}
```
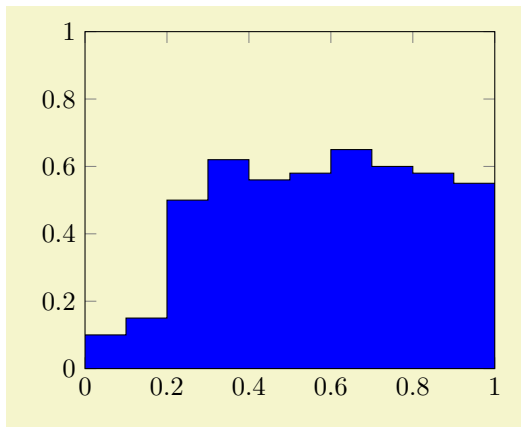
```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
\begin{axis}[ymin=0,ymax=1,enlargelimits=false]
\addplot
    [const plot,fill=blue,draw=black]
coordinates
{(0,0.1)    (0.1,0.15) (0.2,0.5)   (0.3,0.62)
 (0.4,0.56) (0.5,0.58) (0.6,0.65)  (0.7,0.6)
 (0.8,0.58) (0.9,0.55) (1,0.52)}
    \closedcycle;
\end{axis}
\end{tikzpicture}
```

/tikz/**const plot mark left**   (no value)

\addplot+[const plot mark left]

   An alias for 'const plot'.

/tikz/**const plot mark right**   (no value)

\addplot+[const plot mark right]

   A variant which places marks on the right of each line segment, causing plots to be left-sided continuous at the given coordinates.
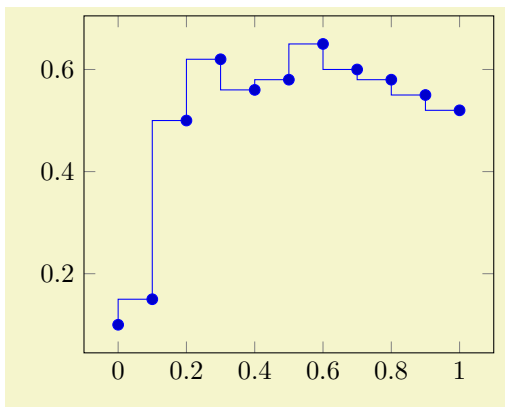
```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
\begin{axis}
\addplot+[const plot mark right]
coordinates
{(0,0.1)    (0.1,0.15) (0.2,0.5)   (0.3,0.62)
 (0.4,0.56) (0.5,0.58) (0.6,0.65)  (0.7,0.6)
 (0.8,0.58) (0.9,0.55) (1,0.52)};
\end{axis}
\end{tikzpicture}
```

/tikz/**const plot mark mid**   (no value)

\addplot+[const plot mark mid]

   A variant which places marks in the middle of each line segment, causing plots to be symmetric around its data points.

```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
\begin{axis}
\addplot+[const plot mark mid]
coordinates
{(0,0.1)     (0.1,0.15)  (0.2,0.5)    (0.3,0.62)
 (0.4,0.56) (0.5,0.58)  (0.6,0.65)   (0.7,0.6)
 (0.8,0.58) (0.9,0.55)  (1,0.52)};
\end{axis}
\end{tikzpicture}
```

Note that "symmetric" is only true for constant mesh width: if the x–distances between adjacent data points differ, `const plot mark mid` will produce vertical lines in the middle between each pair of consecutive points.

/tikz/jump mark left   (no value)

\addplot+[jump mark left]

A variant of '`const plot mark left`' which does not draw vertical lines.

```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
\begin{axis}[samples=8]
\addplot+[jump mark left,domain=-5:0]
    {4*x^2 - 5};

\addplot+[jump mark right,domain=-5:0]
    {0.7*x^3 + 50};
\end{axis}
\end{tikzpicture}
```

/tikz/jump mark right   (no value)

\addplot+[jump mark right]

A variant of '`const plot mark right`' which does not draw vertical lines.

/tikz/jump mark mid   (no value)

\addplot+[jump mark mid]

A variant of '`const plot mark mid`' which does not draw vertical lines.
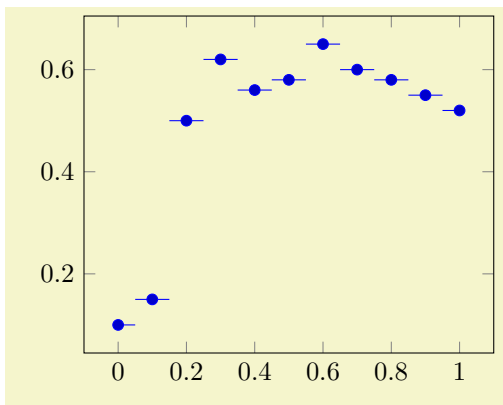
```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
\begin{axis}
\addplot+[jump mark mid]
coordinates
{(0,0.1)     (0.1,0.15)  (0.2,0.5)    (0.3,0.62)
 (0.4,0.56) (0.5,0.58)  (0.6,0.65)   (0.7,0.6)
 (0.8,0.58) (0.9,0.55)  (1,0.52)};
\end{axis}
\end{tikzpicture}
```

4.5.4 Bar Plots

Bar plots place horizontal or vertical bars at coordinates. Multiple bar plots in one axis can be stacked on top of each other or aligned next to each other.

/tikz/xbar   (no value)

\addplot+[xbar]

Places horizontal bars between the ($y = 0$) line and each coordinate.

This option is used on a per-plot basis and configures only the visualization of coordinates. The figure-wide style /pgfplots/xbar also sets reasonable options for ticks, legends and multiple plots.
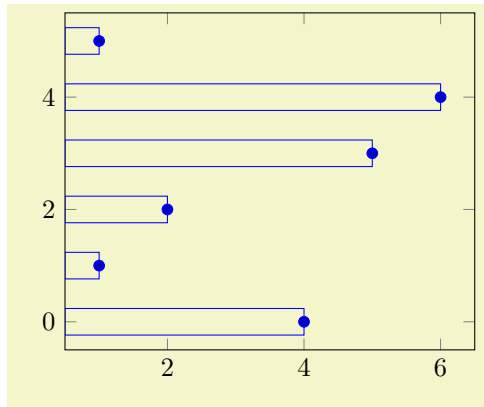

```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
\begin{axis}
\addplot+[xbar] coordinates
    {(4,0) (1,1) (2,2)
     (5,3) (6,4) (1,5)};
\end{axis}
\end{tikzpicture}
```

Bars are centered at plot coordinates with width `bar width`. Using bar plots usually means more than just a different way of how to connect coordinates, for example to draw ticks outside of the axis, change the legend's appearance or introduce shifts if multiple \addplot commands appear.

There is a preconfigured style for xbar which is installed automatically if you provide xbar as argument to the axis environment which provides this functionality.
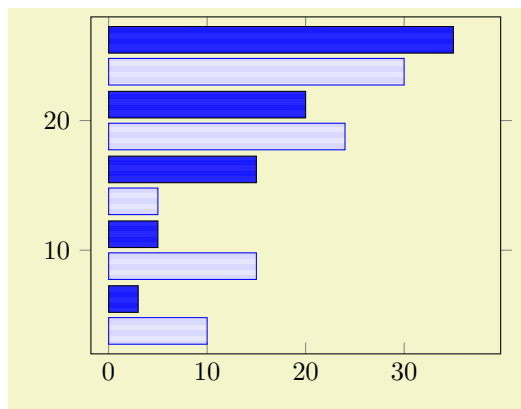

```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
\begin{axis}[xbar,enlargelimits=0.15]
\addplot
[draw=blue,pattern=horizontal lines light blue]
coordinates
    {(10,5) (15,10) (5,15) (24,20) (30,25)};

\addplot
[draw=black,pattern=horizontal lines dark blue]
coordinates
    {(3,5) (5,10) (15,15) (20,20) (35,25)};
\end{axis}
\end{tikzpicture}
```

Here xbar yields /pgfplots/xbar because it is an argument to the axis, not to a single plot.

For bar plots, it is quite common to provide textual coordinates or even descriptive nodes near the bars. This can be implemented using the keys symbolic y coords and nodes near coords, respectively:
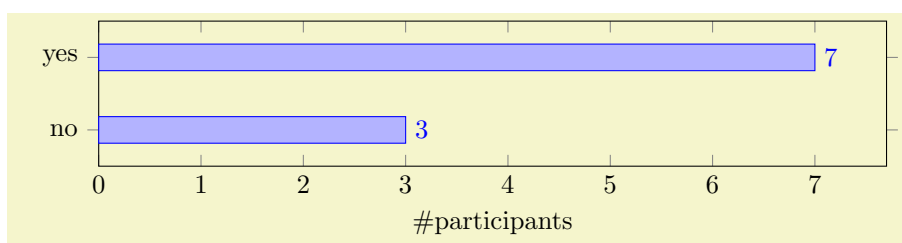
```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
  \begin{axis}[
    xbar, xmin=0,
    width=12cm, height=3.5cm, enlarge y limits=0.5,
    xlabel={\#participants},
    symbolic y coords={no,yes},
    ytick=data,
    nodes near coords, nodes near coords align={horizontal},
    ]
    \addplot coordinates {(3,no) (7,yes)};
  \end{axis}
\end{tikzpicture}
```

The `symbolic y coords` defines a dictionary of accepted coordinates which are then expected in y coordinates and the `nodes near coords` key displays values as extra nodes (see their reference documentations for details). The example employs `enlarge y limits` in order to get some more free space since the default spacing is not always appropriate for bar plots.

Note that it might be quite important to include `xmin`=0 explicitly as in the example above. Without it, the lower bound will be used:
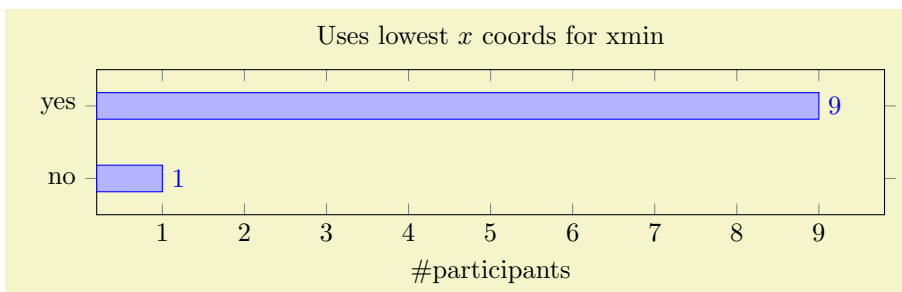

```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
  \begin{axis}[
      title=Uses lowest $x$ coords for xmin,
    xbar,
    width=12cm, height=3.5cm, enlarge y limits=0.5,
    xlabel={\#participants},
    symbolic y coords={no,yes},
    ytick=data,
    nodes near coords, nodes near coords align={horizontal},
    ]
    \addplot coordinates {(1,no) (9,yes)};
  \end{axis}
\end{tikzpicture}
```

Besides line, fill, and colorstyles, bars can be configured with `bar width` and `bar shift`, see below.

/pgfplots/**xbar**={⟨*shift for multiple plots*⟩}   (style, default **2pt**)

This style sets `/tikz/xbar` *and* some commonly used options concerning horizontal bars for the complete axis. This is automatically done if you provide `xbar` as argument to an axis argument, see above.

The `xbar` style defines shifts if multiple plots are placed into one axis. It draws bars adjacent to each other, separated by ⟨*shift for multiple plots*⟩. Furthermore, it sets the style `bar cycle list` and sets tick and legend appearance options.

The style is defined as follows.

```
\pgfplotsset{
    /pgfplots/xbar/.style={
        /tikz/xbar,
        bar cycle list,
        tick align=outside,
        xbar legend,
        /pgfplots/bar shift auto={#1},
    },
}
```

/pgfplots/bar shift auto={⟨*shift for multiple plots*⟩}   (default 2pt)

The formula for bar shift assigns shifts dependent on the total number of plots and the current plot's number. It is designed to fill a total width of $n \cdot$bar width$+(n-1) \cdot$⟨*shift for multiple plots*⟩. The 0.5 compensates for centering.

The style is defined as

```
\pgfplotsset{
    /pgfplots/bar shift auto/.style={%
        /pgf/bar shift={%
                % total width = n*w + (n-1)*skip
                % -> subtract half for centering
                -0.5*(\numplotsofactualtype*\pgfplotbarwidth + (\numplotsofactualtype-1)*(#1))  +
                % the '0.5*w' is for centering
                (.5+\plotnumofactualtype)*\pgfplotbarwidth + \plotnumofactualtype*(#1)},%
    },
}
```

/tikz/ybar   (no value)

\addplot+[ybar]

Like xbar, this option generates bar plots. It draws vertical bars between the ($x = 0$) line and each input coordinate.
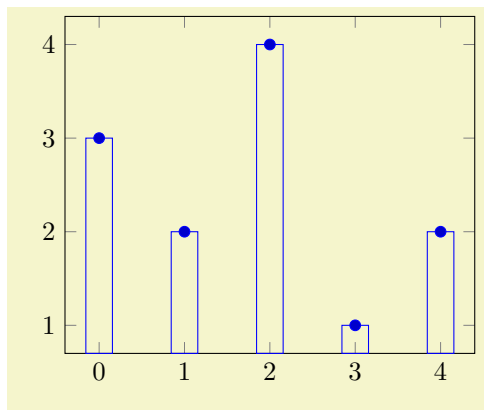

```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
\begin{axis}
\addplot+[ybar] plot coordinates
    {(0,3) (1,2) (2,4) (3,1) (4,2)};
\end{axis}
\end{tikzpicture}
```

The example above simply changes how input coordinates shall be visualized. As mentioned for xbar, one usually needs modified legends and shifts for multiple bars in the same axis.

There is a predefined style which installs these customizations when provided to the axis environment:
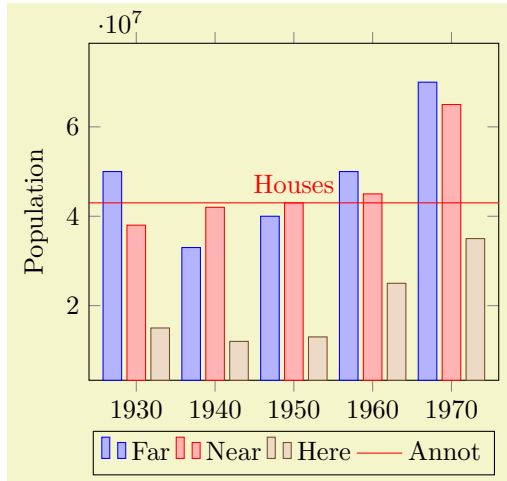
```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
\begin{axis}[
    x tick label style={
        /pgf/number format/1000 sep=},
    ylabel=Population,
    enlargelimits=0.15,
    legend style={at={(0.5,-0.15)},
        anchor=north,legend columns=-1},
    ybar,
    bar width=7pt,
]
\addplot
    coordinates {(1930,50e6) (1940,33e6)
        (1950,40e6) (1960,50e6) (1970,70e6)};

\addplot
    coordinates {(1930,38e6) (1940,42e6)
        (1950,43e6) (1960,45e6) (1970,65e6)};

\addplot
    coordinates {(1930,15e6) (1940,12e6)
        (1950,13e6) (1960,25e6) (1970,35e6)};

\addplot[red,line legend,sharp plot,
    update limits=false]
    coordinates {(1910,4.3e7) (1990,4.3e7)}
    node[above] at (1950,4.3e7) {Houses};

\legend{Far,Near,Here,Annot}
\end{axis}
\end{tikzpicture}
```
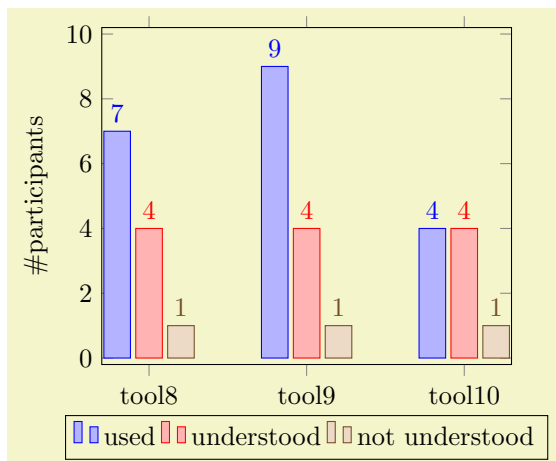
Here, `ybar` yields `/pgfplots/ybar` because it is an argument to the axis, not to a single plot. The style affects the first three `\addplot` commands. Note that it shifts them horizontally around the plot coordinates. The fourth `\addplot` command is some kind of annotation which doesn't `update limits`.

The `ybar` style can be combined with `symbolic x coords` in a similar way as described for `xbar`:

```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
\begin{axis}[
    ybar,
    enlargelimits=0.15,
    legend style={at={(0.5,-0.15)},
        anchor=north,legend columns=-1},
    ylabel={\#participants},
    symbolic x coords={tool8,tool9,tool10},
    xtick=data,
    nodes near coords,
    nodes near coords align={vertical},
    ]
\addplot coordinates {(tool8,7) (tool9,9) (tool10,4)};
\addplot coordinates {(tool8,4) (tool9,4) (tool10,4)};
\addplot coordinates {(tool8,1) (tool9,1) (tool10,1)};
\legend{used,understood,not understood}
\end{axis}
\end{tikzpicture}
```

As for `xbar`, the bar width and shift can be configured with `bar width` and `bar shift`. However, the bar shift is better provided as argument to `/pgfplots/ybar` since this style will overwrite the bar shift. Thus, prefer `/pgfplots/ybar`=4pt to set the bar shift.

Sometimes it is useful to write the y values directly near the bars. This can be realized using the `nodes near coords` method:
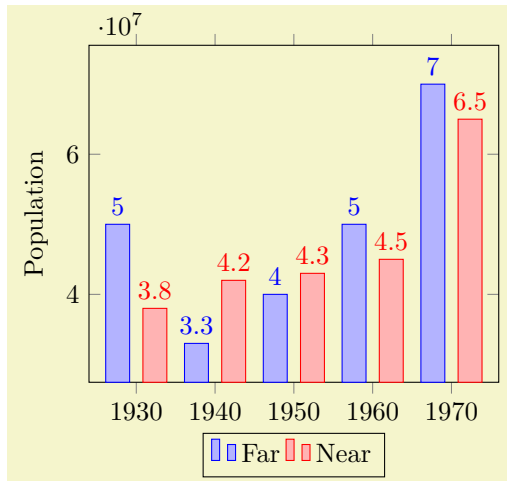
```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
\begin{axis}[
    x tick label style={
        /pgf/number format/1000 sep=},
    ylabel=Population,
    enlargelimits=0.15,
    legend style={at={(0.5,-0.15)},
        anchor=north,legend columns=-1},
    ybar=5pt,% configures 'bar shift'
    bar width=9pt,
    nodes near coords,
    point meta=y *10^-7 % the displayed number
]
\addplot
    coordinates {(1930,50e6) (1940,33e6)
        (1950,40e6) (1960,50e6) (1970,70e6)};

\addplot
    coordinates {(1930,38e6) (1940,42e6)
        (1950,43e6) (1960,45e6) (1970,65e6)};

\legend{Far,Near}
\end{axis}
\end{tikzpicture}
```

Any support style changes are possible, of course. A useful example for bar plots might be to use rotated tick labels:
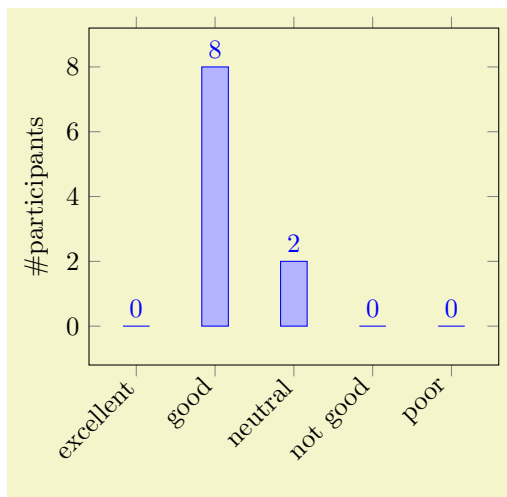

```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
  \begin{axis}[
    ybar,
    enlargelimits=0.15,
    legend style={at={(0.5,-0.2)},
      anchor=north,legend columns=-1},
    ylabel={\#participants},
    symbolic x coords={excellent,good,neutral,%
        not good,poor},
    xtick=data,
    nodes near coords,
    nodes near coords align={vertical},
    x tick label style={rotate=45,anchor=east},
    ]
    \addplot coordinates {(excellent,0) (good,8)
        (neutral,2) (not good,0) (poor,0)};
  \end{axis}
\end{tikzpicture}
```

/pgfplots/**ybar**={⟨*shift for multiple plots*⟩}   (style, default **2pt**)

   As /pgfplots/xbar, this style sets the /tikz/ybar option to draw vertical bars, but it also provides commonly used options for vertical bars.

   If you supply ybar to an axis environment, /pgfplots/ybar will be chosen instead of /tikz/ybar.

   It changes the legend, draws ticks outside of the axis lines and draws multiple \addplot arguments adjacent to each other; block–centered at the *x* coordinate and separated by ⟨*shift for multiple plots*⟩. It will also install the bar shift for every node near coord. Furthermore, it installs the style bar cycle list. It is defined similarly to /pgfplots/xbar.

/pgfplots/**bar cycle list**   (no value)

   A style which installs cycle lists for multiple bar plots.

```
\pgfplotsset{
    /pgfplots/bar cycle list/.style={/pgfplots/cycle list={%
        {blue,fill=blue!30!white,mark=none},%
        {red,fill=red!30!white,mark=none},%
        {brown!60!black,fill=brown!30!white,mark=none},%
        {black,fill=gray,mark=none},%
        }
    },
}
```

/pgf/bar width={⟨*dimension or unit*⟩}   (initially `10pt`)

Configures the width used by `xbar` and `ybar`. It is accepted to provide mathematical expressions.

As of PGFPLOTS 1.7, it is allows to provide an *unit* as `bar width`. In this case, the `bar width` will be interpreted as axis unit:
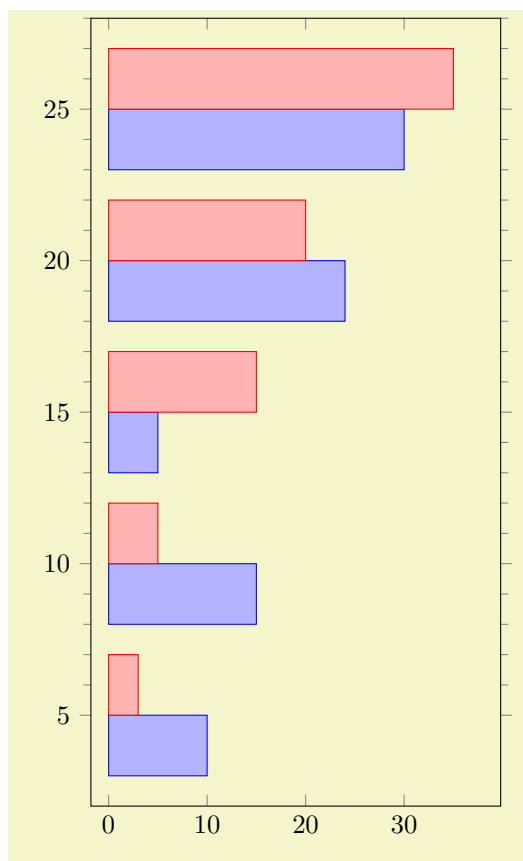

```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
\begin{axis}[
    xbar=0pt,% space of 0pt between adjacent bars
    bar width=2,
    width=7cm,
    height=12cm,
    minor y tick num=4,
    ytick=data,
    enlargelimits=0.15]
\addplot
coordinates
    {(10,5) (15,10) (5,15) (24,20) (30,25)};
\addplot
coordinates
    {(3,5) (5,10) (15,15) (20,20) (35,25)};
\end{axis}
\end{tikzpicture}
```

In order to interprete arguments as units, you have to write `\pgfplotsset{compat=1.7}` (or newer) into your preamble. Older versions will implicitly append the `pt` suffix if the argument is no dimension.

\pgfplotbarwidth

A mathematical expression which results in the fully computed value of `bar width` (i.e. it includes any unit computations).

Note that you may need to `enlargelimits` in order to see the complete bar – PGFPLOTS will not automatically update the axis limits to respect `bar width`.

/pgf/bar shift={⟨*dimension or unit*⟩}   (initially `0pt`)

Configures a shift for `xbar` and `ybar`. Use `bar shift` together with `bar width` to draw multiple bar plots into the same axis. It is accepted to provide mathematical expressions.

As of PGFPLOTS 1.7, it is allows to provide an *unit* as `bar shift`. In this case, the `bar shift` will be interpreted as axis unit.

\pgfplotbarshift

A mathematical expression which results in the fully computed value of `bar shift` (i.e. it includes any unit computations).

Note that you may need to `enlargelimits` in order to see the complete bar – PGFPLOTS will not automatically update the axis limits to respect `bar shift`.

/pgfplots/bar direction=auto|x|y   (initially `auto`)

If PGFPLOTS encounters a value `bar width`=1 (i.e. *without* dimension like `1pt`), it attempts to evaluate the bar's direction.

The default configuration `auto` assumes that you write something like `ybar,bar width`=1. In this case, it is clear that you have a y bar and PGFPLOTS assumes `bar direction`=y.

However, this context information is unavailable. In this case, you can use the choice `x` if PGFPLOTS in unaware that it works on an `xbar` plot or `y` if PGFPLOTS is unaware that you meant an `ybar` plot.

/tikz/ybar interval   (no value)

\addplot+[ybar interval]

This plot type produces vertical bars with width (and shift) relatively to intervals of coordinates.

There is one conceptional difference when working with intervals: an interval is defined by *two* coordinates. Since `ybar` has one value for each interval, the ith bar is defined by

1. the y value of the ith coordinates,
2. the x value of the ith coordinate as left interval boundary,
3. the x value of the $(i+1)$th coordinate as right interval boundary.

Consequently, there is *one coordinate too much*: the last coordinate will *only* be used to determine the interval width; its y value doesn't influence the bar appearance.

It is installed on a per-plot basis and configures *only* the visualization of coordinates. See the style `/pgfplots/ybar interval` which configures the appearance of the complete figure.
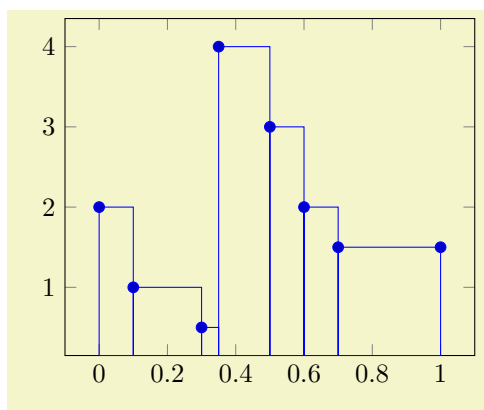

```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
\begin{axis}
\addplot+[ybar interval] plot coordinates
    {(0,2) (0.1,1) (0.3,0.5) (0.35,4) (0.5,3)
     (0.6,2) (0.7,1.5) (1,1.5)};
\end{axis}
\end{tikzpicture}
```
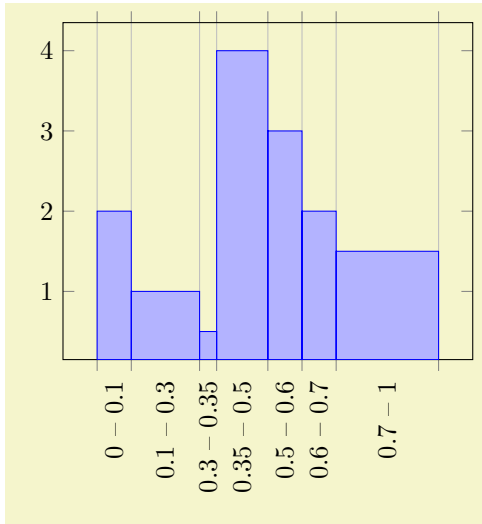
```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
\begin{axis}[ybar interval,
    xtick=data,
    xticklabel interval boundaries,
    x tick label style=
        {rotate=90,anchor=east}
    ]
\addplot coordinates
    {(0,2) (0.1,1) (0.3,0.5) (0.35,4) (0.5,3)
     (0.6,2) (0.7,1.5) (1,1.5)};
\end{axis}
\end{tikzpicture}
```
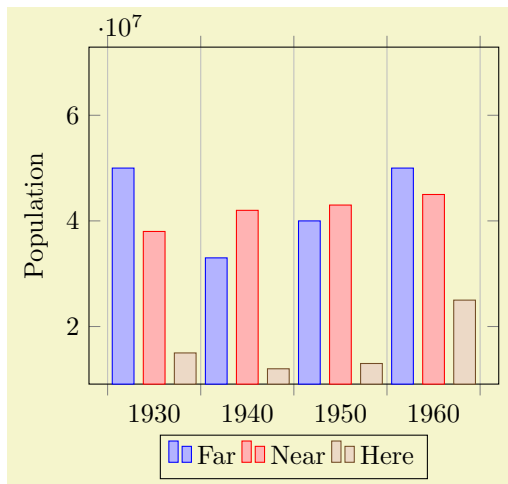
```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
\begin{axis}[
    x tick label style={
        /pgf/number format/1000 sep=},
    ylabel=Population,
    enlargelimits=0.05,
    legend style={at={(0.5,-0.15)},
        anchor=north,legend columns=-1},
    ybar interval=0.7,
]
\addplot
    coordinates {(1930,50e6) (1940,33e6)
        (1950,40e6) (1960,50e6) (1970,70e6)};

\addplot
    coordinates {(1930,38e6) (1940,42e6)
        (1950,43e6) (1960,45e6) (1970,65e6)};

\addplot
    coordinates {(1930,15e6) (1940,12e6)
        (1950,13e6) (1960,25e6) (1970,35e6)};
\legend{Far,Near,Here}
\end{axis}
\end{tikzpicture}
```

/pgfplots/ybar interval={⟨*relative width*⟩}   (style, default 1)

A style which is intended to install options for ybar interval for a complete figure. This includes tick and legend appearance, management of multiple bar plots in one figure and a more adequate cycle list using the style bar cycle list.

/tikz/xbar interval   (no value)

\addplot+[xbar interval]

As ybar interval, just for horizontal bars.
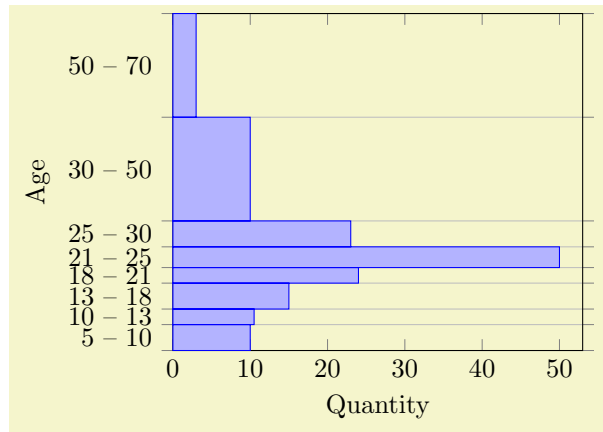
```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
\begin{axis}[
    xmin=0,xmax=53,
    ylabel=Age,
    xlabel=Quantity,
    enlargelimits=false,
    ytick=data,
    yticklabel interval boundaries,
    xbar interval,
]
\addplot
    coordinates {(10,5) (10.5,10) (15,13)
        (24,18) (50,21) (23,25) (10,30)
        (3,50) (3,70)};
\end{axis}
\end{tikzpicture}
```

/pgfplots/**xbar interval**={⟨*relative width*⟩}   (style, default 1)

A style which is intended to install options for **xbar interval** for a complete figure, see the style /pgfplots/**ybar interval** for details.

/pgfplots/**xticklabel interval boundaries**   (no value)
/pgfplots/**yticklabel interval boundaries**   (no value)
/pgfplots/**zticklabel interval boundaries**   (no value)

These are style keys which set **x tick label as interval** (see page 337 for details) and configure the tick appearance to be ⟨*start*⟩ – ⟨*end*⟩ for each tick interval.

4.5.5   Histograms

This section has been moved to the **statistics** library, see Section 5.12.2 on page 497.

4.5.6   Box Plots

This section has been moved to the **statistics** library, see Section 5.12.1 on page 486.

4.5.7   Comb Plots

Comb plots are very similar to bar plots except that they employ single horizontal/vertical lines instead of rectangles.

/tikz/**xcomb**   (no value)

\addplot+[**xcomb**]
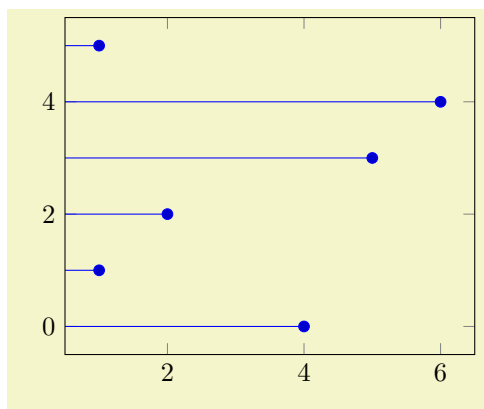

```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
\begin{axis}
\addplot+[xcomb] coordinates
    {(4,0) (1,1) (2,2)
      (5,3) (6,4) (1,5)};
\end{axis}
\end{tikzpicture}
```

/tikz/**ycomb**   (no value)

\addplot+[ycomb]
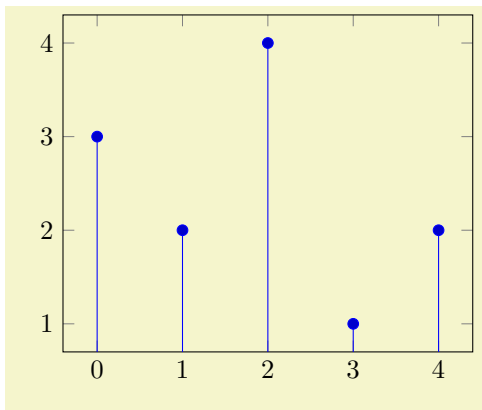
```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
\begin{axis}
\addplot+[ycomb] plot coordinates
    {(0,3) (1,2) (2,4) (3,1) (4,2)};
\end{axis}
\end{tikzpicture}
```

4.5.8 Quiver Plots (Arrows)

/pgfplots/quiver={⟨options with 'quiver/' prefix⟩}

\addplot+[quiver={⟨options with 'quiver/' prefix⟩}]

    A plot type which draws small arrows, starting at (x, y), in direction of (u, v).
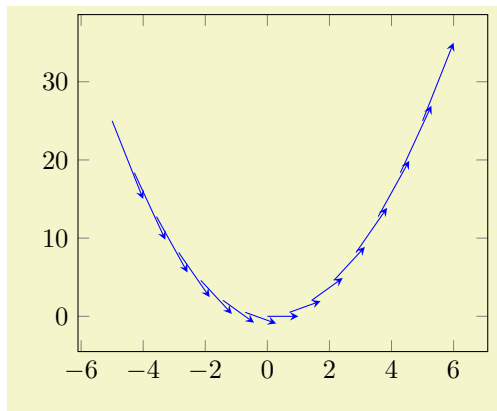
```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
\begin{axis}
    \addplot[blue,
        quiver={u=1,v=2*x},
        -stealth,samples=15] {x^2};
\end{axis}
\end{tikzpicture}
```

    The base point (x, y) is provided as before; in the example above, it is generated by plot expression and yields (x, x^2). The vector direction (u, v) needs to be given in addition. Our example with quiver/u=1 and quiver/v=2*x results in $u = 1$ and $v = 2x$. Thus, we have defined and visualized a vector field for the derivative of $f(x) = x^2$.

    A common example is to visualize the gradient $(\partial_x f, \partial_y f)(x, y)$ of a two–dimensional function $f(x, y)$:
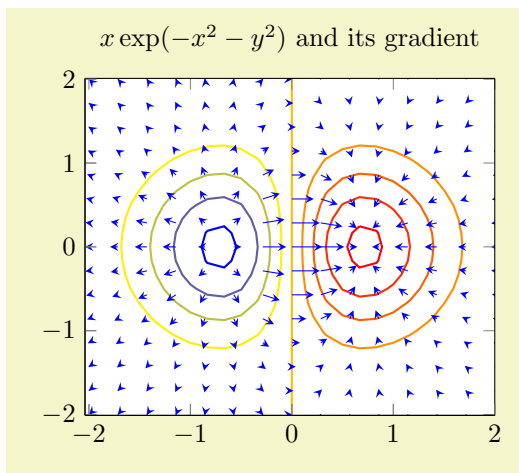
```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
    \begin{axis}[
        title={$x \exp(-x^2-y^2)$ and its gradient},
        domain=-2:2,
        view={0}{90},
        axis background/.style={fill=white},
    ]
        \addplot3[contour gnuplot={number=9,
            labels=false},thick]
                {exp(0-x^2-y^2)*x};
        \addplot3[blue,
            quiver={
              u={exp(0-x^2-y^2)*(1-2*x^2)},
              v={exp(0-x^2-y^2)*(-2*x*y)},
              scale arrows=0.3,
              },
            -stealth,samples=15]
                {exp(0-x^2-y^2)*x};
    \end{axis}
\end{tikzpicture}
```

The example visualizes $f(x, y) = x \exp(-x^2 - y^2)$ using `contour gnuplot` as first step. The options `contour/number` and `contour/labels` provide fine-tuning for the contour and are not of interest here (so is the `axis background` which just improves visibility of contour lines). What we are interested in is the `quiver=` style: it defines u and v to some two–dimensional expressions. Furthermore, we used `quiver/scale arrows` to reduce the arrow size. The `-stealth` is a TikZ style which configures outgoing arrow styles of type 'stealth'. The `samples=15` key configures how we get our input data. In our case, we have input data $(x_i, y_j, f(x_i, y_j))$ with 15 samples for each, i and j.

It is also possible to place quiver plots on a prescribed z value:
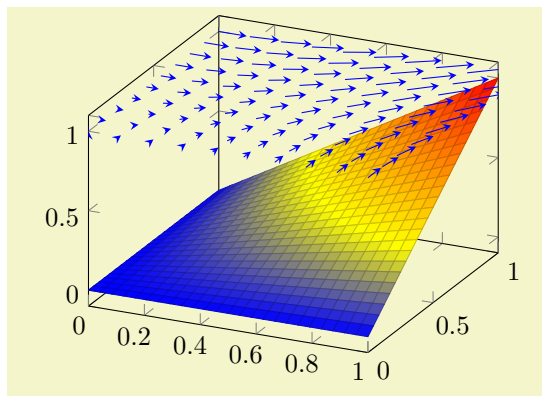

```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
\begin{axis}[
    domain=0:1,
    xmax=1,
    ymax=1,
]
\addplot3[surf] {x*y};
\addplot3[blue,/pgfplots/quiver,
    quiver/u=y,
    quiver/v=x,
    quiver/w=0,
    quiver/scale arrows=0.1,
    -stealth,samples=10] {1};
\end{axis}
\end{tikzpicture}
```

Here, the quiver plots is placed on top of a `surf`. It visualizes the gradient (using a common scale factor of $1/10$ to reduce the arrow lengths). The `quiver/w=0` means that arrows have no z difference, and the `{1}` argument indicates that all start at $(x_i, y_j, 1)$. Here, the values (x_i, y_j) are sampled in the `domain=0:1` argument (with `samples=10`), i.e. arrows start at $(x_i, y_j, 1)$ and end at $(x_i + y_j/10, y_j + x_i/10, 1)$.

So far, quiver plots do not assume a special sequence of input points. This has two consequences: first, you can plot any vector field by considering just $(x, y) + (u, v)$ (or $(x, y, z) + (u, v, w)$) – the data doesn't necessarily need to be a two–dimensional function (as opposed to `surf` etc). On the other hand, you need to provide `quiver/scale arrows` manually since `quiver` doesn't know the mesh width in case you provide matrix data[12].

Note that quiver plots are currently not available together with logarithmic axes.

/pgfplots/**quiver/u**=⟨*expression*⟩	(initially 0)
/pgfplots/**quiver/v**=⟨*expression*⟩	(initially 0)
/pgfplots/**quiver/w**=⟨*expression*⟩	(initially 0)

These keys define how the vector directions (u, v) (or, for three dimensional plots, (u, v, w)) shall be set.

The ⟨*expression*⟩ can be a constant expression like `quiver/u=1` or `quiver/u=42*5`. It may also depend on the final base point values using the values x, y or z as in the example above. In this context, x yields the x coordinate of the point where the vector starts, y the y coordinate and so on.

Attention: the fact that x refers to *the final x coordinate* means that parametric plots *should use t as variable*[13]. Consider the following example:

---

[12] Actually, I might add something like `quiver/scale arrows=auto` in the future, I don't know yet. Loops through input data are slow in TeX, automatic mesh widths computation even more...

[13] Sorry for this usability issue.
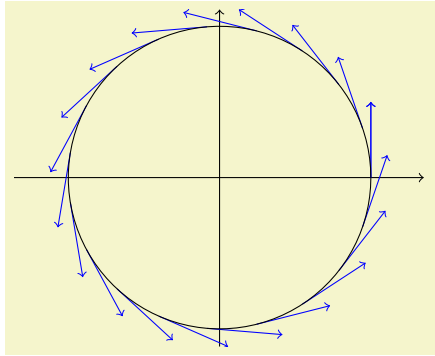
```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
\begin{axis}[axis equal,
 axis lines=middle,
 axis line style={->},
 tick style={color=black},
 xtick=\empty,
 ytick=\empty
]
  \addplot[samples=20, domain=0:2*pi,
    % the default choice 'variable=\x' leads to
    % unexpected results here!
    variable=\t,
    quiver={
        u={-sin(deg(t))},
        v={cos(deg(t))},
        scale arrows=0.5,
        ->,blue]
    ({cos(deg(t))}, {sin(deg(t))});
  \addplot[samples=100, domain=0:2*pi]
    ({cos(deg(x))}, {sin(deg(x))});
\end{axis}
\end{tikzpicture}
```

Here, a parametric plot is used to draw a circle and tangent vectors. The choice `variable=\t` plays a functional role besides naming conventions: it allows to access the parametric variable within the expressions for both `u` and `v`. On the other hand, we could have used `u=y` and `v=-x` since `x` expands to the x coordinate with value `sin(deg(t))` and `y` expands to the y coordinate `cos(deg(t))`.

Another important application is to use *table column references* like `quiver/u=\thisrow{col}` in conjunction with `\addplot table`:
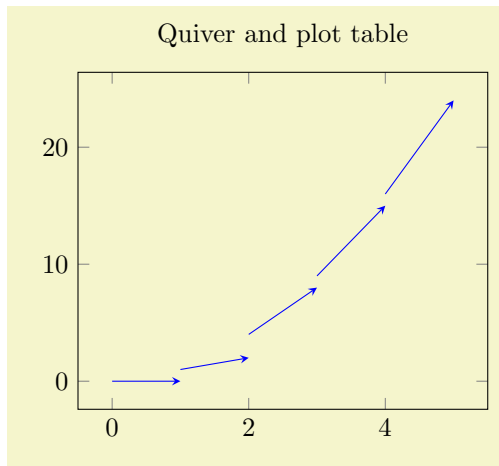

```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
\begin{axis}[title=Quiver and plot table]
    \addplot[blue,
        quiver={u=\thisrow{u},v=\thisrow{v}},
        -stealth]
    table
    {
    x y u v
    0 0 1 0
    1 1 1 1
    2 4 1 4
    3 9 1 6
    4 16 1 8
    };
\end{axis}
\end{tikzpicture}
```

Here, the ⟨*expression*⟩ employs `\thisrow` which always refers to the actual row of `\addplot table`. Note that ⟨*expression*⟩ should always be of numeric type (no symbolic input extensions are supported currently).

/pgfplots/**quiver/u value**={⟨*value*⟩}   (initially 0)
/pgfplots/**quiver/v value**={⟨*value*⟩}   (initially 0)
/pgfplots/**quiver/w value**={⟨*value*⟩}   (initially 0)

These keys have the *same function* as `quiver/u` and its variants. However, they don't call the math parser, so only single values are allowed (including something like `\thisrow{columnname}`).

/pgfplots/**quiver/colored**   (no value)
/pgfplots/**quiver/colored**={⟨*color*⟩}

Allows to define an individual color for each arrow. Omitting the argument '⟨*color*⟩' is identical to `quiver/colored=mapped color` which uses the `point meta` to get colors for every arrow.

If you just want to set the same color for every arrow, prefer using `\addplot[blue,quiver]` which is more efficient.

/pgfplots/**quiver/scale arrows**={⟨*scale*⟩} (initially `1`)

Allows to rescale the arrows by a factor. This may be necessary if the arrow length is longer than the distance between adjacent base points (x_i, y_i). There may come a feature to rescale them automatically.

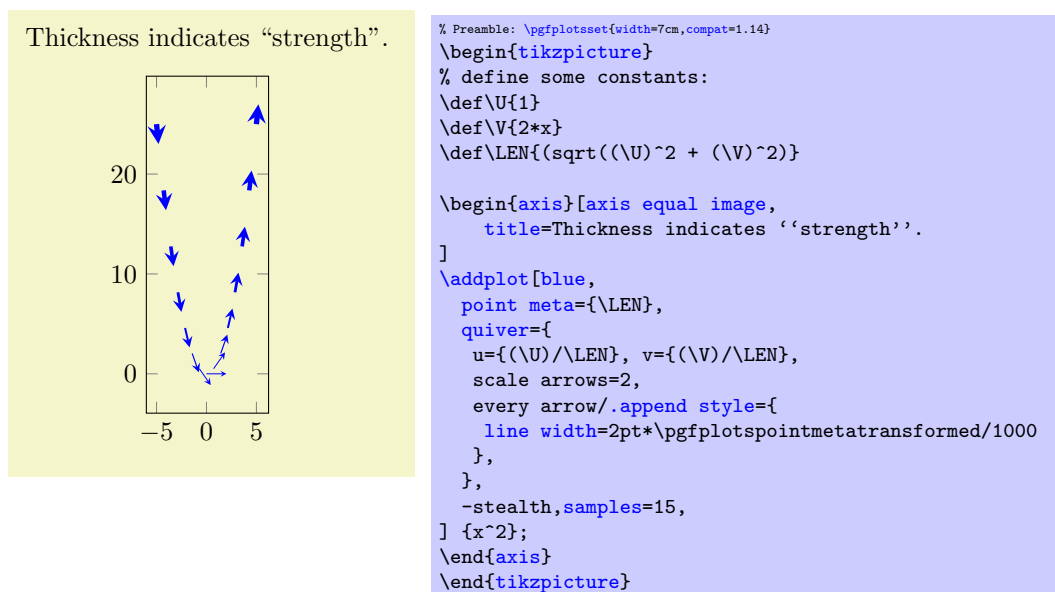/pgfplots/**quiver/update limits**=true|false (initially `true`)

A boolean indicating whether points $(x, y) + (u, v)$ shall contribute to the axis limits.

/pgfplots/**quiver/every arrow** (style, initially `empty`)

Allows to provide individual arrow styles.

The style can contain any TikZ drawing option. It will be evaluated for every individual arrow and may depend upon anything which is available at visualization time.

In particular, this includes `point meta` data, typically using `\pgfplotspointmetatransformed` $\in [0, 1000]$ where 0 corresponds to `point meta min` and 1000 corresponds to `point meta max`:


```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
% define some constants:
\def\U{1}
\def\V{2*x}
\def\LEN{(sqrt((\U)^2 + (\V)^2)}

\begin{axis}[axis equal image,
    title=Thickness indicates ``strength''.
]
\addplot[blue,
  point meta={\LEN},
  quiver={
    u={(\U)/\LEN}, v={(\V)/\LEN},
    scale arrows=2,
    every arrow/.append style={
     line width=2pt*\pgfplotspointmetatransformed/1000
    },
  },
  -stealth,samples=15,
] {x^2};
\end{axis}
\end{tikzpicture}
```

In the example, we have some 2d vector field stored in helper constants `\U` and `\V`. The length of each vector is stored in `\LEN` here. The `quiver` plot as such contains unit length vectors – and the `\LEN` enters an `every arrow` style to get varying `line width`.

An `every arrow` style might also depend upon `mapped color` (provided `point meta` has been set).

Again, if you do not need individual arrow styles, prefer using a plot style (`cycle list` or argument to `\addplot`) which is more efficient.

/pgfplots/**quiver/before arrow**/.code={⟨...⟩}
/pgfplots/**quiver/after arrow**/.code={⟨...⟩}

Advanced keys for more fine tuning of the display. They allow to install some TeX code manually before or after the drawing operations for single arrows. Both are initially empty.

/pgfplots/**quiver/quiver legend** (style, no value)

A style which redefines `legend image code` in order to produce a suitable legend for `quiver` plots.

It is implicitly activated whenever `quiver` plot handlers are selected.
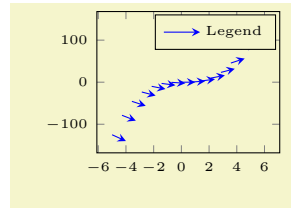
```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
\begin{axis}[tiny]
\addplot[blue,
    quiver={u=1,v=3*x},
    -stealth,
    samples=15]
    {x^3};
\addlegendentry{Legend}
\end{axis}
\end{tikzpicture}
```

4.5.9   Stacked Plots

/pgfplots/stack plots=x|y|false   (initially `false`)

Allows stacking of plots in either x or y direction. Stacking means to add either x- or y coordinates of successive \addplot commands on top of each other.
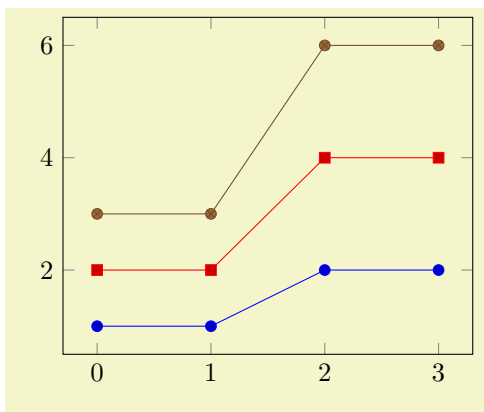
```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
    \begin{axis}[stack plots=y]
    \addplot coordinates
        {(0,1) (1,1) (2,2) (3,2)};
    \addplot coordinates
        {(0,1) (1,1) (2,2) (3,2)};
    \addplot coordinates
        {(0,1) (1,1) (2,2) (3,2)};
    \end{axis}
\end{tikzpicture}
```

The current implementation for stack plots does *not* interpolate missing coordinates. That means stacking will fail if the plots have different grids.

/pgfplots/ybar stacked=plus|minus   (style, default `plus`)

The plot handler stack plots is particularly useful for bar plots. There are two possible modes of operation: the first is to set stack plots=y,/tikz/ybar. It activates just these two features without making them aware of each other. The second is to set ybar stacked which activates the two features *and* makes them aware of each other.

If you use stack plots together with /tikz/ybar, you have kind of a low–level implementation which is kind of "raw":
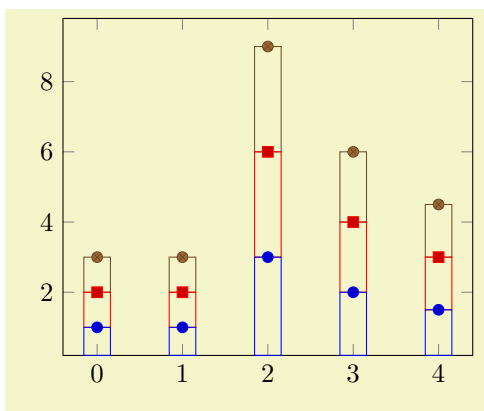
```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
    \begin{axis}[stack plots=y,/tikz/ybar]
    \addplot coordinates
        {(0,1) (1,1) (2,3) (3,2) (4,1.5)};
    \addplot coordinates
        {(0,1) (1,1) (2,3) (3,2) (4,1.5)};
    \addplot coordinates
        {(0,1) (1,1) (2,3) (3,2) (4,1.5)};
    \end{axis}
\end{tikzpicture}
```

Using ybar stacked enables stacked vertical bars (i.e. ybar and stack plots=y) *and* it also adjusts the legend and tick appearance and assigns a useful cycle list. To this end, it should be given as option to the axis:
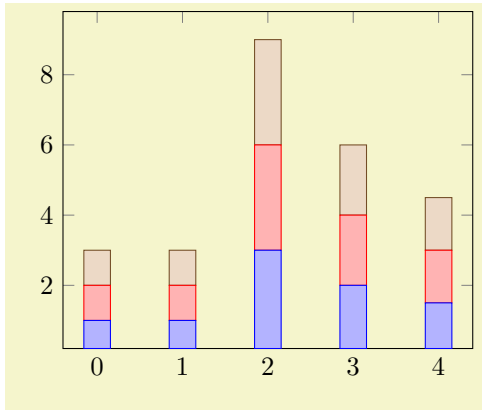
```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
    \begin{axis}[ybar stacked]
    \addplot coordinates
        {(0,1) (1,1) (2,3) (3,2) (4,1.5)};
    \addplot coordinates
        {(0,1) (1,1) (2,3) (3,2) (4,1.5)};
    \addplot coordinates
        {(0,1) (1,1) (2,3) (3,2) (4,1.5)};
    \end{axis}
\end{tikzpicture}
```
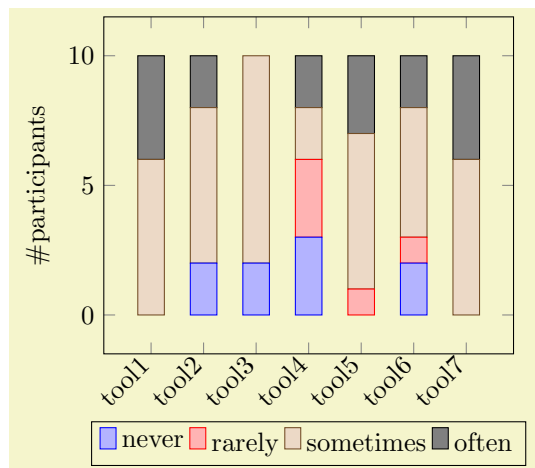
```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
\begin{axis}[
    ybar stacked,
    enlargelimits=0.15,
    legend style={at={(0.5,-0.20)},
      anchor=north,legend columns=-1},
    ylabel={\#participants},
    symbolic x coords={tool1, tool2, tool3, tool4,
        tool5, tool6, tool7},
    xtick=data,
    x tick label style={rotate=45,anchor=east},
    ]
\addplot+[ybar] plot coordinates {(tool1,0) (tool2,2)
  (tool3,2) (tool4,3) (tool5,0) (tool6,2) (tool7,0)};
\addplot+[ybar] plot coordinates {(tool1,0) (tool2,0)
  (tool3,0) (tool4,3) (tool5,1) (tool6,1) (tool7,0)};
\addplot+[ybar] plot coordinates {(tool1,6) (tool2,6)
  (tool3,8) (tool4,2) (tool5,6) (tool6,5) (tool7,6)};
\addplot+[ybar] plot coordinates {(tool1,4) (tool2,2)
  (tool3,0) (tool4,2) (tool5,3) (tool6,2) (tool7,4)};
\legend{never, rarely, sometimes, often}
\end{axis}
\end{tikzpicture}
```

/pgfplots/xbar stacked=plus|minus   (style, default plus)

The same remarks as for ybar stacked hold for xbar stacked as well: xbar stacked is a figure-wide
style which enables stacked horizontal bars (i.e. xbar and stack plots=x). It also adjusts the legend
and tick appearance and assigns a useful cycle list.

Consequently, one can have a "raw" picture which combines stacking and bars as in the following picture
(i.e. without xbar stacked):
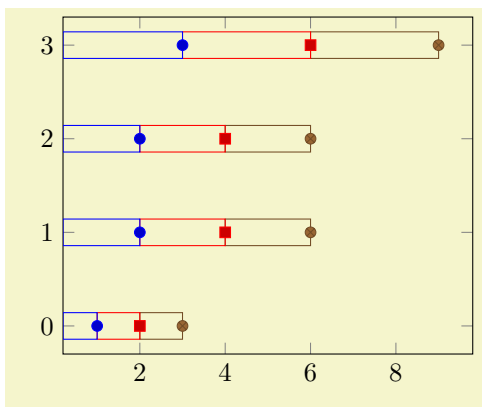
```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
    \begin{axis}[stack plots=x,/tikz/xbar]
    \addplot coordinates
        {(1,0) (2,1) (2,2) (3,3)};
    \addplot coordinates
        {(1,0) (2,1) (2,2) (3,3)};
    \addplot coordinates
        {(1,0) (2,1) (2,2) (3,3)};
    \end{axis}
\end{tikzpicture}
```

Alternatively, one activates xbar stacked right after \begin{axis} and benefits from several style
adoptions.

```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
    \begin{axis}[xbar stacked]
    \addplot coordinates
        {(1,0) (2,1) (2,2) (3,3)};
    \addplot coordinates
        {(1,0) (2,1) (2,2) (3,3)};
    \addplot coordinates
        {(1,0) (2,1) (2,2) (3,3)};
    \end{axis}
\end{tikzpicture}
```
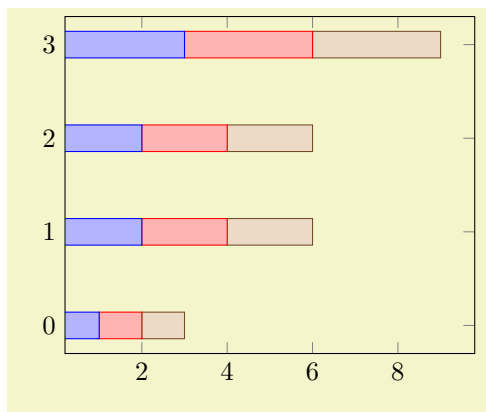
/pgfplots/stack dir=plus|minus   (initially plus)

    Configures the direction of stack plots. The value plus will add coordinates of successive plots while minus subtracts them.

/pgfplots/reverse stacked plots=true|false   (initially true, default true)

    Configures the sequence in which stacked plots are drawn. This is more or less a technical detail which should not be changed in any normal case.

    The motivation is as follows: suppose multiple \addplot commands are stacked on top of each other and they are processed in the order of appearance. Then, the second plot could easily draw its lines (or fill area) on top of the first one - hiding its marker or line completely. Therefor, PGFPLOTS reverses the sequence of drawing commands.

    This has the side-effect that any normal TikZ-paths inside of an axis will also be processed in reverse sequence.

/pgfplots/stacked ignores zero=true|false   (initially true, default true)

    Configures stacked plots to ignore "zero" increments.

    In this context, "ignore" means to suppress visualization if an increment vanishes.

    Configuring \pgfplotsset{compat=1.9} (or higher) activates this feature for xbar stacked and ybar stacked.

/pgfplots/stacked ignores zero/default=true|false   (initially true)
/pgfplots/stacked ignores zero/markers=true|false   (initially true)
/pgfplots/stacked ignores zero/errorbars=true|false   (initially false)

    A detail key which allows to customize how and where to apply stacked ignores zero. This key is *ignored* unless stacked ignores zero=true. Its default configuration is to suppress visualization of an empty increment for the standard visualization and for markers. Error bars will be displayed, though (the error bar is typically non-empty even if the increment is 0).

/pgfplots/xbar interval stacked=plus|minus   (style, default plus)

    A style similar to /pgfplots/xbar stacked for the interval based bar plot variant.

/pgfplots/ybar interval stacked=plus|minus   (style, default plus)

    A style similar to /pgfplots/ybar stacked for the interval based bar plot variant.

Stacked Bar Plots and Nodes Near Coords

It is possible to combine ybar stacked and xbar stacked with nodes near coords. In contrast to non-stacked plots, it appears to be of limited use to draw a node near the top of the stack. Instead, one typically wants to see the *difference* added in each stacking step. To this end, PGFPLOTS will automatically reconfigure nodes near coords to display the added values in the center of each new bar:
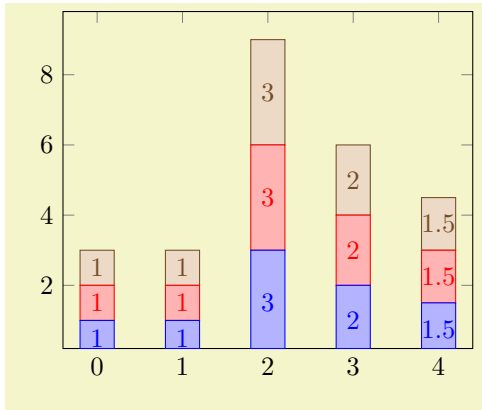
```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
% needs \pgfplotsset{compat=1.9} or newer!
\begin{tikzpicture}
    \begin{axis}[ybar stacked,nodes near coords,
        bar width=0.4]
    \addplot coordinates
        {(0,1) (1,1) (2,3) (3,2) (4,1.5)};
    \addplot coordinates
        {(0,1) (1,1) (2,3) (3,2) (4,1.5)};
    \addplot coordinates
        {(0,1) (1,1) (2,3) (3,2) (4,1.5)};
    \end{axis}
\end{tikzpicture}
```
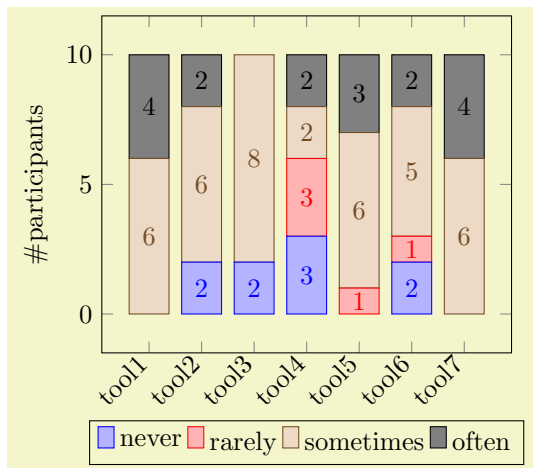


```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
% needs \pgfplotsset{compat=1.9} or newer!
\begin{tikzpicture}
\begin{axis}[
    ybar stacked,
    bar width=15pt,
    nodes near coords,
    enlargelimits=0.15,
    legend style={at={(0.5,-0.20)},
      anchor=north,legend columns=-1},
    ylabel={\#participants},
    symbolic x coords={tool1, tool2, tool3, tool4,
        tool5, tool6, tool7},
    xtick=data,
    x tick label style={rotate=45,anchor=east},
    ]
\addplot+[ybar] plot coordinates {(tool1,0) (tool2,2)
  (tool3,2) (tool4,3) (tool5,0) (tool6,2) (tool7,0)};
\addplot+[ybar] plot coordinates {(tool1,0) (tool2,0)
  (tool3,0) (tool4,3) (tool5,1) (tool6,1) (tool7,0)};
\addplot+[ybar] plot coordinates {(tool1,6) (tool2,6)
  (tool3,8) (tool4,2) (tool5,6) (tool6,5) (tool7,6)};
\addplot+[ybar] plot coordinates {(tool1,4) (tool2,2)
  (tool3,0) (tool4,2) (tool5,3) (tool6,2) (tool7,4)};
\legend{never, rarely, sometimes, often}
\end{axis}
\end{tikzpicture}
```

Note that the preceding example contains no nodes for coordinates with value 0. This is due to the key `stacked ignores zero` which is active if `compat`=1.9 or newer: empty increments will be discarded.

This automatic reconfiguration is essentially part of the styles `xbar stacked` or `ybar stacked`: both reconfigure `nodes neard coords`. Note that this feature has been introduced in version 1.9. In order to maintain backwards compatible to previous work-arounds, you have to write `compat`=1.9 to get these effects.
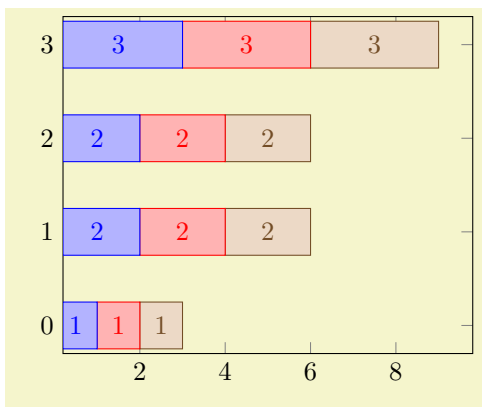

```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
    \begin{axis}[xbar stacked,nodes near coords,
        bar width=0.5]
    \addplot coordinates
        {(1,0) (2,1) (2,2) (3,3)};
    \addplot coordinates
        {(1,0) (2,1) (2,2) (3,3)};
    \addplot coordinates
        {(1,0) (2,1) (2,2) (3,3)};
    \end{axis}
\end{tikzpicture}
```

Stacked Plots with Negative Values

The meaning of negative values in `xbar stacked` or `ybar stacked` and their visualization depends on the use-case, and they need to be defined. PGFPLOTS offers two different interpretations of negative values in the context of stacked plots:

/pgfplots/**stack negative**=on previous|separate   (initially `separate`)

The choice `on previous` will simply sum any values as they are found in the input data. Thus, if you have four plots which are stacked on top of each other, and the first has value 10, the second value 50, and the third value -10, and the fourth has 30, the final value will be $10 + 50 - 10 + 30 = 80$. However, visualizing a bar of negative size as a usual `xbar stacked` graph is hard to read and requires vertical offsets in this context. This can be accomplished as follows:
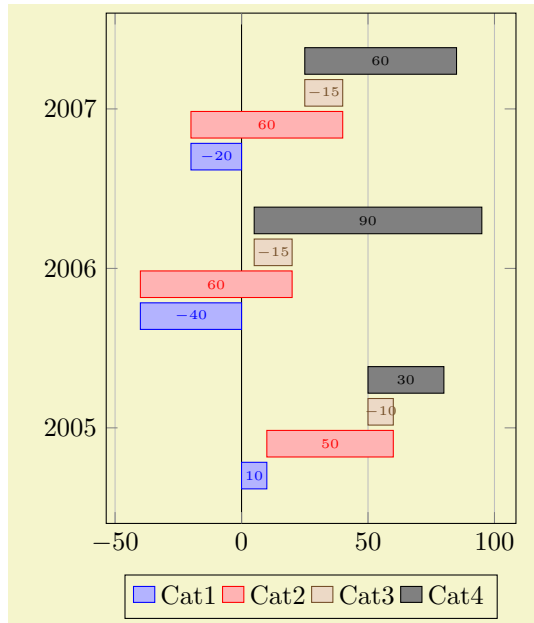

```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
\pgfplotstableread{
Year    Cat1  Cat2    Cat3    Cat4
2005    10    50      -10     30
2006    -40   60      -15     90
2007    -20   60      -15     60
}\mytable

\begin{axis}[
  xbar stacked,
  stack negative=on previous,
  %
  xmajorgrids,
  legend style={at={(0.5,-0.1)},
      anchor=north,legend columns=-1},
  bar width=10pt,
  bar shift auto,
  nodes near coords,
  nodes near coords style={font=\tiny},
  y=60pt,
  ytick distance=1,
  enlarge y limits=0.3,
  /pgf/number format/1000 sep=,
  extra x ticks={0},
  extra x tick style={grid style={black},
      xticklabel=\empty},
  ]
  \addplot table [x index=1,y=Year] {\mytable};
  \addplot table [x index=2,y=Year] {\mytable};
  \addplot table [x index=3,y=Year] {\mytable};
  \addplot table [x index=4,y=Year] {\mytable};
  \legend{Cat1,Cat2,Cat3,Cat4}
\end{axis}
\end{tikzpicture}
```

In this case, the values for $y = 2005$ resemble our input case of $10 + 50 - 10 + 30 = 80$. It is a "normal" `xbar stacked` with the configuration `stack negative`=on `previous` – but with the special key `bar shift auto` which is also used in order to create grouped `xbar` charts: every `\addplot` receives a vertical offset.

Despite the similiarity with "waterfall charts", this is not indented to be a waterfall chart. At the time of this writing, PGFPLOTS has no support for waterfall charts.

The choice `stack negative`=on `previous` is the *initial* value for

- all but stacked bar plots,
- all plots if `compat` is less than `1.13`.

As of `compat`=1.13, the initial value of `stack negative` is `separate` for `xbar stacked`, `ybar stacked`, and their * `interval` based variants.

The alternative choice `separate` tracks the start points of bars *separately* for negative and non-negative values:
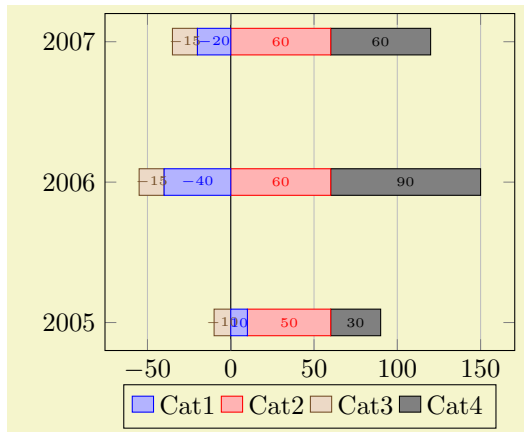
```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
\pgfplotstableread{
Year     Cat1  Cat2     Cat3    Cat4
2005     10    50       -10     30
2006     -40   60       -15     90
2007     -20   60       -15     60
}\mytable

\begin{axis}[
  xbar stacked,
  % is default anyway:
  stack negative=separate,
  %
  /pgf/number format/1000 sep=,
  xmajorgrids,
  nodes near coords,
  nodes near coords style={font=\tiny},
  ytick distance=1,
  legend style={at={(0.5,-0.1)},
      anchor=north,legend columns=-1},
  extra x ticks={0},
  extra x tick style={grid style={black},
      xticklabel=\empty},
  ]
  \addplot table [x index=1,y=Year] {\mytable};
  \addplot table [x index=2,y=Year] {\mytable};
  \addplot table [x index=3,y=Year] {\mytable};
  \addplot table [x index=4,y=Year] {\mytable};
  \legend{Cat1,Cat2,Cat3,Cat4}
\end{axis}
\end{tikzpicture}
```

In this case, positive contributions extend into the positive x axis whereas negative contributions extend into the negative x axis. There is no final sum (or better: there are two final sums). The effect is as if you would have defined two separate axes, one for the positive contributions and one for the negative ones and aligned them at the origin.

As of `compat`=1.13, `stack negative`=separate is the initial setting for stacked bar plots. Older compatibility levels use `stack negative`=on previous.

4.5.10   Area Plots

Area plots means two–dimensional plots in which an area is filled between a couple of curves. Note that this is a rather incomplete characterization as `mesh`, `surf`ace, and `patch` plots are, of course, also "area plots" of some sort.

This section covers two types of area plots, namely those which are defined by `stack plots` and those which are defined using `\addplot fill between`.

Filling Using Stacked Plots

The first (and older) option to fill areas between plots is a combination of `\closedcycle` and `stack plots`. They can be combined with any other plot type.
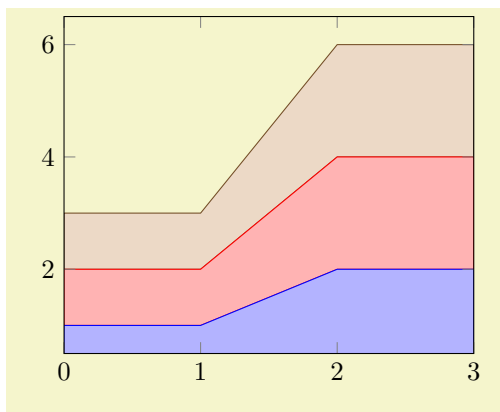
```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
    \begin{axis}[
        stack plots=y,
        area style,
        enlarge x limits=false]
    \addplot coordinates
        {(0,1) (1,1) (2,2) (3,2)}
        \closedcycle;
    \addplot coordinates
        {(0,1) (1,1) (2,2) (3,2)}
        \closedcycle;
    \addplot coordinates
        {(0,1) (1,1) (2,2) (3,2)}
        \closedcycle;
    \end{axis}
\end{tikzpicture}
```

The main property of this kind of area visualization is that all plots of an axis are taken together, and since they are stacked, they form areas.

Area plots may need modified legends, for example using the `area legend` key. Furthermore, one may want to consider the `axis on top` key such that filled areas do not overlap ticks and grid lines since such plots typically cover huge areas of the axis.

Note that Area plots which rely on `stack plots` have one severe limitation: stacking works if and only if each plot has the same coordinates (in our case of `stack plots`=y, each plot has the same x coordinates).

/pgfplots/**area style**   (style, no value)

A style which sets

```
\pgfplotsset{
    /pgfplots/area style/.style={%
        area cycle list,
        area legend,
        axis on top,
    }}
```

/pgfplots/**area cycle list**   (style, no value)

A style which installs a `cycle list` suitable for area plots. The initial configuration of this style simply invokes the `bar cycle list` which does also provide filled plot styles.
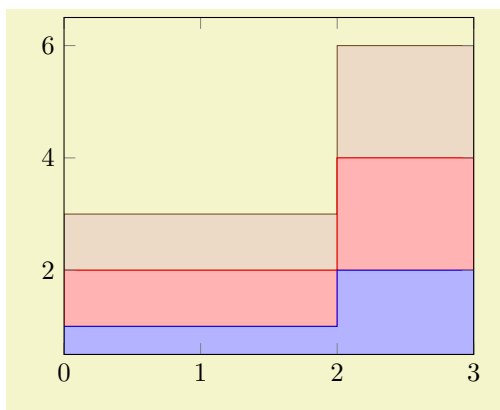

```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
    \begin{axis}[
        const plot,
        stack plots=y,
        area style,
        enlarge x limits=false]
    \addplot coordinates
        {(0,1) (1,1) (2,2) (3,2)}
        \closedcycle;
    \addplot coordinates
        {(0,1) (1,1) (2,2) (3,2)}
        \closedcycle;
    \addplot coordinates
        {(0,1) (1,1) (2,2) (3,2)}
        \closedcycle;
    \end{axis}
\end{tikzpicture}
```
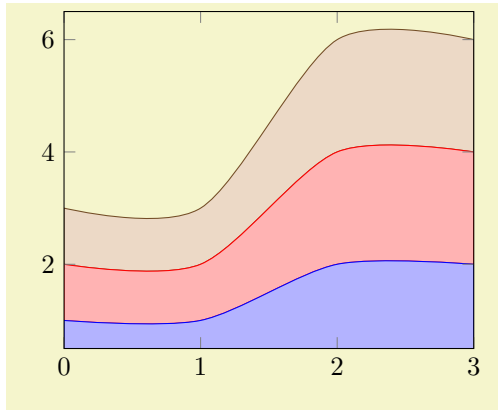
```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
    \begin{axis}[
        smooth,
        stack plots=y,
        area style,
        enlarge x limits=false]
    \addplot coordinates
        {(0,1) (1,1) (2,2) (3,2)}
        \closedcycle;
    \addplot coordinates
        {(0,1) (1,1) (2,2) (3,2)}
        \closedcycle;
    \addplot coordinates
        {(0,1) (1,1) (2,2) (3,2)}
        \closedcycle;
    \end{axis}
\end{tikzpicture}
```

time	1minload	nodes	cpus	processes	memused	memcached	membuf	memtotal
0	18	100	200	20	15	45	1	150
1	25	100	200	30	20	45	2	150
2	25	100	200	30	21	42	2	150
3	30	100	200	30	20	40	2	150
4	30	100	200	30	19	40	1	150
5	80	100	200	30	20	40	3	150
6	120	100	200	10	3	40	3	150
7	180	100	200	10	4	41	3	150
8	183	100	200	10	3	42	2	150
9	178	100	200	10	2	41	1	150
10	180	100	200	20	15	45	2	150
11	184	100	200	20	20	45	3	150
12	170	100	200	20	22	47	4	150
13	164	100	200	20	24	50	4	150
14	150	100	200	20	25	52	3	150
15	148	100	200	20	26	53	2	150
16	149	100	200	30	30	54	2	150
17	154	100	200	30	35	55	1	150

```
\pgfplotstableread{pgfplots.timeseries.dat}\loadedtable
\pgfplotstabletypeset\loadedtable
```
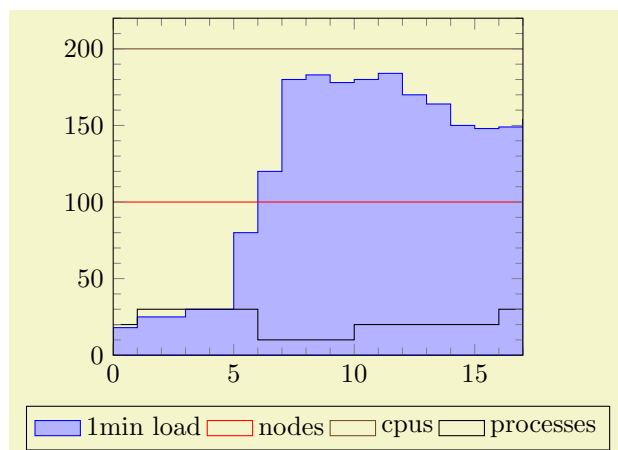
```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\pgfplotstableread
    {pgfplots.timeseries.dat}
    {\loadedtable}

\begin{tikzpicture}
    \begin{axis}[
        ymin=0,
        minor tick num=4,
        enlarge x limits=false,
        axis on top,
        every axis plot post/.append style=
            {mark=none},
        const plot,
        legend style={
            area legend,
            at={(0.5,-0.15)},
            anchor=north,
            legend columns=-1}]

    \addplot[draw=blue,fill=blue!30!white]
     table[x=time,y=1minload] from \loadedtable
        \closedcycle;
    \addplot table[x=time,y=nodes] from \loadedtable;
    \addplot table[x=time,y=cpus] from \loadedtable;
    \addplot table[x=time,y=processes]
        from \loadedtable;
    \legend{1min load,nodes,cpus,processes}
    \end{axis}
\end{tikzpicture}
```
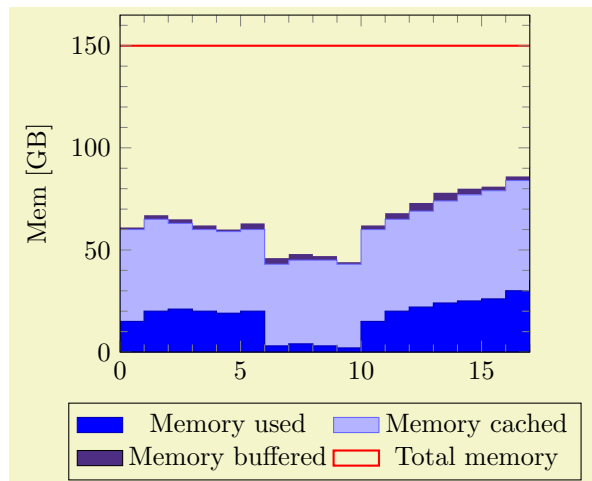
```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\pgfplotstableread{pgfplots.timeseries.dat}\loadedtable

\begin{tikzpicture}
    \begin{axis}[
        ymin=0,
        minor tick num=4,
        enlarge x limits=false,
        const plot,
        axis on top,
        stack plots=y,
        cycle list={%
            {blue!70!black,fill=blue},%
            {blue!60!white,fill=blue!30!white},%
            {draw=none,fill={rgb:red,138;green,82;blue,232}},%
            {red,thick}%
        },
        ylabel={Mem [GB]},
        legend style={
            area legend,
            at={(0.5,-0.15)},
            anchor=north,
            legend columns=2}]

    \addplot table[x=time,y=memused]      from \loadedtable \closedcycle;
    \addplot table[x=time,y=memcached]    from \loadedtable \closedcycle;
    \addplot table[x=time,y=membuf]       from \loadedtable \closedcycle;
    \addplot+[stack plots=false]
             table[x=time,y=memtotal]     from \loadedtable;
    \legend{Memory used,Memory cached,Memory buffered,Total memory}
    \end{axis}
\end{tikzpicture}
```

Filling Under/Between Named Plots

The second way to fill areas under or between plots is the `fillbetween` library shipped with PGFPLOTS.

Ti*k*Z allows to name a plot or a path using `name path`. The `fillbetween` library offers the special "plot type" `\addplot fill between` which expects two such named paths on input. Then, it generates filled areas between these named paths.

The biggest difference to Area plots by means of `stack plots` as discussed in the previous section is that `\addplot fill between` accepts *arbitrary* input plots: the coordinates can vary, the ranges can vary, even `smooth` and `sharp plot` can be combined. In addition, `\addplot fill between` allows to select only sub–regions between the two input paths by means of its `soft clip` feature, and it accepts individually styled fill segments using its styles `every even segment`, `every segment no ⟨index⟩`, etc.

The reference documentation is Section 5.7, but the following examples attempt to cover basic use–cases around fill–between. Please refer to the reference documentation in Section 5.7 for an in–depth discussion of every involved key.

The following advanced example selects two partial areas using `soft clip` in order to fill these areas:
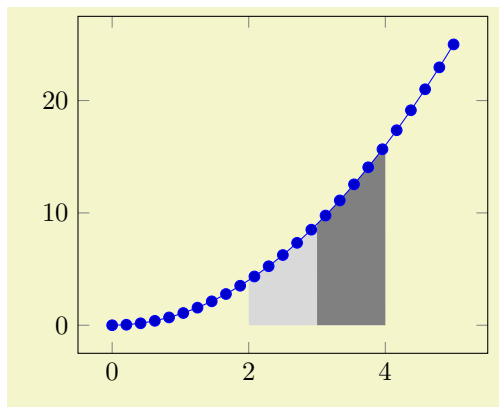

```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
% requires \usepgfplotslibrary{fillbetween}
\begin{tikzpicture}
\begin{axis}
    \addplot+[name path=A,domain=0:5] {x^2};

    \path[name path=B]
        (\pgfkeysvalueof{/pgfplots/xmin},0) --
        (\pgfkeysvalueof{/pgfplots/xmax},0);

    \addplot[gray] fill between[of=A and B,
        soft clip={domain=3:4},
        ];

    \addplot[gray!30] fill between[of=A and B,
        soft clip={domain=2:3},
        ];
\end{axis}
\end{tikzpicture}
```

The preceding example is characterized by two paths, each of which is named using `name path`. The path named 'A' is a plot of x^2. The other path named 'B' is actually nothing but the visible x axis, the `\path` instruction means that it is not drawn at all. Note that `\pgfkeysvalueof{/pgfplots/xmin}` expands to the visible lower x axis limit. Finally, we see two `\addplot fill between` instructions, both with the selection `of=A and B` and both with (different) values of `soft clip`. The `soft clip` key restricts the filled segments to the bounding rectangle defined by some path ⟨*lower corner*⟩ `rectangle` ⟨*upper corner*⟩ where the two arguments are the lower– and upper corner of an invisible rectangular bounding box. In our case, this bounding box has been defined by some `domain` restriction and the upper and lower axis limits. Only those parts of the filled segment makes up the result of `\addplot fill between`.

This restriction to a specific interval (or better: rectangle) is also available when stroking the involved paths 'A' or 'B': PGFPLOTS comes with `decoration=soft clip` which can be combined with `postaction` as follows.
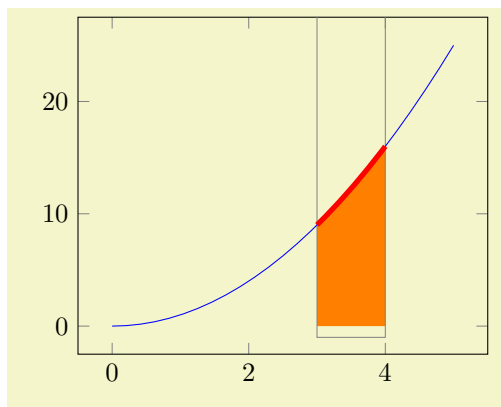

```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
% requires \usepgfplotslibrary{fillbetween}
\begin{tikzpicture}
\begin{axis}
    % define some common macro
    \def\clippath{
        (3,-1)
        rectangle
        (4,100)
    }
    \draw[help lines] \clippath;

    \addplot+[name path=A,domain=0:5,
        mark=none,
        postaction={decorate,red,line width=2pt,
            decoration={
                soft clip,
                soft clip path={\clippath},
            },
        },
    ] {x^2};

    \path[name path=B]
        (\pgfkeysvalueof{/pgfplots/xmin},0) --
        (\pgfkeysvalueof{/pgfplots/xmax},0);

    \addplot[orange] fill between[of=A and B,
        soft clip={\clippath},
    ];
\end{axis}
\end{tikzpicture}
```

The preceding example has a `\def\clippath` which defines a re-usable bounding box. Here, the `fill between` statement is similar to the preceding example, with the only difference that our macro is used as value. The main difference is the `postaction` in plot 'A'. A `postaction` is a Ti*k*Z construct which allows to draw the same path twice. The second time the plot is drawn makes use of the option list after `postaction`. In our case, it is a `decoration` which will be drawn in `red` with thick lines. The `decoration` applies a `soft clip` path. In this context, `soft clip` is applied to one path only, but the idea is the same: only the parts within the `soft clip` argument are displayed.

Note that `fill between` is also possible for arbitrary plots, not just the x axis. In fact, one can combine any two plots.
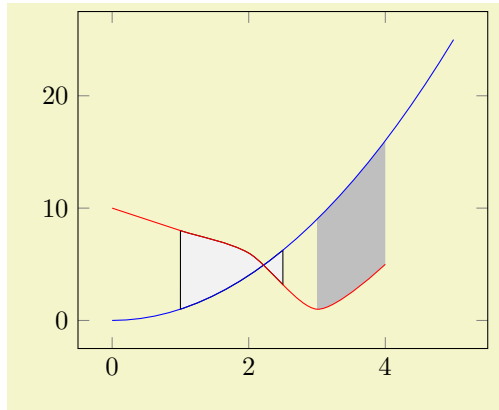
```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
% requires \usepgfplotslibrary{fillbetween}
\begin{tikzpicture}
\begin{axis}
    \addplot[blue,name path=A,domain=0:5] {x^2};

    \addplot[red,name path=B,smooth] table {
        x y
        0 10
        1 8
        2 6
        3 1
        4 5
    };

    \addplot[gray!50] fill between[of=A and B,
        soft clip={domain=3:4},
    ];

    \addplot[gray!10,draw=black] fill between[
        of=A and B,
        soft clip={domain=1:2.5},
    ];
\end{axis}
\end{tikzpicture}
```

The preceding example has two plots with a different number of samples, a different range, and a different input method. Nevertheless, the area between these two plots can be filled just as in the previous examples, including any intersections.

It is also possible to define individual styles for the filled segments. To this end, one has to set the `split` key which activates separate output paths. This enables the use of special styles which is shown in in the following example. Here, we have two styles with explicitly numbered segment indices:
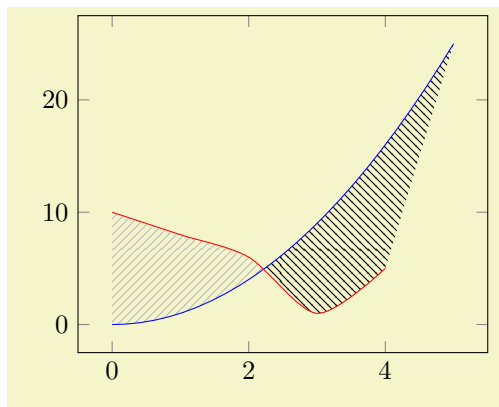
```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
% requires \usepgfplotslibrary{fillbetween}
\begin{tikzpicture}
\begin{axis}
    \addplot[blue,name path=A,domain=0:5] {x^2};

    \addplot[red,name path=B,smooth] table {
        x y
        0 10
        1 8
        2 6
        3 1
        4 5
    };

    \addplot[gray] fill between[of=A and B,
        split,
        every segment no 0/.style=
            {pattern color=gray!50,
             pattern=north east lines},
        every segment no 1/.style=
            {pattern=north west lines},
    ];

\end{axis}
\end{tikzpicture}
```

Note that the example has no `soft clip` argument. Consequently, it fills between the start– and end points of the involved paths. The `split` argument combined with the styles yields individually drawn fill segments.

Further reading: see Section 5.7.

4.5.11 Closing Plots (Filling the Area Under Plots)

`\closedcycle`

Provide `\closedcycle` as ⟨*trailing path commands*⟩ after `\addplot` to draw a closed line from the last plot coordinate to the first one.

Use `\closedcycle` whenever you intend to fill the area under a plot.
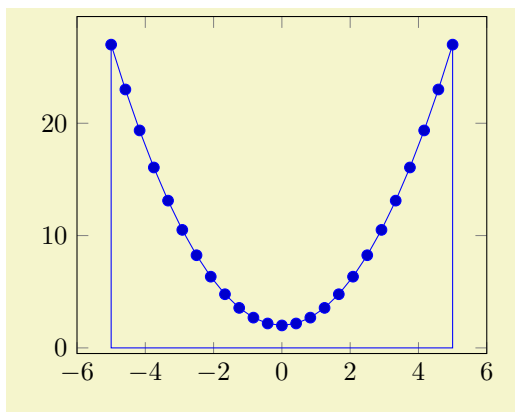
```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
    \begin{axis}
    \addplot {x^2+2} \closedcycle;
    \end{axis}
\end{tikzpicture}
```
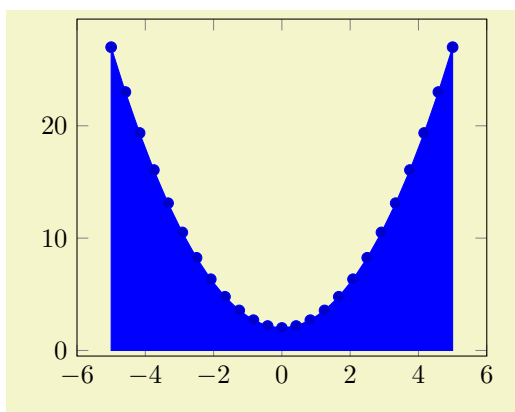
```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
    \begin{axis}
    \addplot+[fill] {x^2+2} \closedcycle;
    \end{axis}
\end{tikzpicture}
```

In case of stacked plots, `\closedcycle` connects the current plot with the previous plot instead of connecting with the x axis[14].
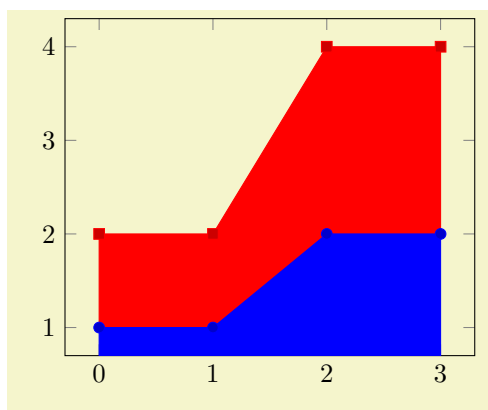
```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
    \begin{axis}[stack plots=y]
    \addplot+[fill] coordinates
        {(0,1) (1,1) (2,2) (3,2)} \closedcycle;
    \addplot+[fill] coordinates
        {(0,1) (1,1) (2,2) (3,2)} \closedcycle;
    \end{axis}
\end{tikzpicture}
```

Closing a plot is also possible for *three–dimensional axes*, see Section 4.6.3 on page 130.

Note that `\closedcycle` has been designed for functions (i.e. for a plot where every x has at most one y value). For arbitrary curves, you can safely use the TikZ path `--cycle` instead which simply connects the last and the first path element:

---

[14] The implementation for stacked plots requires some additional logic to determine the filled area: `\closedcycle` will produce a `plot coordinates` command with *reversed* coordinates of the previous plot. This is usually irrelevant for end users, but it assumes that the plot's type is symmetric. Since constant plots are inherently asymmetric, `\closedcycle` will use `const plot mark right` as reversed sequence for `const plot mark left`.
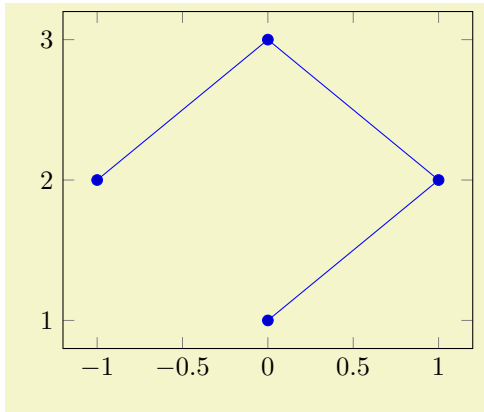
```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
    \begin{axis}
    \addplot coordinates
        {(0,1) (1,2) (0,3) (-1,2)};
    \end{axis}
\end{tikzpicture}
```
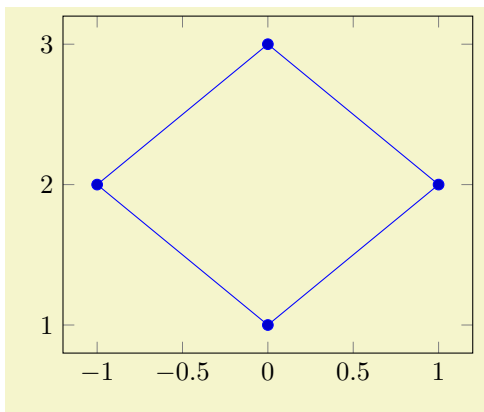
```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
    \begin{axis}
    \addplot coordinates
        {(0,1) (1,2) (0,3) (-1,2)} --cycle;
    \end{axis}
\end{tikzpicture}
```
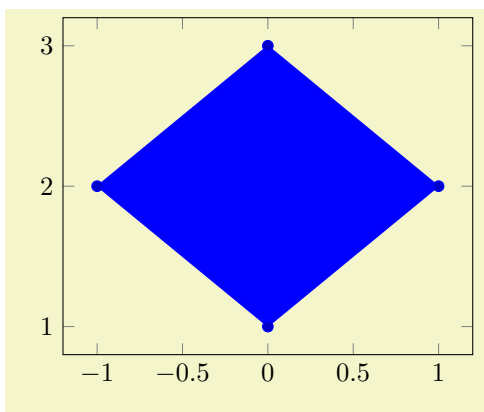
```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
    \begin{axis}
    \addplot+[fill] coordinates
        {(0,1) (1,2) (0,3) (-1,2)} --cycle;
    \end{axis}
\end{tikzpicture}
```

The `--cycle` is actually a path instruction of [7]; it connects the first and the last coordinate of one path. Note that this is automatically done for `fill`ed paths.

4.5.12 Scatter Plots

The most simple scatter plots produce the same as the line plots above – but they contain only markers. They are enabled using the `only marks` key of Ti*k*Z.

/tikz/`only marks` (no value)

\addplot+[`only marks`]

Draws a simple scatter plot: all markers have the same appearance.
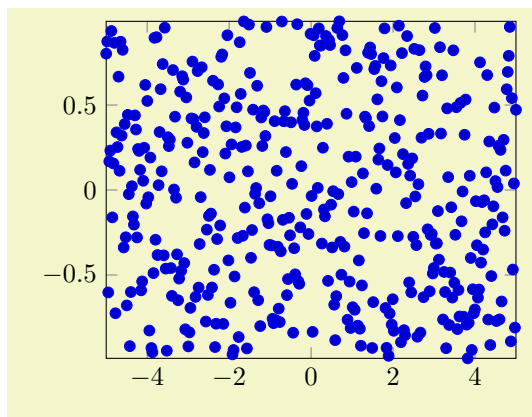
```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
    \begin{axis}[enlargelimits=false]
    \addplot+[only marks,samples=400]
        {rand};
    \end{axis}
\end{tikzpicture}
```

The only marks visualization style simply draws marks at every coordinate. Marks can be set with mark=⟨*mark name*⟩ and marker options like size and color can be specified using the mark options=⟨*style options*⟩ key (or by modifying the every mark style). The available markers along with the accepted style options can be found in Section 4.7 on page 181.

More sophisticated scatter plots change the marker appearance for each data point. An example is that marker colors depend on the magnitude of function values $f(x)$ or other provided coordinates. The term "scatter plot" will be used for this type of plot in the following sections.

Scatter plots require "source" coordinates. These source coordinates can be the y coordinate, or explicitly provided additional values.

/pgfplots/scatter   (no value)

\addplot+[scatter]

Enables marker appearance modifications. The default implementation acquires "source coordinates" for every data point (see scatter src below) and maps them linearly into the current color map. The resulting color is used as draw and fill color of the marker.
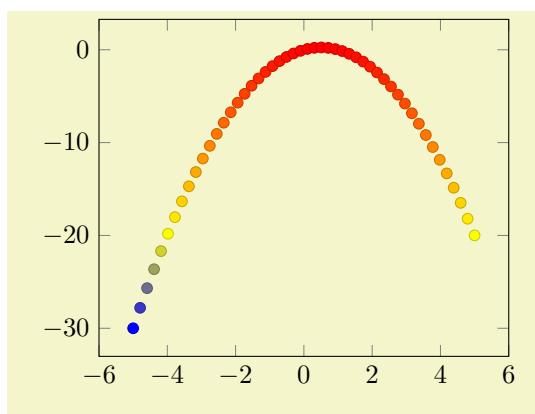

```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
    \begin{axis}
    \addplot+[scatter,only marks,
        samples=50,scatter src=y]
        {x-x^2};
    \end{axis}
\end{tikzpicture}
```

The key scatter is simply a boolean variable which enables marker modifications. It applies only to markers and it can be combined with any other plot type.
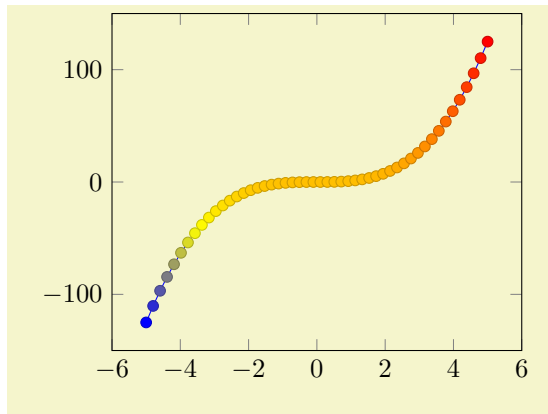
```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
    \begin{axis}
    \addplot+[scatter,
        samples=50,scatter src=y]
        {x^3};
    \end{axis}
\end{tikzpicture}
```

Scatter plots can be configured using a set of options. One of them is mandatory, the rest allows fine grained control over marker appearance options.

/pgfplots/scatter src=none|⟨*expression*⟩|x|y|z|f(x)|explicit|explicit symbolic   (initially none)

This key is necessary for any scatter plot and it is set to f(x) as soon as scatter is activated and no different choice has been made. It needs to be provided as ⟨*option*⟩ for \addplot to configure the value used to determine marker appearances. Actually, scatter src is nothing but an alias for point meta, so the main documentation for this key is on page 227. However, we summarize the choices here together with scatter plot examples.

Usually, scatter src provides input data (numeric or string type) which is used to determine colors and other style options for markers. The default configuration expects numerical data which is mapped linearly into the current color map.

The value of scatter src determines how to get this data: the choices x, y and z will use either the x, y or z coordinates to determine marker options. Any coordinate filters, logarithms or stacked-plot computations have already been applied to these values (use rawx, rawy and rawz for unprocessed values). The special choice f(x) is the same as y for two dimensional plots and the same as z for three dimensional plots. The choice explicit expects the scatter source data as additional coordinate from the coordinate input streams (see Section 4.3.1 for how to provide input meta data or below for some small examples). They will be treated as numerical data. The choice explicit symbolic also expects scatter source data as additional meta information for each input coordinate, but it treats them as strings, not as numerical data. Consequently, no arithmetics is performed. It is the task of the scatter plot style to do something with it. See, for example, the scatter/classes style below. Finally, it is possible to provide an arbitrary mathematical expression which involves zero, one or more of the values x (the current x coordinate), y (the current y coordinate) or z (the current z coordinate, if any).

If data is read from tables, mathematical expressions might also involve \thisrow{⟨*column name*⟩} or \thisrowno{⟨*column index*⟩} to access any of the table cells in the current row.

Here are examples for how to provide data for the choices explicit and explicit symbolic.

```
\begin{tikzpicture}
    \begin{axis}
        % provide color data explicitly using [<data>]
        % behind coordinates:
        \addplot+[scatter,scatter src=explicit]
            coordinates {
                (0,0) [1.0e10]
                (1,2) [1.1e10]
                (2,3) [1.2e10]
                (3,4) [1.3e10]
                % ...
            };

        % Assumes a datafile.dat like
        % xcolname  ycolname    colordata
        % 0         0           0.001
        % 1         2           0.3
        % 2         2.1         0.4
        % 3         3           0.5
        % ...
        % the file may have more columns.
        \addplot+[scatter,scatter src=explicit]
            table[x=xcolname,y=ycolname,meta=colordata]
                {datafile.dat};
        % Same data as last example:
        \addplot+[scatter,scatter src=\thisrow{colordata}+\thisrow{ycolname}]
            table[x=xcolname,y=ycolname]
                {datafile.dat};

        % Assumes a datafile.dat like
        % 0         0           0.001
        % 1         2           0.3
        % 2         2.1         0.4
        % 3         3           0.5
        % ...
        % the first three columns will be used here:
        \addplot+[scatter,scatter src=explicit]
            file {datafile.dat};
    \end{axis}
\end{tikzpicture}
```

Please note that scatter src≠none results in computational work even if scatter=false.

/pgfplots/scatter/use mapped color={⟨options for each marker⟩}   (style, initially draw=mapped
    color!80!black,fill=mapped color)

This style is installed by default. When active, it recomputes the color mapped color for every processed
point coordinate by transforming the scatter src coordinates into the current color map linearly.
Then, it evaluates the options provided as ⟨options for each marker⟩ which are expected to depend on
mapped color.

The user interface for color maps is described in Section 4.7.6.
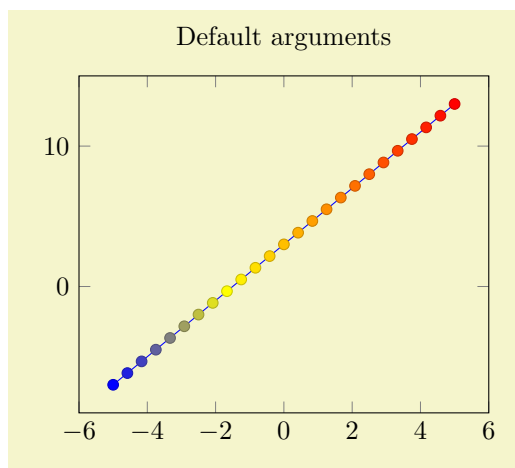

```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
\begin{axis}[title=Default arguments]
\addplot+[scatter,scatter src=y]
    {2*x+3};
\end{axis}
\end{tikzpicture}
```

Black fill color and varying draw color
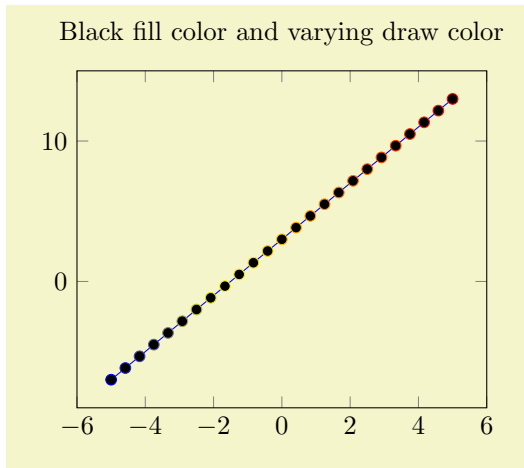

```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
\begin{axis}[
    title=Black fill color and varying draw color,
    scatter/use mapped color=
        {draw=mapped color,fill=black}]
\addplot+[scatter,scatter src=y]
    {2*x+3};
\end{axis}
\end{tikzpicture}
```

Black draw color and varying fill color
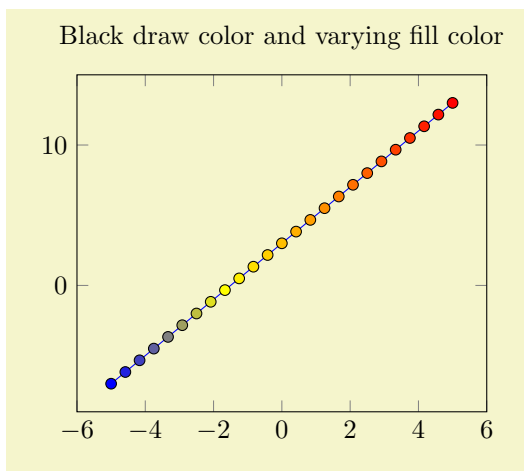

```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
\begin{axis}[
    title=Black draw color and varying fill color,
    scatter/use mapped color=
        {draw=black,fill=mapped color}]
\addplot+[scatter,scatter src=y]
    {2*x+3};
\end{axis}
\end{tikzpicture}
```
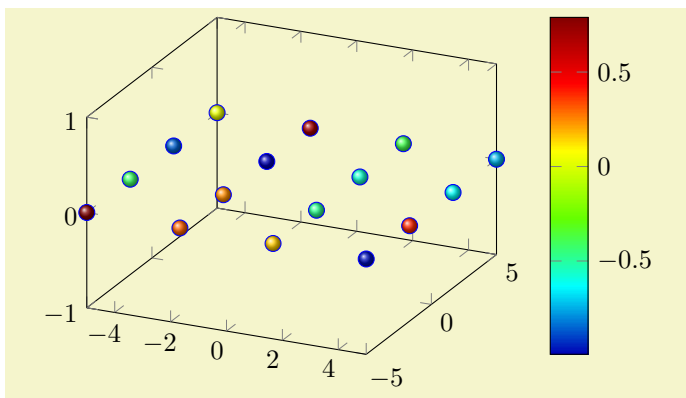


```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
\begin{axis}[colormap/bluered,colorbar]
\addplot3+[samples=4,
    z buffer=sort,
    % enable scatter:
    scatter,
    % redefine appearance:
    scatter/use mapped color={ball color=mapped color},
    % configure input:
    scatter src=rand,
    only marks,
    mark=ball,
    mark size=3pt,
]
        {0};
\end{axis}
\end{tikzpicture}
```

This key is actually a style which redefines @pre marker code and @post marker code (see below).

Remark: The style use mapped color *re*defines @pre marker code and @post marker code. There is a starred variant **use mapped color*** which *appends* the functionality while keeping the old marker code.

/pgfplots/scatter/classes={⟨*styles for each class name*⟩}

A scatter plot style which visualizes points using several classes. The style assumes that every point coordinate has a class label attached, that means the choice scatter src=explicit symbolic is assumed[15]. A class label can be a number, but it can also be a symbolic constant. Given class labels for every point, ⟨*styles for each class name*⟩ contains a comma-separated list which associates appearance options to each class label.
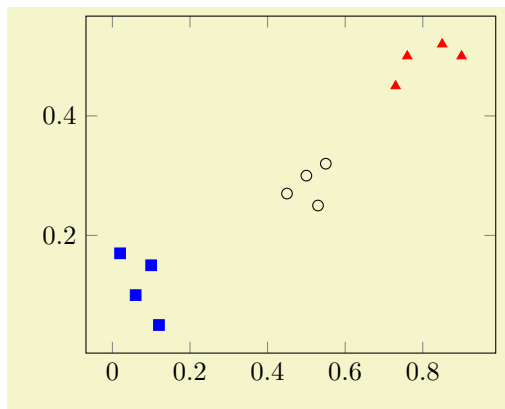

```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
\begin{axis}[scatter/classes={
    a={mark=square*,blue},%
    b={mark=triangle*,red},%
    c={mark=o,draw=black}}]

    % \addplot[] is better than \addplot+[] here:
    % it avoids scalings of the cycle list
    \addplot[scatter,only marks,
        scatter src=explicit symbolic]
        coordinates {
            (0.1,0.15)   [a]
            (0.45,0.27)  [c]
            (0.02,0.17)  [a]
            (0.06,0.1)   [a]
            (0.9,0.5)    [b]
            (0.5,0.3)    [c]
            (0.85,0.52)  [b]
            (0.12,0.05)  [a]
            (0.73,0.45)  [b]
            (0.53,0.25)  [c]
            (0.76,0.5)   [b]
            (0.55,0.32)  [c]
        };
\end{axis}
\end{tikzpicture}
```

In this example, the coordinate (0.1,0.15) has the associated label 'a' while (0.45,0.27) has the label 'c' (see Section 4.3 for details about specifying point meta data). Now, the argument to scatter/classes contains styles for every label – for label 'a', square markers will be drawn in color blue.

The generation of a legend works as for a normal plot – but scatter/classes requires one legend entry for every provided class. It communicates the class labels to the legend automatically. It works as if there had been different \addplot commands, one for every class label.

It is also possible to provide scatter/classes as argument to a single plot, allowing different scatter plots in one axis.

_____

[15]If scatter src is not explicit symbolic, we expect a numeric argument which is rounded to the nearest integer. The resulting integer is used a class label. If that fails, the numeric argument is truncated to the nearest integer. If that fails as well, the point has no label.
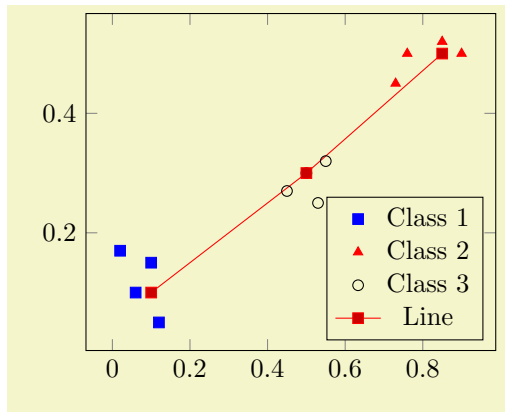
```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
\begin{axis}[legend pos=south east]
    % The data file contains:
    % x       y      label
    % 0.1    0.15    a
    % 0.45   0.27    c
    % 0.02   0.17    a
    % 0.06   0.1     a
    % 0.9    0.5     b
    % 0.5    0.3     c
    % 0.85   0.52    b
    % 0.12   0.05    a
    % 0.73   0.45    b
    % 0.53   0.25    c
    % 0.76   0.5     b
    % 0.55   0.32    c
    \addplot[
        % clickable coords={\thisrow{label}},
        scatter/classes={
            a={mark=square*,blue},%
            b={mark=triangle*,red},%
            c={mark=o,draw=black,fill=black}%
        },
        scatter,only marks,
        scatter src=explicit symbolic]
    table[x=x,y=y,meta=label]
            {plotdata/scattercl.dat};

    \addplot coordinates
        {(0.1,0.1) (0.5,0.3) (0.85,0.5)};
    \legend{Class 1,Class 2,Class 3,Line}
\end{axis}
\end{tikzpicture}
```

In general, the format of ⟨*styles for each class name*⟩ is a comma separated list of ⟨*label*⟩={⟨*style options*⟩}.

Attention: The keys `every mark` and `mark options` have *no effect* when used inside of ⟨*styles for each class name*⟩! So, instead of assigning `mark options`, you can simply provide the options directly. They apply only to markers anyway.

Remark: To use `\label` and `\ref` in conjunction with `scatter/classes`, you can provide the class labels as optional arguments to `\label` in square brackets:

```
\addplot[
    scatter/classes={
        a={mark=square*,blue},%
        b={mark=triangle*,red},%
        c={mark=o,draw=black,fill=black}%
    },
    scatter,only marks,
    scatter src=explicit symbolic]
    % [and coordinate input here... ]
    ;

\label[a]{label:for:first:class}
\label[b]{label:for:second:class}
\label[c]{label:for:third:class}

...
First class is \ref{label:for:first:class}, second is \ref{label:for:second:class}.
```

Remark: It is possible to click into the plot to display labels with mouse popups, see the `clickable coords` key of the `clickable` library.

Remark: The style `scatter/classes` *re*defines `@pre marker code` and `@post marker code`. There is a starred variant `scatter/classes*` which *appends* the functionality while keeping the old marker code.

/pgfplots/**nodes near coords**={⟨*content*⟩}	(default \pgfmathprintnumber\pgfplotspointmeta)
/pgfplots/**nodes near coords*** ={⟨*content*⟩}	(default \pgfmathprintnumber\pgfplotspointmeta)

A `scatter` plot style which places text nodes near every coordinate.
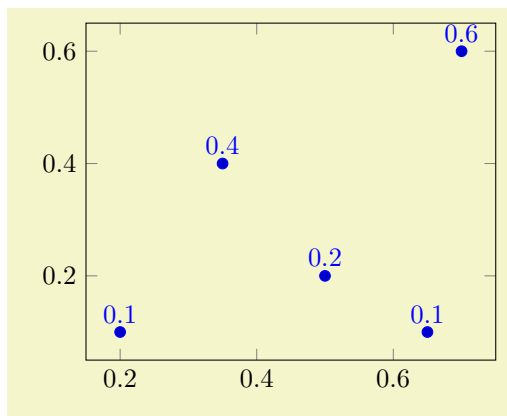

```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
\begin{axis}[nodes near coords]
    \addplot+[only marks] coordinates {
        (0.5,0.2) (0.2,0.1) (0.7,0.6)
        (0.35,0.4) (0.65,0.1)};
\end{axis}
\end{tikzpicture}
```

The ⟨*content*⟩ is, if nothing else has been specified, the content of the "point meta", displayed using the default ⟨*content*⟩=\pgfmathprintnumber{\pgfplotspointmeta}. The macro \pgfplotspoint-meta contains whatever has been selected by the `point meta` key, it defaults to the y coordinate for two dimensional plots and the z coordinate for three dimensional plots.

Since `point meta`=explicit symbolic allows to treat string data, you can provide textual descriptions which will be shown inside of the generated nodes[16]:
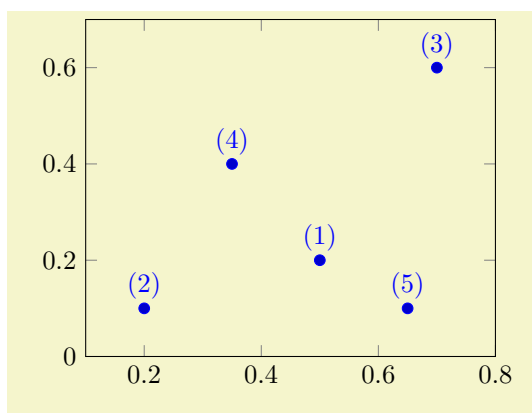

```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
\begin{axis}[nodes near coords,enlargelimits=0.2]
    \addplot+[only marks,
        point meta=explicit symbolic]
    coordinates {
        (0.5,0.2) [(1)]
        (0.2,0.1) [(2)]
        (0.7,0.6) [(3)]
        (0.35,0.4) [(4)]
        (0.65,0.1) [(5)]
    };
\end{axis}
\end{tikzpicture}
```

The square brackets are the way to provide explicit `point meta` for `plot coordinates`. Please refer to the documentation of `plot file` and `plot table` for how to get point meta from files.

The ⟨*content*⟩ can also depend on something different than \pgfplotspointmeta. But since ⟨*content*⟩ is evaluated during \end{axis}, PGFPLOTS might not be aware of any special information inside of ⟨*content*⟩ – you'll need to communicate it to PGFPLOTS with the `visualization depends on` key as follows:

---

[16]In this case, the \pgfmathprintnumber will be skipped automatically.
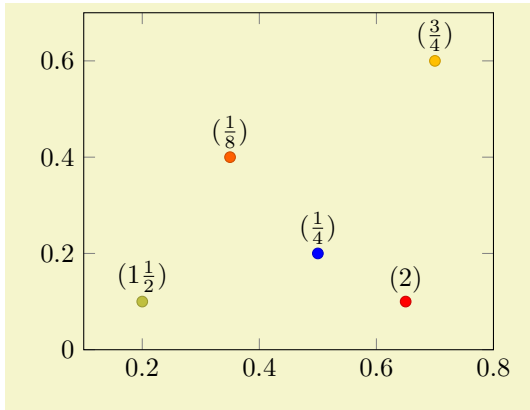
```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
    \begin{axis}[enlargelimits=0.2]
        \addplot[
          scatter,mark=*,only marks,
          % we use 'point meta' as color data...
          point meta=\thisrow{color},
          % ... therefore, we can't use it as argument for nodes near coords ...
          nodes near coords*={$(\pgfmathprintnumber[frac]\myvalue)$},
          % ... which requires to define a visualization dependency:
          visualization depends on={\thisrow{myvalue} \as \myvalue},
        ]
        table {
            x       y     color     myvalue
            0.5     0.2   1         0.25
            0.2     0.1   2         1.5
            0.7     0.6   3         0.75
            0.35    0.4   4         0.125
            0.65    0.1   5         2
        };
    \end{axis}
\end{tikzpicture}
```

The example uses a `scatter` plot to get different colors, where the `scatter src` (or, equivalently, `point meta`) is already used to define the markers color. In addition to the colored `scatter` plot, we'd like to add `nodes near coords`, where the displayed nodes should contain `\thisrow{myvalue}`. To do so, we define `scatter,point meta=\thisrow{color}` (just as described in the previous sections). Furthermore, we use nodes near coords* in order to *combine* different `scatter` styles (see below for details). The value for `nodes near coords*` depends on `\thisrow{myvalue}`, but we can't use `\pgf-plotspointmeta` (which is already occupied). Thus, we communicate the additional input data by means of `visualization depends on={\thisrow{myvalue} \as \myvalue}`. The statement defines a new macro, `\myvalue`, and assigns the value `\thisrow{myvalue}`. Furthermore, it configures PGF-PLOTS to remember this particular macro and its contents until `\end{axis}` (see the documentation for `visualization depends on` for details).

The style `nodes near coords` might be useful for bar plots, see `ybar` for an example of `nodes near coords`.

Remarks and Details:

- `nodes near coords` uses the same options for line styles and colors as the current plot. This may be changed using the style `every node near coord`, see below.

- `nodes near coords` is actually one of the `scatter` plot styles. It redefines `scatter/@pre marker code` to generate several TikZ `\node` commands.

  In order to use `nodes near coords` together with other `scatter` plot styles (like `scatter/use mapped color` or `scatter/classes`), you may append a star to each of these keys. The variant nodes near coords* will *append* code to `scatter/@pre marker code` without overwriting the previous value.

- Consider using `enlargelimits` together with `nodes near coords` if text is clipped away.

- Currently `nodes near coords` does not work satisfactorily for `ybar interval` or `xbar interval`, sorry.

`/pgfplots/every node near coord`   (style, no value)

A style used for every node generated by `nodes near coords`. It is initially empty.

`/pgfplots/nodes near coords style`={⟨*key-value-list*⟩}

An abbreviation for `every node near coord/.append style`={⟨*key-value-list*⟩}.

It appends options to the already existing style `every node near coord`.

`/pgfplots/node near coords style`={⟨*key-value-list*⟩}

An abbreviation for `every node near coord/.append style`={⟨*key-value-list*⟩}.

It appends options to the already existing style `every node near coord`.

`/pgfplots/node near coord style`={⟨*key-value-list*⟩}

An abbreviation for `every node near coord/.append style`={⟨*key-value-list*⟩}.

It appends options to the already existing style `every node near coord`.

`/pgfplots/nodes near coords align`={⟨*alignment method*⟩}   (initially `auto`)

Specifies how to align nodes generated by `nodes near coords`.

Possible choices for ⟨*alignment method*⟩ are

- `auto` uses `horizontal` if the x coordinates are shown or `vertical` in all other cases. This checks the current value of `point meta`.
- `horizontal` uses `left` if `\pgfplotspointmeta` < 0 and `right` otherwise.
- `vertical` uses `below` if `\pgfplotspointmeta` < 0 and `above` otherwise.
- It is also possible to provide any TikZ alignment option such as `anchor`=`north east`, `below` or something like that. It is also allowed to provide multiple options.

`/pgfplots/scatter/position`=`absolute`|`relative`   (initially `relative`)

Allows to choose how to position scatter plot markers. This applies only if the `scatter` option is `true`.

The choice `relative` is the initial configuration, it means that the scatter marker is placed at the given point's coordinates. Technically, it means that the transformation matrix is shifted such that `(0,0)` is right at the current point's coordinates. This is typically what you want.

The choice `absolute` allows to position a scatter plot marker absolutely, for example by means of `axis cs`. This can be combined with `nodes near coords` and a suitable set of ⟨*options*⟩ in `every node near coord/.style`={⟨*options*⟩}: one could say `at`=`{(\coordindex,\coordindex*5)}` or something like that. Note that this choice necessarily needs an `at` key to specify the node's position, otherwise its position will be undefined[17].

`/pgfplots/scatter/@pre marker code/.code`={⟨. . . ⟩}
`/pgfplots/scatter/@post marker code/.code`={⟨. . . ⟩}

These two keys constitute the public interface which determines the marker appearance depending on scatter source coordinates.

Redefining them allows fine grained control even over marker types, line styles and colors.

The scatter plot algorithm works as follows:

1. The scatter source coordinates form a data stream whose data limits are computed additionally to the axis limits. This step is skipped for `symbolic` meta data.

2. Before any markers are drawn, a linear coordinate transformation from these data limits to the interval $[0.0, 1000.0]$ is initialised.

3. Every scatter source coordinate[18] will be transformed linearly and the result is available as macro `\pgfplotspointmetatransformed` $\in [0.0, 1000.0]$.

---

[17]Well, it will be the origin of the canvas. Which is not necessarily the same as the origin of your axis.

[18]During the evaluation, the public macros `\pgfplotspointmeta` and `\pgfplotspointmetarange` indicate the source coordinate and the source coordinate range in the format $a : b$ (for log–axis, they are given in fixed-point representation and for linear axes in floating point).

The decision is thus based on per thousands of the data range. The transformation is skipped for `symbolic` meta data (and the meta data is simply contained in the mentioned macro).

4. The PGF coordinate system is translated such that (`0pt`,`0pt`) is the plot coordinate.

5. The code of `scatter/@pre marker code` is evaluated (without arguments).

6. The standard code which draws markers is evaluated.

7. The code of `scatter/@post marker code` is evaluated (without arguments).

The idea is to generate a set of appearance keys which depends on `\pgfplotspointmetatransformed`. Then, a call to `\scope[⟨generated keys⟩]` as @pre code and the associated `\endscope` as @post code will draw markers individually using `[⟨generated keys⟩]`.

A technical example is shown below. It demonstrates how to write user defined routines, in this case a three–class system[19].
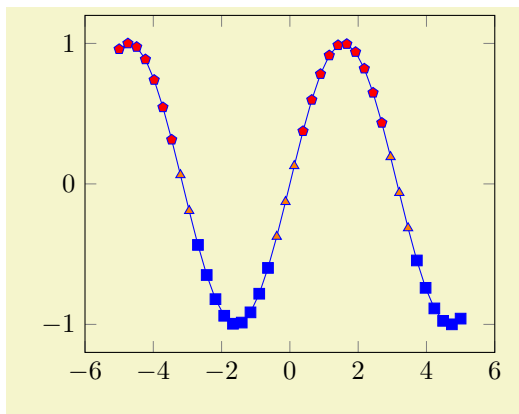
```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
% Low-Level scatter plot interface Example:
% use three different marker classes
% 0% - 30%   : first class
% 30% - 60%  : second class
% 60% - 100% : third class
\begin{axis}[
scatter/@pre marker code/.code={%
    \ifdim\pgfplotspointmetatransformed pt<300pt
        \def\markopts{mark=square*,fill=blue}%
    \else
        \ifdim\pgfplotspointmetatransformed pt<600pt
            \def\markopts{mark=triangle*,fill=orange}%
        \else
            \def\markopts{mark=pentagon*,fill=red}%
        \fi
    \fi
    \expandafter\scope\expandafter[\markopts]
},%
scatter/@post marker code/.code={%
    \endscope
}]

\addplot+[scatter,scatter src=y,
    samples=40]
    {sin(deg(x))};

\end{axis}
\end{tikzpicture}
```

Please note that `\ifdim` compares TeX lengths, so the example employs the suffix `pt` for any number used in this context. That doesn't change the semantics. The two (!) `\expandafter` constructions make sure that `\scope` is invoked with the *content* of `\markopts` instead of the macro name `\markopts`.

4.5.13   1D Colored Mesh Plots

/pgfplots/**mesh** (no value)

`\addplot+[`**mesh**`]`

Uses the current color map to determine colors for each fixed line segment. Each line segment will get the same color.

---

[19]Please note that you don't need to copy this particular example: the multiple–class example is also available as predefined style `scatter/classes`.
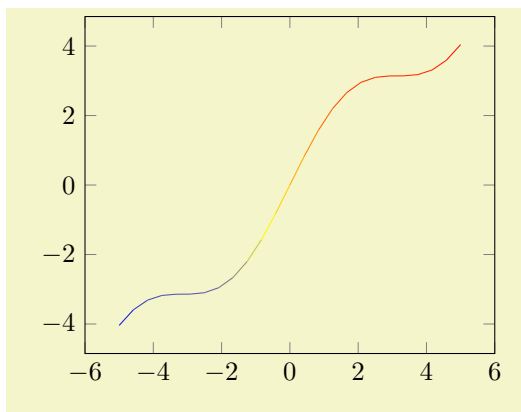
```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
    \begin{axis}
    \addplot[mesh] {x+sin(deg(x))};
    \end{axis}
\end{tikzpicture}
```

The color data is per default the y value of the plot. It can be reconfigured using the `point meta` key (which is actually the same as `scatter src`). The following example provides the color data explicitly for `plot coordinates`, using the square bracket notation.
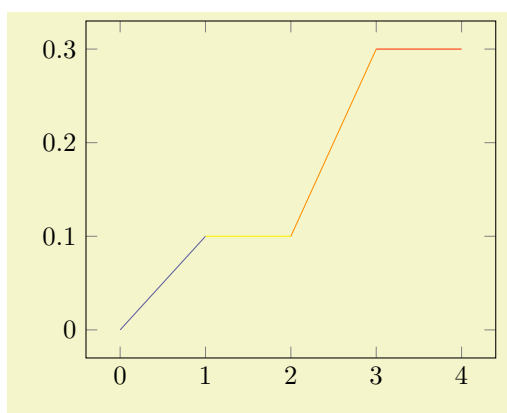
```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
    \begin{axis}
    \addplot[mesh,point meta=explicit]
        coordinates {
            (0,0)   [0]
            (1,0.1) [1]
            (2,0.1) [2]
            (3,0.3) [3]
            (4,0.3) [4]
        };
    \end{axis}
\end{tikzpicture}
```

This one-dimensional `mesh` plot is actually a special case of the twodimensional mesh plots, so more detailed configuration, including how to change the color data, can be found in Section 4.6.5.

4.5.14   Interrupted Plots

Sometimes it is desirable to draw parts of a single plot separately, without connection between the parts (discontinuities). PGFPLOTS offers three ways to generate interrupted plots:

1. `empty line`s in the input file or

2. by providing `unbounded coords` or

3. by providing unbounded `point meta`.

Interrupted Plots using Empty Lines

The first way to generate interrupted plots is simple; it needs no extra key (only `\pgfplotsset{compat`=1.4} or newer in your preamble):
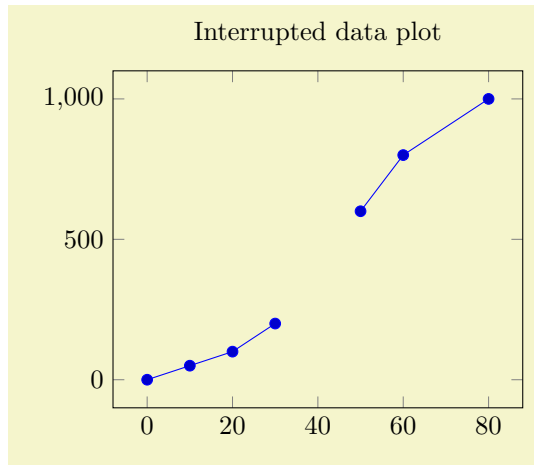
```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
\begin{axis}[
    title=Interrupted data plot]

    \addplot coordinates {
        (0,0) (10,50) (20,100) (30,200)

        (50,600) (60,800) (80,1000)
    };
\end{axis}
\end{tikzpicture}
```

Here, PGFPLOTS runs with the default configuration empty line=auto which interpretes empty lines as "jump" markers. This works for any data input method, i.e. using \addplot coordinates, \addplot table, and \addplot file.

Note that empty line is useful for two–dimensional plots only since it has a special meaning for three–dimensional plots (in which case empty line=scanline decodes matrices).

Interrupted Plots using Unbounded Coordinate Values

The second way to generate interrupted plots addresses the case where empty lines are unavailable or impossible (due to limitations of the tool generating the data file, for example). In this case, interrupted plots can be achieved using the unbounded coords key combined with coordinate values nan, inf or -inf.

/pgfplots/unbounded coords=discard|jump   (initially discard)

This key configures what to do if one or more coordinates of a single point are unbounded. Here, unbounded means it is either $\pm\infty$ (+inf or -inf) or it has the special "not–a–number" value nan.

The initial setting discard discards the complete point and a warning is issued in the log file[20]. This setting has the same effect as if the unbounded point did not occur: PGFPLOTS will interpolate between the bounded adjacent points.

The alternative jump allows interrupted plots: it provides extra checking for these coordinates and does not interpolate over them; only those line segments which are adjacent to unbounded coordinates will be skipped.

---
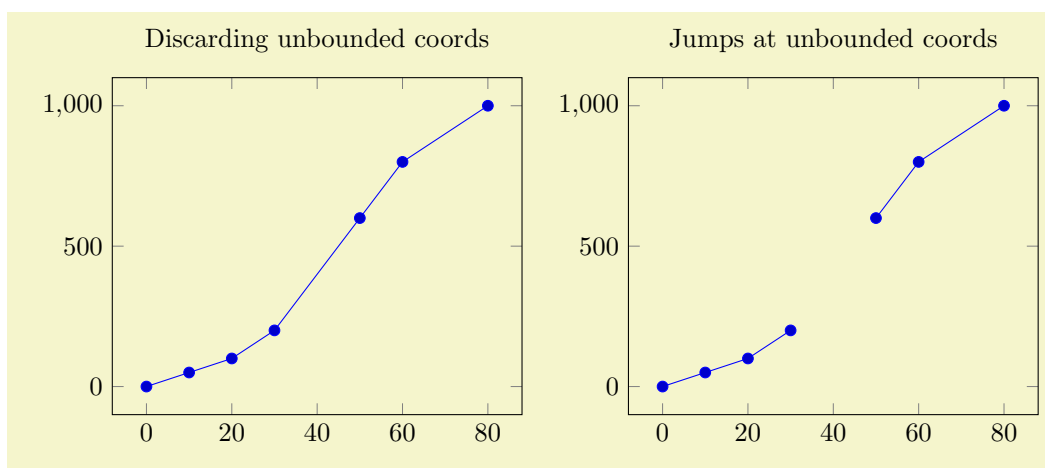
[20]The warning can be disabled with `filter discard warning=false`.

```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
\begin{axis}[
    title=Discarding unbounded coords,
    unbounded coords=discard]

    \addplot coordinates {
        (0,0) (10,50) (20,100) (30,200)
        (40,inf) (50,600) (60,800) (80,1000)
    };
\end{axis}
\end{tikzpicture}
\begin{tikzpicture}
\begin{axis}[
    title=Jumps at unbounded coords,
    unbounded coords=jump]
    \addplot coordinates {
        (0,0) (10,50) (20,100) (30,200)
        (40,inf) (50,600) (60,800) (80,1000)
    };
\end{axis}
\end{tikzpicture}
```

For plot expression and its friends, it is more likely to get very large floating point numbers instead of inf. In this case, consider using the restrict x to domain key described on page 387.

The unbounded coords=jump method does also work for mesh/surface plots: every face adjacent to an unbounded coordinate will be discarded in this case. The following example sets up a (cryptic) coordinate filter which cuts out a quarter of the domain and replaces its values with nan:
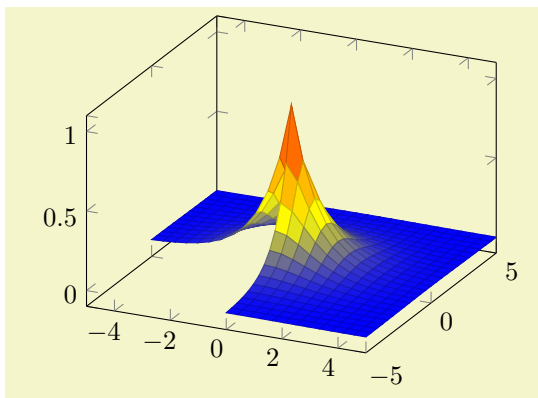

```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
\begin{axis}[
  unbounded coords=jump,
  x filter/.expression={ x<0 && y<0 ? nan : x},
]
  \addplot3[surf] {exp(-sqrt(x^2 + y^2))};
\end{axis}
\end{tikzpicture}
```

This example requires unbounded coords=jump *and* an unbounded value (like nan) in order to work. Choosing either unbounded coords=discard or an empty string to discard values would result in a broken lattice which would confuse PGFPLOTS. Note that the same example can be achieved using the method in the following chapter, see the associated example below.

Interrupted Plots using Unbounded Point Meta Values

The third way to generate interrupted plots is designed for input data which forms a mesh, i.e. for three–dimensional plots: in this case, point meta is expected (by mesh or surf and its variants). If one of the involved coordinates has an unbounded value for its point meta, all adjacent patches which require the point meta will be omitted.

The following example has *one* of its point meta values set to nan (not a number):
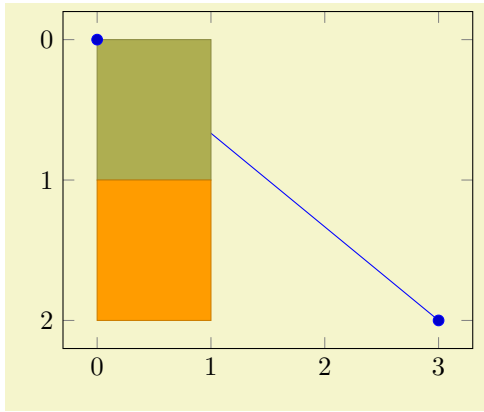
```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
\begin{axis}[y dir=reverse]
\addplot coordinates {(0,0) (3,2)};

\addplot[surf,point meta=explicit] coordinates {
(0,0) [0] (1,0) [1] (2,0) [2] (3,0) [3]

(0,1) [4] (1,1) [5] (2,1) [nan] (3,1) [7]

(0,2) [8] (1,2) [9] (2,2) [10] (3,2) [11]
};
\end{axis}
\end{tikzpicture}
```

Note that all four adjacent cells are omitted since the default `shader` is `shader=flat` mean, an averaging scheme which fails to compute the averages.

If we use `flat corner`, only one cell becomes invisible:
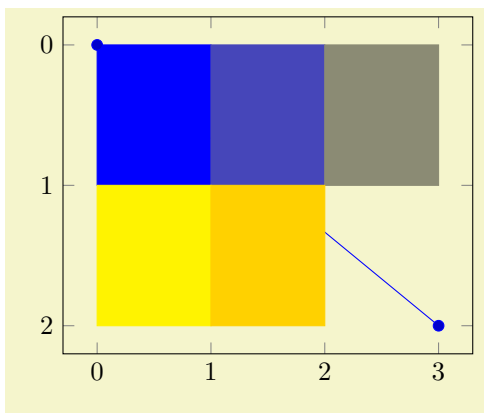
```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
\begin{axis}[y dir=reverse,shader=flat corner]
\addplot coordinates {(0,0) (3,2)};

\addplot[surf,point meta=explicit] coordinates {
(0,0) [0] (1,0) [1] (2,0) [2] (3,0) [3]

(0,1) [4] (1,1) [5] (2,1) [nan] (3,1) [7]

(0,2) [8] (1,2) [9] (2,2) [10] (3,2) [11]
};
\end{axis}
\end{tikzpicture}
```

The case `shader=flat corner` choose the color of the *first* vertex of each patch. For `mesh input=lattice` as in our example above, this applies to the rectangle with vertices $(2, 1)$, $(3, 1)$, $(2, 2)$, $(3, 2)$.

The feature can be used to choose `point meta` accordingly, for example to strip certain pieces of the input:
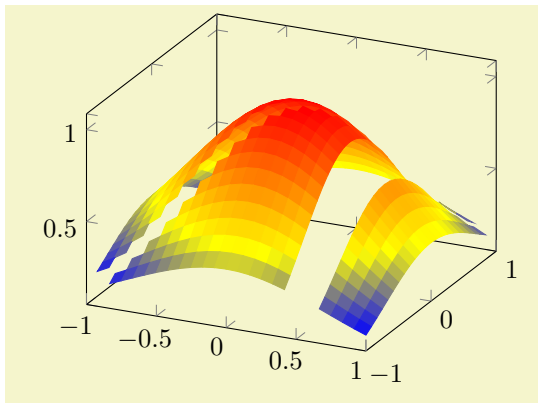
```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
\begin{axis}[shader=flat corner,domain=-1:1]
\addplot3[surf,
    point meta={
      abs(x-y)<0.1 || abs(x-0.5)<0.1 ? nan : z
    }
]
    {exp(-x^2-y^2)};
\end{axis}
\end{tikzpicture}
```

The expression removes all points where $x == y$ or $x == \frac{1}{2}$ (approximately) and assigns the color value $f(x, y)$ for all other coordinates.

This approach can also be applied to the example of the previous subsection, i.e. to
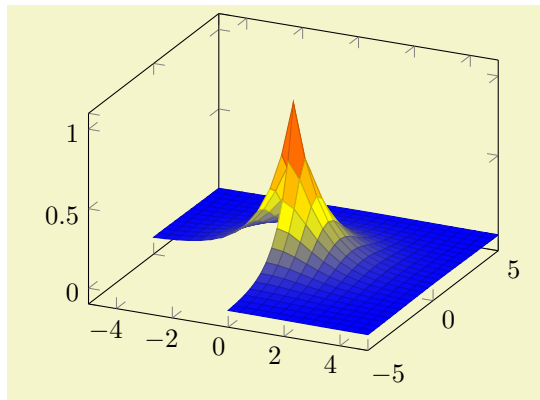
```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
\begin{axis}[
  point meta={x<0 && y<0 ? nan : z},
  ]
  \addplot3[surf] {exp(-sqrt(x^2 + y^2))};
\end{axis}
\end{tikzpicture}
```

Limitations   of this approach: coordinate filtering by means of `point meta` still includes the omitted patch segments into the limit computation. This is different than `x filter` and its variants which also updates axis limits accordingly.

More about this coordinate filtering can be found in Section 4.22 "Skipping Or Changing Coordinates – Filters".

4.5.15   Patch Plots

Patch Plots visualize a sequence of one or more triangles (or other sorts of patches). These triangles can be drawn with a single color (`shader=flat` and `shader=faceted interp`) or with interpolated colors (`shader=interp`).

There are both two- and three-dimensional patch plots, both with the same interface and the same keys. Therefore, the reference documentation for patch plots can be found in Section 4.6.13 together with three–dimensional patch plots.

4.5.16   Image (Matrix) Plots

A `matrix plot` consists of an input matrix and one colored cell for each element of the input matrix. Such plots are a special case of a `surf`ace plot and are described in all detail in section 4.6.12 together with other options about surface and mesh plots.

4.5.17   Polar Coordinates / Polar Axes

Polar coordinates can be provided in any kind of axis by means of `data cs=polar`, please refer to its reference documentation of page 388.

Polar axes are available by means of `\usepgfplotslibrary{polar}`; please refer to Section 5.10.

4.5.18   Tieline Plots

Tieline plots are a special application in `ternaryaxis`. They are part of `\usepgfplotslibrary{ternary}`; please refer to Section 5.13.2 on page 513.

4.5.19   Smith Charts

Smith charts have a special coordinate system and a part of `\usepgfplotslibrary{smitchart}`; please refer to Section 5.11.

4.6   Three Dimensional Plot Types

PGFPLOTS provides three dimensional visualizations like scatter, line, mesh or surface plots. This section explains the methods to provide input coordinates and how to use the different plot types.

4.6.1 Before You Start With 3D

Before we delve into the capabilities of PGFPLOTS for three dimensional visualization, let me start with some preliminary remarks. The reason to use PGFPLOTS for three dimensional plots are similar to those of normal, two dimensional plots: the possibility to get consistent fonts and document consistent styles combined with high–quality output.

While this works very nice for (not too complex) two dimensional plots, it requires considerably more effort than non–graphical documents. This is even more so for three dimensional plots. In other words: PGFPLOTS' three dimensional routines are slow. There are reasons for this and some of them may vanish in future versions. But one of these reasons is that TEX has never been designed for complex visualisation techniques. Consider using `lualatex` (and at least `compat`=1.12) in order to reduce compilation times and to avoid memory limitations. Also consider the image externalization routines mentioned in Section 7.1, in particular the `external` library to reduce typesetting time. Besides the speed limitations, three dimensional plots reach memory limits easily. Therefore, the plot complexity of three dimensional plots is limited to relatively coarse resolutions. Section 7.1 also discusses methods to extend the initial TEX memory limits.

Another issue which arises in three dimensional visualization is depth: it is necessary to decide which items are to be drawn in front of others. PGFPLOTS supports z buffering techniques up to a certain extend: it works pretty well for single scatter plots (`z buffer`=sort), mesh or surface plots (`z buffer`=auto) or parametric mesh and surface plots (`z buffer`=sort). However, it cannot combine different `\addplot` commands, those will be drawn in the order of appearance. You may encounter the limitations sometimes. Maybe it will be improved in future versions.

If you decide that you need high complexity, speed and 100% reliable z buffers (depth information), you should consider using other visualization tools and return to PGFPLOTS in several years. If you can wait for a complex picture and you do not even see the limitations arising from z buffering limitations, you should use PGFPLOTS. Again, consider using the automatic picture externalization with the `external` library discussed in Section 7.1.

4.6.2 The \addplot3 Command: Three Dimensional Coordinate Input

`\addplot3`[⟨*options*⟩] ⟨*input data*⟩ ⟨*trailing path commands*⟩;

The `\addplot3` command is the main interface for any three dimensional plot. It works in the same way as its two dimensional variant `\addplot` which has been described in all detail in Section 4.3 on page 43.

The `\addplot3` command accepts the same input methods as the `\addplot` variant, including expression plotting, coordinates, files and tables. However, a third coordinate is necessary for each of these methods which is usually straight–forward and is explained in all detail in the following.

Furthermore, `\addplot3` has a way to decide whether a *line* visualization or a *mesh* visualization has to be done. The first one is a map from one dimension into $\mathbb{R}^3$ and the latter one a map from two dimensions to $\mathbb{R}^3$. Here, the keys `mesh/rows` and `mesh/cols` are used to define mesh sizes (matrix sizes). Usually, you don't have to care about that because the coordinate input routines already allow either one- or two-dimensional structure.

The precise rules how PGFPLOTS distinguishes between line visualization and mesh visualization is as follows:

1. If the key `mesh input`=patches has been used, PGFPLOTS relies on the current `patch type` (which has an inherent dimension).

2. For all other values of `mesh input` (like `mesh input`=lattice and `mesh input`=image), PGFPLOTS proceeds as follows:

   - It auto-completes the values for `mesh/rows` and `mesh/cols` (or uses their prescribed values).
   - If these keys describe a matrix of size $1 \times N$ or $N \times 1$, PGFPLOTS assumes that it is a line.

   The "auto-completion" depends on how you provide your data.

   - If you use `\addplot3 expression`, `mesh/rows` and `mesh/cols` are computed from the values `samples` and `samples y`. By default, `\addplot3 expression` always samples a mesh. If you want it to sample a line, set `samples y`=1 (or, equivalently, `y domain`=0:0).
   - If you use `\addplot3 table`, `\addplot3 coordinates`, or `\addplot3 file`, you have basically two options: either you provide at least one of `mesh/rows` or `mesh/cols` explicitly, or you format the input table by means of end–of–scanline markers as outlined in `empty line`=auto or

empty line=scanline. In this case, PGFPLOTS counts scanline lengths and uses mesh/ordering to conclude how to determine the matrix values.

Thus, if you have empty lines in your input table, PGFPLOTS will automatically identify the matrix size.

If you do *not* have empty lines, PGFPLOTS expects at least one of mesh/rows or mesh/cols.

\addplot3 coordinates {⟨*coordinate list*⟩};
\addplot3[⟨*options*⟩] coordinates {⟨*coordinate list*⟩} ⟨*trailing path commands*⟩;

The \addplot3 coordinates method works like its two–dimensional variant, \addplot coordinates which is described in all detail on page 46:

A long list of coordinates (⟨*x*⟩,⟨*y*⟩,⟨*z*⟩) is expected, separated by white spaces. The input list can be either an unordered series of coordinates, for example for scatter or line plots. It can also have matrix structure, in which case an empty line (which is equivalent to "\par") marks the end of one matrix row. Matrix structure can also be provided if one of mesh/rows or mesh/cols is provided explicitly.
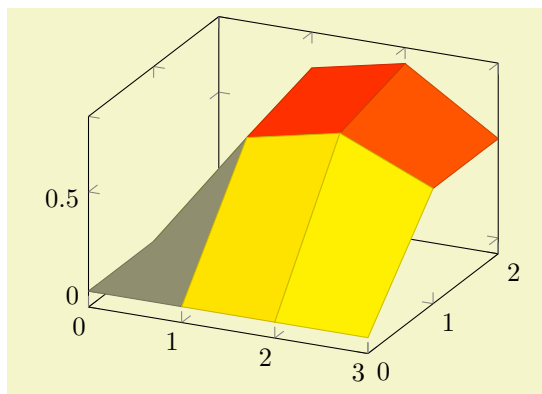

```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
    \begin{axis}
        % this yields a 3x4 matrix:
        \addplot3[surf] coordinates {
            (0,0,0) (1,0,0)   (2,0,0)   (3,0,0)

            (0,1,0) (1,1,0.6) (2,1,0.7) (3,1,0.5)

            (0,2,0) (1,2,0.7) (2,2,0.8) (3,2,0.5)
        };
    \end{axis}
\end{tikzpicture}
```

Here, \addplot3 reads a matrix with three rows and four columns. The empty lines separate one row from the following.

As for the two–dimensional plot coordinates, it is possible to provide (constant) mathematical expressions inside of single coordinates. The syntax (⟨*x*⟩,⟨*y*⟩,⟨*z*⟩) [⟨*meta*⟩] can be used just as for two dimensional plot coordinates to provide explicit color data; error bars are also supported.

\addplot3 table [⟨*column selection*⟩]{⟨*file*⟩};
\addplot3[⟨*options*⟩] table [⟨*column selection*⟩]{⟨*file*⟩} ⟨*trailing path commands*⟩;

The \addplot3 table input works in the same way as its two dimensional counterpart \addplot table. It only expects a column for the *z* coordinates.

As for \addplot3 coordinates, an empty line in the file marks the end of one matrix row.

For matrix data in files, it is important to specify the ordering in which the matrix entries have been written. The default configuration is mesh/ordering=x varies, so you need to change it to mesh/ordering=y varies in case you have columnwise ordering.
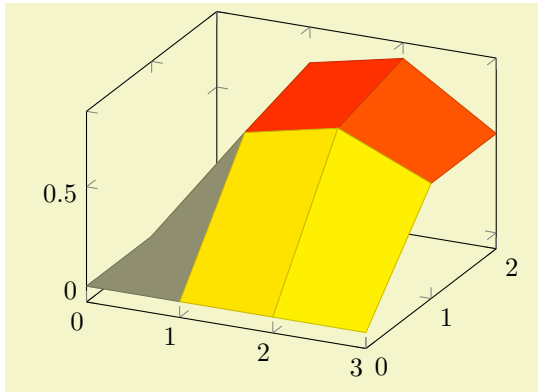
```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
    \begin{axis}
    % this yields a 3x4 matrix:
    \addplot3[surf] table {
        0 0 0
        1 0 0
        2 0 0
        3 0 0

        0 1 0
        1 1 0.6
        2 1 0.7
        3 1 0.5

        0 2 0
        1 2 0.7
        2 2 0.8
        3 2 0.5
        };
    \end{axis}
\end{tikzpicture}
```

\addplot3 file {⟨name⟩};
\addplot3[⟨options⟩] file {⟨name⟩} ⟨trailing path commands⟩;

Deprecation note: If you have data files, you should generally use \addplot table. The input type \addplot file is almost the same, but considerably less powerful. It is only kept for backwards compatibility.

The \addplot3 file input method is the same as \addplot file – it only expects one more coordinate. Thus, the input file contains x_i in the first column, y_i in the second column and z_i in the third.

A further column is read after z_i if point meta=explicit has been requested, see the documentation of \addplot file on page 73 for details.

As for \addplot3 coordinates, an empty line in the file marks the end of one matrix row.
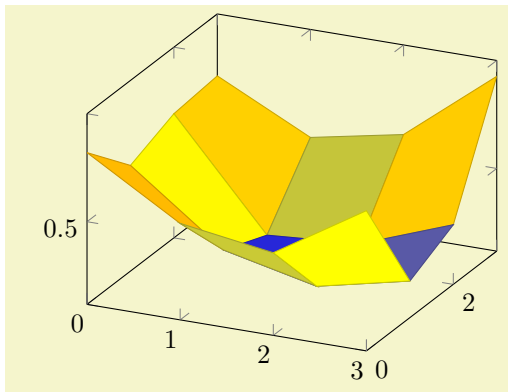

```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
    \begin{axis}
        % We have 'plotdata/first3d.dat' with
        %---------
        % 0 0 0.8
        % 1 0 0.56
        % 2 0 0.5
        % 3 0 0.75
        %
        % 0 1 0.6
        % 1 1 0.3
        % 2 1 0.21
        % 3 1 0.3
        %
        % 0 2 0.68
        % 1 2 0.22
        % 2 2 0.25
        % 3 2 0.4
        %
        % 0 3 0.7
        % 1 3 0.5
        % 2 3 0.58
        % 3 3 0.9
        % -> yields a 4x4 matrix:
        \addplot3[surf] file {plotdata/first3d.dat};
    \end{axis}
\end{tikzpicture}
```

For matrix data in files, it is important to specify the ordering in which the matrix entries have been written. The default configuration is mesh/ordering=x varies, so you need to change it to mesh/ordering=y varies in case you have columnwise ordering.

/pgfplots/mesh/rows={⟨*integer*⟩}
/pgfplots/mesh/cols={⟨*integer*⟩}

For visualization of mesh or surface plots which need some sort of matrix input, the dimensions of the input matrix need to be known in order to visualize the plots correctly. The matrix structure may be known from end–of–row marks (`empty line`s as general end–of–scanline markers in the input stream) as has been described above.

If the matrix structure is not yet known, it is necessary to provide at least one of `mesh/rows` or `mesh/cols` where `mesh/rows` indicates the number of samples for y coordinates whereas `mesh/cols` is the number of samples used for x coordinates (see also `mesh/ordering`).

Thus, the following example is also a valid method to define an input matrix.
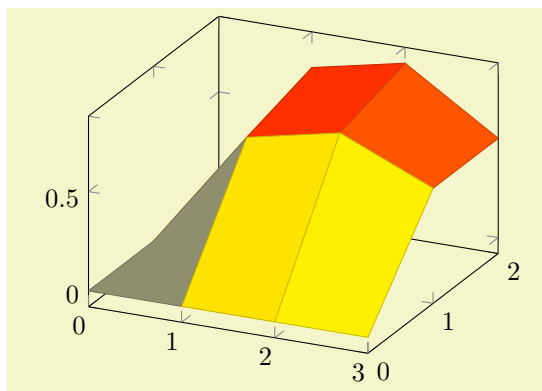
```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
    \begin{axis}
        % this yields also a 3x4 matrix:
        \addplot3[surf,mesh/rows=3] coordinates {
            (0,0,0) (1,0,0)   (2,0,0)   (3,0,0)
            (0,1,0) (1,1,0.6) (2,1,0.7) (3,1,0.5)
            (0,2,0) (1,2,0.7) (2,2,0.8) (3,2,0.5)
        };
    \end{axis}
\end{tikzpicture}
```

It is enough to supply one of `mesh/rows` or `mesh/cols` – the missing value will be determined automatically.

If you provide one of `mesh/rows` or `mesh/cols`, any end–of–row marker seen inside of input files or coordinate streams will be ignored.

/pgfplots/mesh/scanline verbose=true|false   (initially `false`)

Provides debug messages in the LaTeX output about end–of–scanline markers.

The message will tell whether end–of–scanlines have been found and if they are the same.

/pgfplots/mesh/ordering=x varies|y varies|rowwise|colwise   (initially `x varies`)

Allows to configure the sequence in which matrices (meshes) are read from `\addplot3 coordinates`, `\addplot3 file` or `\addplot3 table`.

Here, `x varies` means a sequence of points where n=`mesh/cols` successive points have the y coordinate fixed. This is intuitive when you write down a function because x is horizontal and y vertical. Note that in matrix terminology, x refers to *column indices* whereas y refers to *row indices*. Thus, `x varies` is equivalent to `rowwise` ordering in this sense. This is the initial configuration.
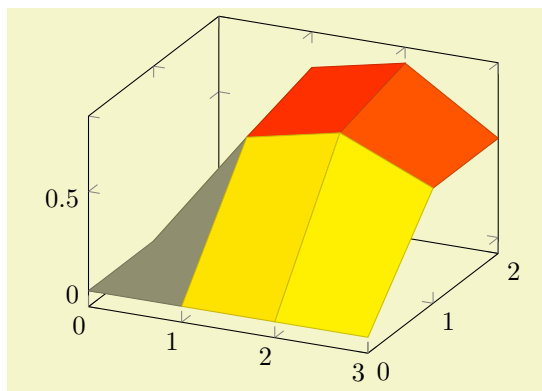
```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
\begin{axis}[mesh/ordering=x varies]
    % this yields a 3x4 matrix in 'x varies'
    % ordering:
    \addplot3[surf] coordinates {
        (0,0,0) (1,0,0)   (2,0,0)   (3,0,0)

        (0,1,0) (1,1,0.6) (2,1,0.7) (3,1,0.5)

        (0,2,0) (1,2,0.7) (2,2,0.8) (3,2,0.5)
    };
\end{axis}
\end{tikzpicture}
```

Note that `mesh/ordering` is mandatory, even though the size of the matrix can be provided in different ways. The example above uses `empty line`s to mark scanlines. One could also say `mesh/rows`=3 and omit the `empty line`s.

Consequently, `mesh/ordering`=`y varies` provides points such that successive m=`mesh/rows` points form a column, i.e. the x coordinate is fixed and the y coordinate changes. In this sense, `y varies` is equivalent to `colwise` ordering, it is actually a matrix transposition.
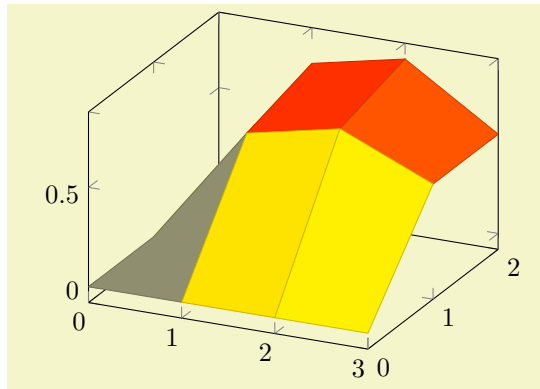

```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
\begin{axis}[mesh/ordering=y varies]
    % this yields a 3x4 matrix in colwise ordering:
    \addplot3[surf] coordinates {
        (0,0,0) (0,1,0)   (0,2,0)

        (1,0,0) (1,1,0.6) (1,2,0.7)

        (2,0,0) (2,1,0.7) (2,2,0.8)

        (3,0,0) (3,1,0.5) (3,2,0.5)
    };
\end{axis}
\end{tikzpicture}
```

Again, note the subtle difference to the common matrix indexing where a column has the second index fixed. PGFPLOTS refers to the way one would write down a function on a sheet of paper (this is consistent with how Matlab (Ⓡ) displays discrete functions with matrices).

`\addplot3 {⟨`*math expression*`⟩} ;`
`\addplot3[⟨`*options*`⟩] {⟨`*math expression*`⟩}` ⟨*trailing path commands*⟩;

Expression plotting also works in the same way as for two dimensional plots. Now, however, a two dimensional mesh is sampled instead of a single line, which may depend on `x` and `y`.

The method `\addplot3 {⟨`*math expr*`⟩}` visualizes the function $f(x, y) = ⟨$*math expr*$⟩$ where $f : [x_1, x_2] \times [y_1, y_2] \to \mathbb{R}$. The interval $[x_1, x_2]$ is determined using the `domain` key, for example using `domain`=`0:1`. The interval $[y_1, y_2]$ is determined using the `y domain` key. If `y domain` is empty, $[y_1, y_2] = [x_1, x_2]$ will be assumed. If `y domain`=`0:0` (or any other interval of length zero), it is assumed that the plot does not depend on `y` (thus, it is a line plot).

The number of samples in x direction is set using the `samples` key. The number of samples in y direction is set using the `samples y` key. If `samples y` is not set, the same value as for x is used. If `samples y` ≤ 1, it is assumed that the plot does not depend on `y` (meaning it is a line plot).
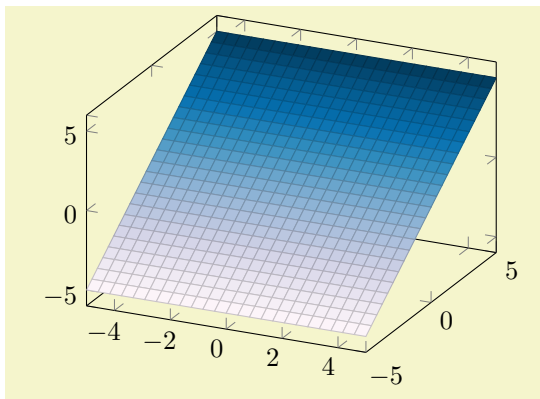

```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
% requires \usepgfplotslibrary{colorbrewer}
\begin{tikzpicture}
    \begin{axis}[colormap/PuBu]
        \addplot3[surf] {y};
    \end{axis}
\end{tikzpicture}
```
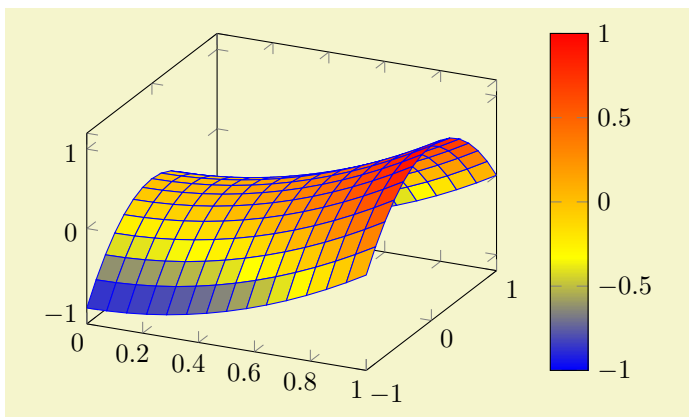
```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
    \begin{axis}[colorbar]
        \addplot3
            [surf,faceted color=blue,
             samples=15,
             domain=0:1,y domain=-1:1]
            {x^2 - y^2};
    \end{axis}
\end{tikzpicture}
```

Expression plotting sets mesh/rows and mesh/cols automatically; these settings don't have any effect for expression plotting.

\addplot3 expression {⟨*math expression*⟩};
\addplot3[⟨*options*⟩] expression {⟨*math expression*⟩} ⟨*trailing path commands*⟩;

The syntax

\addplot3 {⟨*math expression*⟩};

as short-hand equivalent for

\addplot3 expression {⟨*math expression*⟩};

\addplot3 (⟨*x expression*⟩,⟨*y expression*⟩,⟨*z expression*⟩) ;
\addplot3[⟨*options*⟩] (⟨*x expression*⟩,⟨*y expression*⟩,⟨*z expression*⟩) ⟨*trailing path commands*⟩;

A variant of \addplot3 expression which allows to provide different coordinate expressions for the x, y and z coordinates. This can be used to generate parametrized plots.

Please note that \addplot3 (x,y,x^2) is equivalent to \addplot3 expression {x^2}.

Note further that since the complete point expression is surrounded by round braces, round braces inside of ⟨*x expression*⟩, ⟨*y expression*⟩ or ⟨*z expression*⟩ need to be treated specially. Surround the expressions (which contain round braces) with curly braces:

\addplot3 ({⟨*x expr*⟩}, {⟨*y expr*⟩}, {⟨*z expr*⟩});

4.6.3 Line Plots

Three dimensional line plots are generated if the input source has no matrix structure. Line plots take the input coordinates and connect them in the order of appearance.
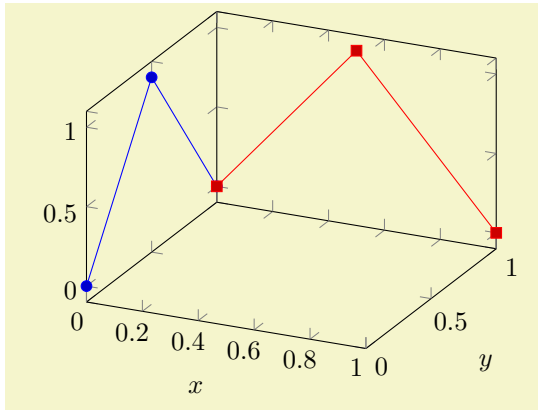
```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
    \begin{axis}[xlabel=$x$,ylabel=$y$]
    \addplot3 coordinates {(0,0,0) (0,0.5,1) (0,1,0)};
    \addplot3 coordinates {(0,1,0) (0.5,1,1) (1,1,0)};
    \end{axis}
\end{tikzpicture}
```

If there is no value for neither `mesh/rows` nor `mesh/cols` or if one of them is 1, PGFPLOTS will draw a line plot. This is also the case if there is no end–of–scanline marker (`empty line`) in the input stream.

For `\addplot3 expression`, this requires to set `samples y`=0 to disable the generation of a mesh.
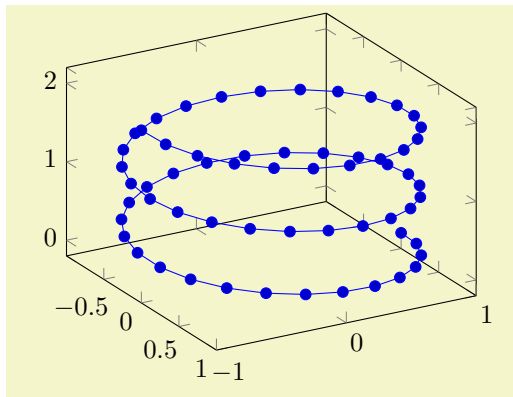

```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
\begin{axis}[view={60}{30}]
\addplot3+[domain=0:5*pi,samples=60,samples y=0]
    ({sin(deg(x))},
     {cos(deg(x))},
     {2*x/(5*pi)});
\end{axis}
\end{tikzpicture}
```

The example above is a parametric plot by expression, i.e. it has three distinct expressions for x, y, and z.

Line plots in three dimensions are also possible for data plots (tables). The most simple case is if you simply provide a series of three–dimensional coordinates which will be connected in the order of appearance:
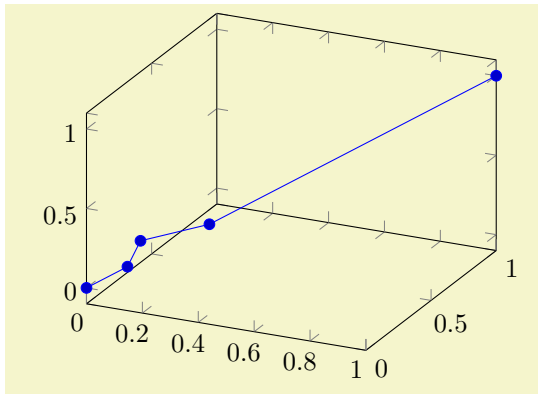

```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
\begin{axis}
\addplot3 table {
    x   y   z
    0   0   0
    0.1 0.1 0.1
    0.1 0.2 0.2
    0.3 0.3 0.3
    1   1   1
    };
\end{axis}
\end{tikzpicture}
```

Note that this plot implicitly has `mesh/rows`=1 because it has no end–of–scanline markers (`empty line`s). If in doubt, you can set `mesh/rows`=1 explicitly to tell PGFPLOTS that you have one–dimensional data (and not a matrix).

Line plots from data files are also possible if the data files only contains two coordinates – and the third should be provided somehow. In this case, the `table/x expr` feature comes into play: it allows to combine data plots and math expressions:
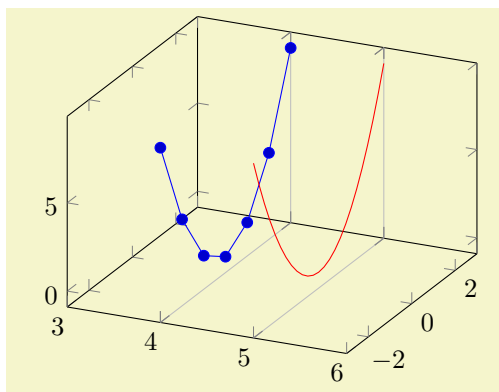
```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
\begin{axis}[
    xmin=3,xmax=6,
    extra x ticks={4,5},
    extra x tick style={xticklabel=\empty,grid=major}
]
\addplot3 table[x expr=4,y=a,z=b] {
a  b
-3 9
-2 4
-1 1
0  0
1  1
2  4
3  9
};
\addplot3[red,domain=-3:3,samples y=0] (5,x,x^2);
\end{axis}
\end{tikzpicture}
```

Here, we have two plots in one axis: one data plot from a data table with just two coordinates and one parametric plot. Both denote the same two functions. For the data plot, `x expr=4` assigns the x coordinate, and `y=a,z=b` define how the input columns map to coordinates. Again, the plot implicitly uses `mesh/rows=1` since there is no end–of–scanline marker. The second plot does the same with the short–handed notation `(5,x,x^2)`. It only samples one–dimensional data due to `samples y=0`. Finally, `extra x ticks` configures two additional ticks for the x axis; this is used to display grid lines for these specific ticks. The `xtickla-bel=\empty` argument avoids overprinted x tick labels at positions $x \in \{4,5\}$.

Three dimensional line plots will usually employ lines to connect points (i.e. the initial `sharp plot` handler of Ti*k*Z). The `smooth` method of Ti*k*Z might also prove be an option. Note that no piecewise constant plot, comb or bar plot handler is supported for three dimensional axes.

Filled Lined Plots in 3D

Closing a line plot is also possible for three–dimensional axes. This works in the same way as outlined in Section 4.5.11 for two–dimensional axes: by using `\closedcycle`.
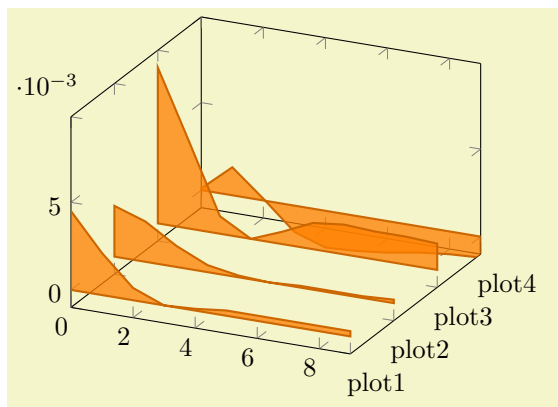

```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
\pgfplotstableread{
plot1      plot2      plot3      plot4
0.0045     0.0029     0.0089     0.0001
0.0024     0.0023     0.0050     0.0016
0.0007     0.0012     0.0010     0.0001
0.0000     0.0004     -0.0000    -0.0015
0.0001     0.0001     0.0007     -0.0021
0.0003     0.0000     0.0015     -0.0020
0.0003     0.0001     0.0017     -0.0018
0.0003     0.0001     0.0016     -0.0015
0.0003     0.0001     0.0016     -0.0013
0.0003     0.0002     0.0015     -0.0012
}\tabledata
\begin{axis}[
    zmin=-0.001,
    area plot/.style={
        fill opacity=0.75,
        draw=orange!80!black,thick,
        fill=orange,
        mark=none,
    },
    ytick={1,...,4},
    yticklabel=plot\pgfmathprintnumber{\tick},
]
\pgfplotsinvokeforeach{4,3,...,1}{
 \addplot3 [area plot] table
   [x expr=\coordindex, y expr=#1, z=plot#1]
     {\tabledata} \closedcycle;
}
\end{axis}
\end{tikzpicture}
```

The difference here is that PGFPLOTS will connect the first and last coordinates on the $z = 0$ plane, or, if $z = 0$ is outside of the axis limits, on the plane $z_{\min}$.

4.6.4 Scatter Plots

Three dimensional scatter plots have the same interface as for two dimensional scatter plots, so all examples of Section 4.5.12 can be used for the three dimensional case as well. The key features are to use `only marks` and/or `scatter` as plot styles.

We provide some more examples which are specific for the three dimensional case.

Our first example uses `only marks` to place the current plot `mark` at each input position:
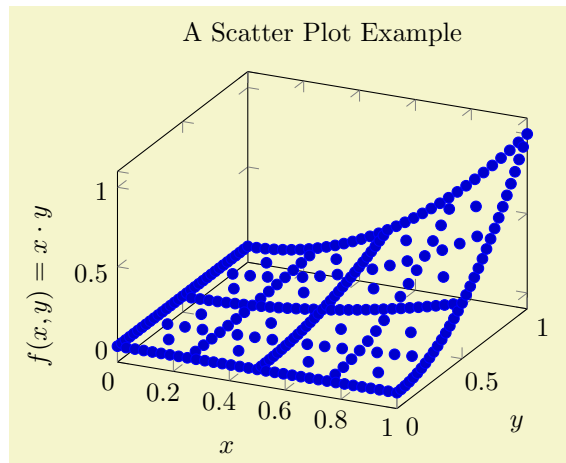

```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
    \begin{axis}[
        xlabel=$x$,
        ylabel=$y$,
        zlabel={$f(x,y) = x\cdot y$},
        title=A Scatter Plot Example]
    % 'pgfplotsexample4_grid.dat' contains a
    % large sequence of input points of the form
    % x_0     x_1       f(x)
    % 0       0         0
    % 0       0.03125   0
    % 0       0.0625    0
    % 0       0.09375   0
    % 0       0.125     0
    % 0       0.15625   0
    \addplot3+[only marks] table
        {plotdata/pgfplotsexample4_grid.dat};
    \end{axis}
\end{tikzpicture}
```

If we add the key `scatter`, the plot mark will also use the colors of the current `colormap`:
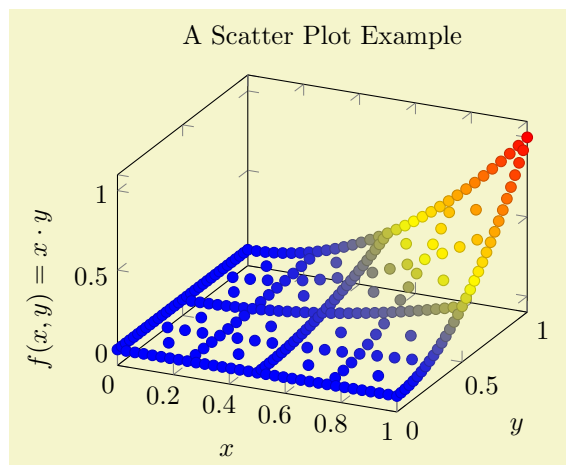

```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
    \begin{axis}[
        xlabel=$x$,
        ylabel=$y$,
        zlabel={$f(x,y) = x\cdot y$},
        title=A Scatter Plot Example]
    \addplot3+[only marks,scatter] table
        {plotdata/pgfplotsexample4_grid.dat};
    \end{axis}
\end{tikzpicture}
```

A more sophisticated example is to draw the approximated function as a `surf` plot (which requires matrix data) and the underlying grid (which is `scatter`ed data) somewhere into the same axis. We choose to place the (x, y) grid points at $z = 1.4$. Furthermore, we want the grid points to be colored according to the value of column `f(x)` in the input table:
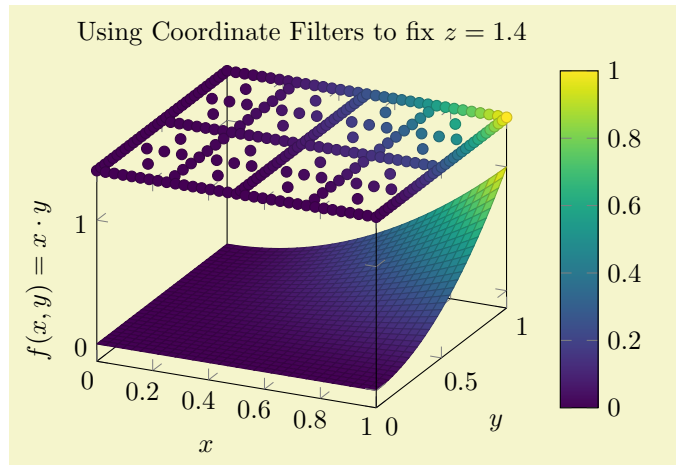
```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
    \begin{axis}[
        3d box,
        zmax=1.4,
        colormap/viridis,
        colorbar,
        xlabel=$x$,
        ylabel=$y$,
        zlabel={$f(x,y) = x\cdot y$},
        title={Using Coordinate Filters to fix $z=1.4$}]
    % 'pgfplotsexample4.dat' contains similar data as in
    % 'pgfplotsexample4_grid.dat', but it uses a uniform
    % matrix structure (same number of points in every scanline).
    % See examples above for extracts.
    \addplot3[surf,mesh/ordering=y varies]
        table {plotdata/pgfplotsexample4.dat};
    \addplot3[scatter,scatter src=\thisrow{f(x)},only marks, z filter/.code={\def\pgfmathresult{1.4}}]
        table {plotdata/pgfplotsexample4_grid.dat};
    \end{axis}
\end{tikzpicture}
```

We used `z filter` to fix the z coordinate to 1.4. We could also have used the `table/z expr`=1.4 feature

```
    \addplot3[scatter,scatter src=\thisrow{f(x)},only marks]
        table[z expr=1.4] {plotdata/pgfplotsexample4_grid.dat};
```

to get exactly the same effect. Choose whatever you like best. The `z filter` works for every coordinate input routine, the `z expr` feature is only available for `plot table`.

The following example uses `mark`=cube* and `z buffer`=sort to place boxes at each input coordinate. The color for each box is determined by `point meta`={x+y+3}. The remaining keys are just for pretty printing.
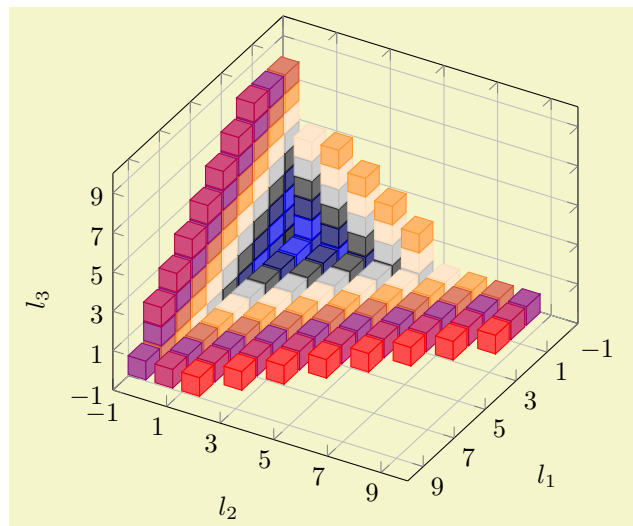
```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
\begin{axis}[
    view={120}{40},
    width=220pt,
    height=220pt,
    grid=major,
    z buffer=sort,
    xmin=-1,xmax=9,
    ymin=-1,ymax=9,
    zmin=-1,zmax=9,
    enlargelimits=upper,
    xtick={-1,1,...,19},
    ytick={-1,1,...,19},
    ztick={-1,1,...,19},
    xlabel={$l_1$},
    ylabel={$l_2$},
    zlabel={$l_3$},
    point meta={x+y+z+3},
    colormap={summap}{
        color=(black); color=(blue);
        color=(black); color=(white)
        color=(orange) color=(violet)
        color=(red)
    },
    scatter/use mapped color={
        draw=mapped color,fill=mapped color!70},
    ]
    % 'pgfplots_scatter4.dat' contains a large sequence of
    % the form
    % l_0   l_1     l_2
    % 1     6       -1
    % -1    -1      -1
    % 0     -1      -1
    % -1    0       -1
    % -1    -1      0
    % 1     -1      -1
    % 0     0       -1
    % 0     -1      0
    \addplot3[only marks,scatter,mark=cube*,mark size=7]
        table {plotdata/pgfplots_scatterdata4.dat};

\end{axis}
\end{tikzpicture}
```

4.6.5 Mesh Plots

/pgfplots/mesh   (no value)

\addplot+[mesh]

A mesh plot uses different colors for each mesh segment. The color is determined using a "color coordinate" which is also called "meta data" throughout this document. It is the same data which is used for surface and scatter plots as well, see Section 4.8.2. In the initial configuration, the "color coordinate" is the z axis (or the y axis for two dimensional plots). This color coordinate is mapped linearly into the current color map to determine the color for each mesh segment. Thus, if the smallest occurring color data is, say, -1 and the largest is 42, points with color data -1 will get the color at the lower end of the color map and points with color data 42 the color of the upper end of the color map.
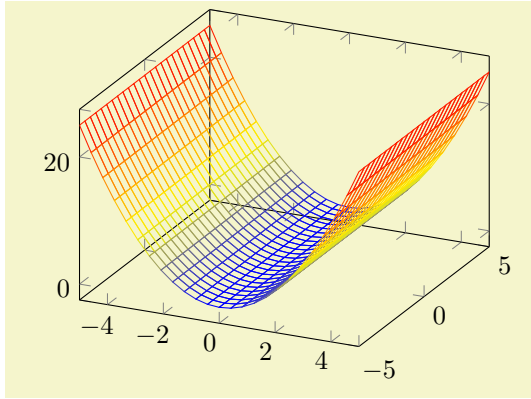
```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
    \begin{axis}
        \addplot3[mesh] {x^2};
    \end{axis}
\end{tikzpicture}
```

A mesh plot can be combined with markers or with the scatter key which also draws markers in different colors.
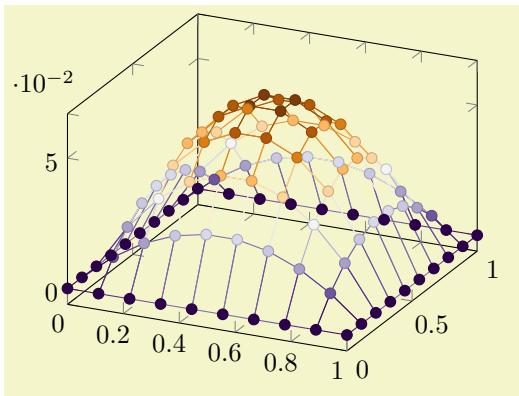

```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
% requires \usepgfplotslibrary{colorbrewer}
\begin{tikzpicture}
    \begin{axis}[colormap/PuOr]
    \addplot3+[mesh,scatter,samples=10,domain=0:1]
        {x*(1-x)*y*(1-y)};
    \end{axis}
\end{tikzpicture}
```
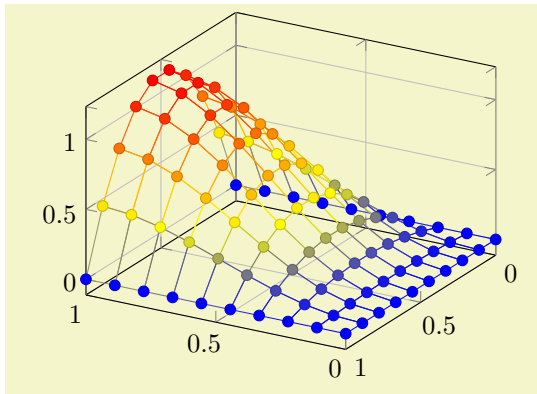


```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
    \begin{axis}[grid=major,view={210}{30}]
    \addplot3+[mesh,scatter,samples=10,domain=0:1]
        {5*x*sin(2*deg(x)) * y*(1-y)};
    \end{axis}
\end{tikzpicture}
```

Occasionally, one may want to hide the background mesh segments. This can be achieved using the surf plot handler (see below) and a specific fill color:

With background   Without background
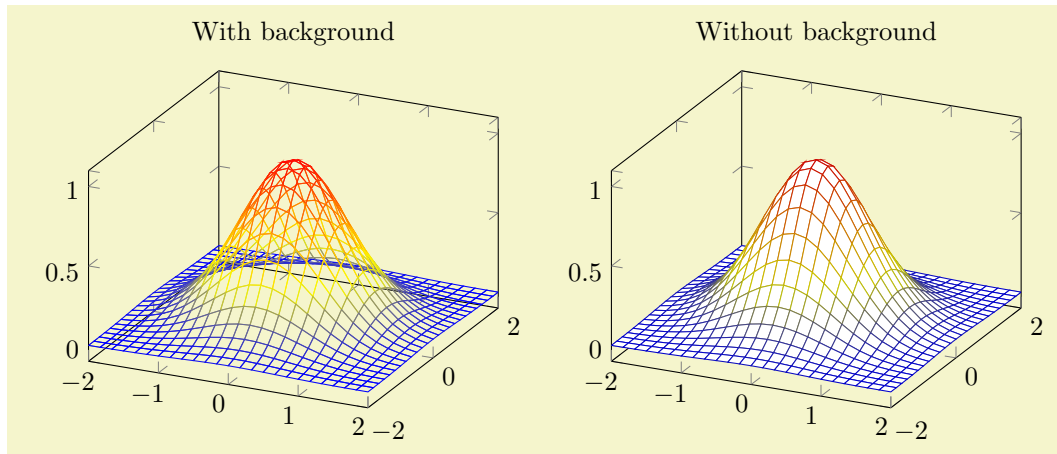

```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
    \begin{axis}[title=With background]
    \addplot3[mesh,domain=-2:2] {exp(-x^2-y^2)};
    \end{axis}
\end{tikzpicture}
\begin{tikzpicture}
    \begin{axis}[title=Without background]
    \addplot3[surf,fill=white,domain=-2:2] {exp(-x^2-y^2)};
    \end{axis}
\end{tikzpicture}
```

The fill color needs to be provided explicitly.

Details:

- A mesh plot uses the same implementation as `shader=flat` to get one color for each single segment. Thus, if `shader=flat` mean, the color for a segment is determined using the *mean* of the color data of adjacent vertices. If `shader=flat` corner, the color of a segment is the color of *the first* adjacent vertex.[21]

- As soon as `mesh` is activated, `color`=mapped color is installed. This is *necessary* unless one needs a different color – but `mapped color` is the only color which reflects the color data.

  It is possible to use a different color using the `color`=⟨*color name*⟩ as for any other plot.

- It is easily possible to add `mark`=⟨*marker name*⟩ to mesh plots, `scatter` is also possible. Scatter plots will use the same color data as for the mesh.
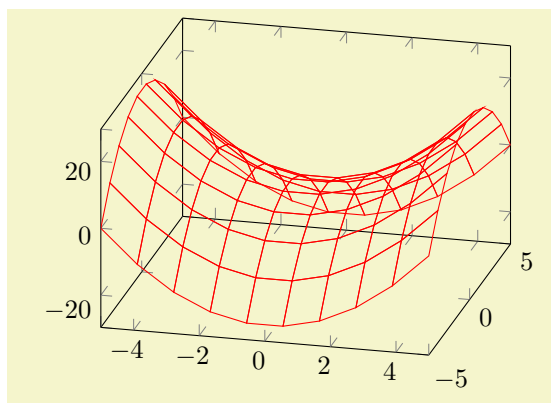

```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
    \begin{axis}[view/az=14]
    \addplot3[mesh,draw=red,samples=10] {x^2-y^2};
    \end{axis}
\end{tikzpicture}
```

Mesh plots use the `mesh legend` style to typeset legend images.

/pgfplots/mesh/check=false|warning|error   (initially error)

Allows to configure whether an error is generated if `mesh/rows` × `mesh/cols` does not equal the total number of coordinates.

---

[21]Starting with PGFPLOTS 1.13 and the associated compatibility level, this holds even in the presence of z buffering.

If you know exactly what you are doing, it may be useful to disable the check. If you are unsure, it is best to leave the initial setting.

/pgfplots/**z buffer**=default|none|auto|sort|reverse x seq|reverse y seq|reverse xy seq (initially default)

This key allows to choose between different z buffering strategies. A z buffer determines which parts of an image should be drawn in front of other parts. Since both, the graphics packages PGF and the final document format .pdf are inherently two dimensional, this work has to be done in TeX. Currently, several (fast) heuristics can be used which work reasonably well for simple mesh- and surface plots. Furthermore, there is a (time consuming) sorting method which also works if the fast heuristics fails.

The z buffering algorithms of PGFPLOTS apply only to a single \addplot command. Different \addplot commands will be drawn on top of each other, in the order of appearance.

The choice **default** checks if we are currently working with a mesh or surface plot and uses **auto** in this case. If not, it sets **z buffer**=none.

The choice **none** disables z buffering. This is also the case for two dimensional axes which don't need z buffering.

The choice **auto** is the initial value for any mesh or surface plot: it uses a very fast heuristics to decide how to execute z buffering for mesh and surface plots. The idea is to reverse either the sequence of all x coordinates, or those of all y coordinates, or both. For regular meshes, this suffices to provide z buffering. In other words: the choice **auto** will use one of the three reverse strategies **reverse * seq** (or none at all). The choice **auto**, applied to **patch** plots, uses **z buffer**=sort since **patch** plots have no matrix structure.

The choice **sort** can be used for scatter, line, mesh, surface and patch plots. It sorts according to the depth of each point (or mesh segment). Sorting in TeX uses a slow algorithm and may require a lot of memory (although it has the expected runtime asymptotics $\mathcal{O}(N \log N)$). The depth of a mesh segment is just *one* number, currently determined as *mean* over the vertex depths. Since **z buffer**=sort is actually just a more intelligent way of drawing mesh segments on top of each other, it may still fail. Failure can occur if mesh segments are large and overlap at different parts of the segment (see Wikipedia "Painter's algorithm"). If you experience problems of this sort, consider reducing the mesh width (the mesh element size) such that they can be sorted independently (for example automatically using **patch refines**=2, see the **patchplots** library).

The remaining choices apply only to mesh/surface plots (i.e. for matrix data) and do nothing more then their name indicates: they reverse the coordinate sequences of the input matrix (using quasi linear runtime). They should only be used in conjunction by **z buffer**=auto.

4.6.6   Surface Plots

/pgfplots/**surf**   (no value)

\addplot+[**surf**]

A surface plot visualizes a two dimensional, single patch using different fill colors for each patch segment. Each patch segment is a (pseudo) rectangle, that means input data is given in form of a data matrix as is discussed in the introductory section about three dimensional coordinates, 4.6.2.
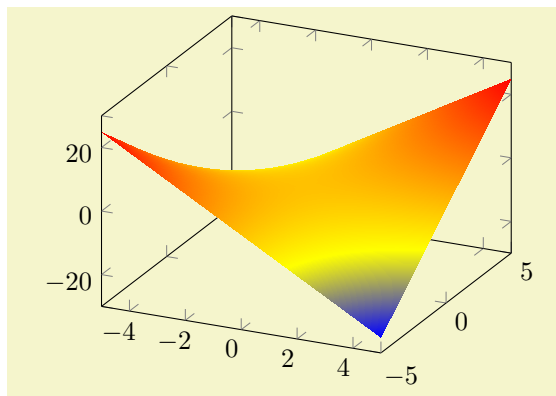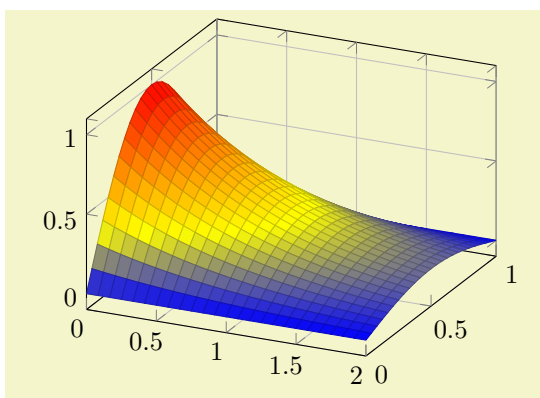


```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
    \begin{axis}
        \addplot3[surf,shader=interp] {x*y};
    \end{axis}
\end{tikzpicture}
```

The simplest way to generate surface plots is to use the plot expression feature, but – as discussed in Section 4.6.2 – other input methods like `\addplot3 table` or `\addplot3 coordinates` are also possible.

The appearance can be configured using `colormap`s, the value of the `shader`, `faceted color` keys and the current `color` and/or `draw`/`fill` color. As for `mesh` plots, the special `color`=mapped `color` is installed for the faces. The stroking color for faceted plots can be set with `faceted color` (see below for details).
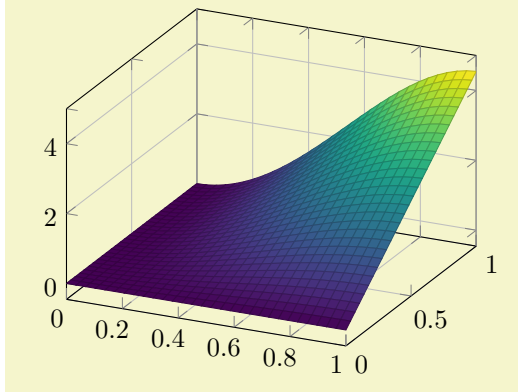

```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
    \begin{axis}[
        grid=major,
        colormap/viridis]
    \addplot3[surf,samples=30,domain=0:1]
        {5*x*sin(2*deg(x)) * y};
    \end{axis}
\end{tikzpicture}
```
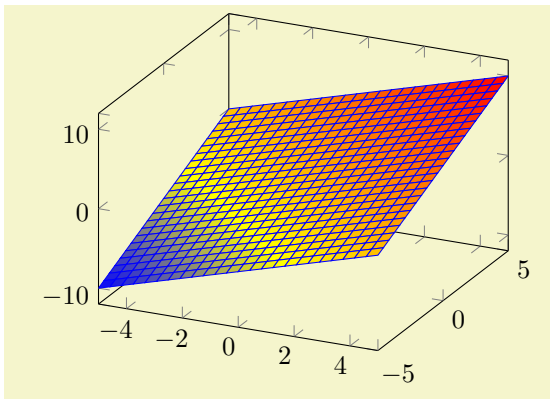


```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
    \begin{axis}
        \addplot3[surf,faceted color=blue] {x+y};
    \end{axis}
\end{tikzpicture}
```
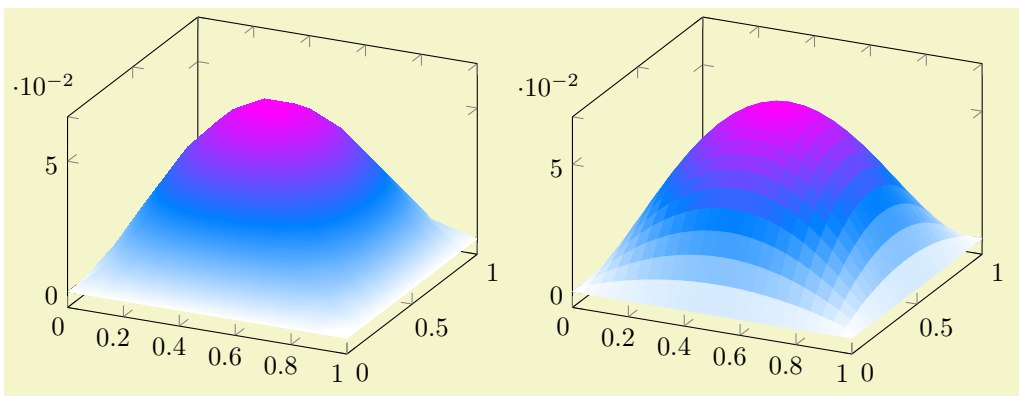


```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
    \begin{axis}[colormap/cool]
    \addplot3[surf,samples=10,domain=0:1,
        shader=interp]
        {x*(1-x)*y*(1-y)};
    \end{axis}
\end{tikzpicture}
\begin{tikzpicture}
    \begin{axis}[colormap/cool]
    \addplot3[surf,samples=25,domain=0:1,
        shader=flat]
        {x*(1-x)*y*(1-y)};
    \end{axis}
\end{tikzpicture}
```
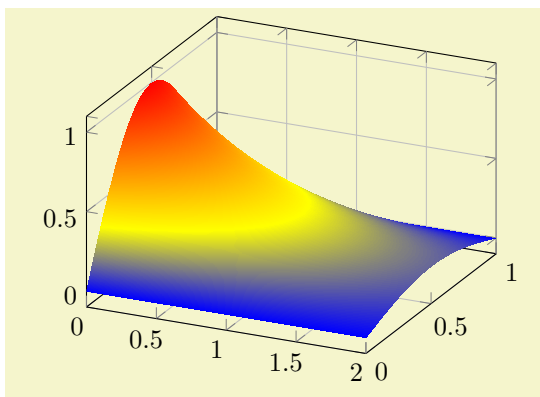
```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
    \begin{axis}[grid=major]
        \addplot3[surf,shader=interp,
            samples=25,domain=0:2,y domain=0:1]
            {exp(-x) * sin(pi*deg(y))};
    \end{axis}
\end{tikzpicture}
```



```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
    \begin{axis}[grid=major]
        \addplot3[surf,shader=faceted,
            samples=25,domain=0:2,y domain=0:1]
            {exp(-x) * sin(pi*deg(y))};
    \end{axis}
\end{tikzpicture}
```

Details about the shading algorithm are provided below in the documentation of `shader`.

Surface plots use the `mesh legend` style to create legend images.

/pgfplots/**shader**=flat|interp|faceted|flat corner|flat mean|faceted interp   (initially `faceted`)

Configures the shader used for surface plots. The shader determines how the color data available at each single vertex is used to fill the surface patch.

The simplest choice is to use one fill color for each segment, the choice `flat`.
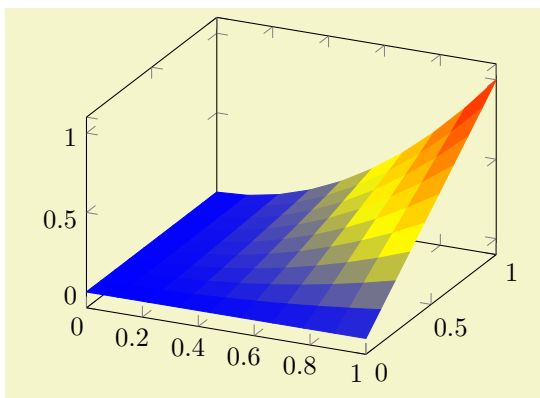

```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
    \begin{axis}
    \addplot3[surf,shader=flat,
        samples=10,domain=0:1]
        {x^2*y};
    \end{axis}
\end{tikzpicture}
```

There are (currently) two possibilities to determine the single color for every segment:

flat corner Uses the color data of one vertex to color the segment. The color of the *first* vertex determines the color of the entire segment. Note that PGFPLOTS ensures that the outcome is always the same, even if the vertices are reordered due to `z buffer`ing or `mesh/ordering`.

Note that PGFPLOTS versions up to and including 1.12 chose one of them without respecting reordering. In order to have the ordering independent of other features, you have to write `compat=1.13` or newer.

flat mean Uses the mean of all four color data values as segment color. This is the initial value as it provides symmetric colors for symmetric functions.

The choice `flat` is actually the same as `flat mean`. Please note that shader=`flat mean` and shader=`flat corner` also influence mesh plots – the choices determine the mesh segment color.

Another choice is shader=`interp` which uses Goraud shading (smooth linear interpolation of two triangles approximating rectangles) to fill the segments.
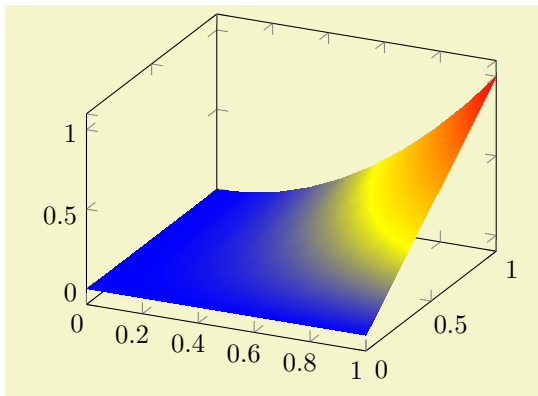

```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
    \begin{axis}
    \addplot3[surf,shader=interp,
        samples=10,domain=0:1]
        {x^2*y};
    \end{axis}
\end{tikzpicture}
```

The shader=`interp` employs a low–level shading implementation which is currently available for the following drivers:

- the postscript driver \def\pgfsysdriver{pgfsys-dvips.def},

- the `pdflatex` driver \def\pgfsysdriver{pgfsys-pdftex.def},

- the `lualatex` driver \def\pgfsysdriver{pgfsys-pdftex.def} and \def\pgfsysdriver{pgfsys-luatex.def},

- the `dvipdfmx` driver \def\pgfsysdriver{pgfsys-dvipdfmx.def}.

For other drivers, the choice shader=`interp` will result in a warning and is equivalent to shader=`flat mean`. See also below for detail remarks.

Note that shader=`interp`,`patch type`=`bilinear` allows real bilinear interpolation, see the `patchplots` library.

The choice shader=`faceted` uses a constant fill color for every mesh segment (as for `flat`) and the value of the key `/pgfplots/faceted color` to draw the connecting mesh elements:
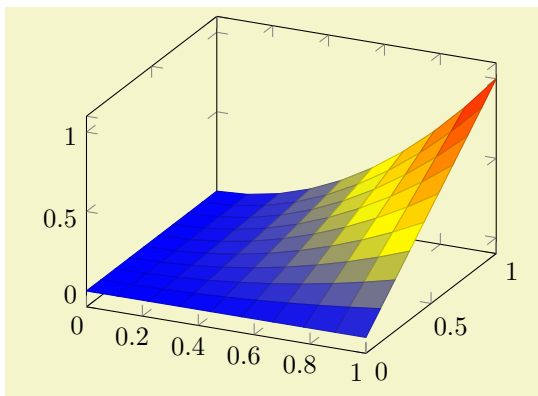

```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
    \begin{axis}
    \addplot3[surf,shader=faceted,
        samples=10,domain=0:1]
        {x^2*y};
    \end{axis}
\end{tikzpicture}
```

The last choice is shader=`faceted interp`. As the name suggests, it is a mixture of `interp` and `faceted` in the sense that each element is shaded using linear triangle interpolation (see also the `patchplots` library for bilinear interpolation) in the same way as for `interp`, but additionally, the edges are colored in `faceted color`:
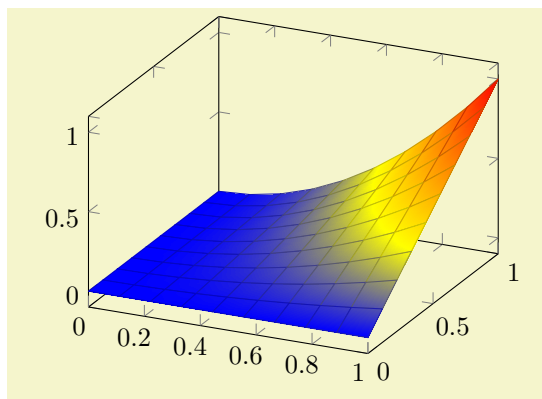
```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
    \begin{axis}
    \addplot3[surf,shader=faceted interp,
        samples=10,domain=0:1]
        {x^2*y};
    \end{axis}
\end{tikzpicture}
```

In principle, there is nothing wrong with the idea as such, and it looks quite good – but it enlarges the resulting pdf document considerably and might take a long time to render. It works as follows: for every mesh element (either triangle for `patch` plots or rectangle for lattice plots), it creates a low level shading. It then fills the single mesh element with that shading, and strokes the edges with `faceted color`. The declaration of that many low level shadings is rather inefficient in terms of pdf objects (large output files) and might render slowly[22]. For orthogonal plots (like `view`={0}{90}), the effect of `faceted interp` can be gained with less cost if one uses two separate `\addplot` commands: one with `surf` and one with `mesh`. Handle this choice with care.

Details:

- All shaders support `z buffer`=sort (starting with version 1.4)

- The choice `shader`=faceted is the same as `shader`=flat – except that it uses a special draw color. So, `shader`=faceted has the same effect as

  `shader`=flat,`draw`=\pgfkeysvalueof{/pgfplots/faceted color}.

- The `flat` shader uses the current `draw` and `fill` colors. They are set with `color`=mapped color and can be overruled with `draw`=⟨draw color⟩ and `fill`=⟨fill color⟩. The `mapped color` always contains the color of the color map.

- You easily add `mark`=⟨plot mark⟩ to mesh and/or surface plots or even colored plot marks with `scatter`. The scatter plot feature will use the same color data as for the surface.

  But: Markers and surfaces do not share the same depth information. They are drawn on top of each other.

- Remarks on `shader`=interp:

  - It uses the current color map in any case, ignoring `draw` and `fill`.

  - For surface plots with lots of points, `shader`=interp produces smaller `pdf` documents, requires less compilation time in TEX and requires less time to display in Acrobat Reader than `shader`=flat.

  - The postscript driver *truncates* coordinates to 24 bit – which might result in a loss of precision (the truncation is not very intelligent). See the `surf shading/precision` key for details. To improve compatibility, this 24 bit truncation algorithm is enabled by default also for pdf documents.

  - The choice `shader`=interp works well with either Acrobat Reader or recent versions of free viewers[23]. However, some free viewers show colors incorrectly (like evince). I hope this message will soon become outdated... if not, provide bug reports to the Linux community to communicate the need to improve support for Type 4 (`patch`) and Type 5 pdf (`surf`) and Type 7 (`patch` and elements of the `patchplots` library) shadings.

  - The `interp` shader yields the same outcome as `faceted interp`,`faceted color`=none, although `faceted interp` requires much more ressources.

---

[22]My experience is as follows: Acrobat reader can efficiently render huge `interp` shadings. But it is very slow for `faceted interp` shadings. Linux viewers like xpdf are reasonably efficient for `interp` (at least with my bugfixes to libpoppler) and are also fast for `faceted interp` shadings.

[23]The author of this package has submitted bugfixes to xpdf/libpoppler which should be part of the current stable versions of many viewers.
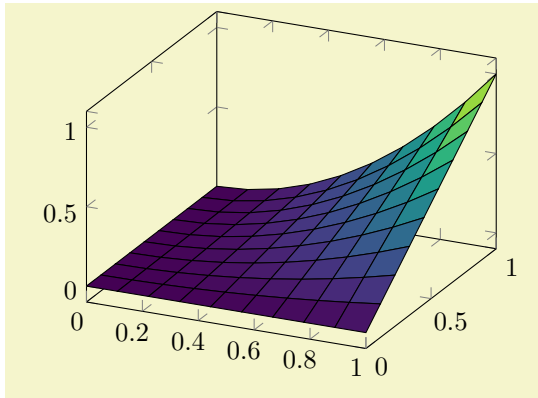
```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
    \begin{axis}[colormap/viridis]
    \addplot3[surf,shader=flat,
        draw=black,
        samples=10,domain=0:1]
        {x^2*y};
    \end{axis}
\end{tikzpicture}
```
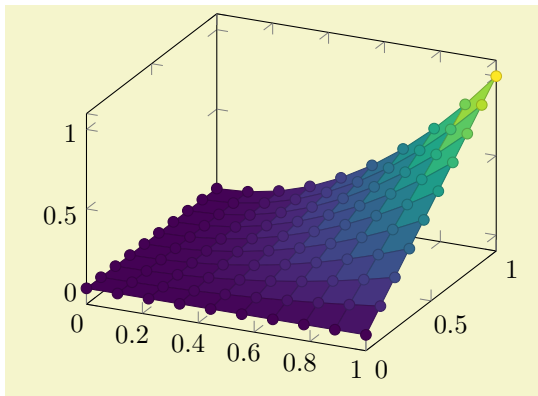


```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
    \begin{axis}[colormap/viridis]
    \addplot3[surf,shader=faceted,
        scatter,mark=*,
        samples=10,domain=0:1]
        {x^2*y};
    \end{axis}
\end{tikzpicture}
```

Note that the `shader` always interacts with `colormap access`. In particular, `colormap access`=piece-wise constant combined with `shader`=`interp` results in a filled contour plot, see Section 4.6.9 for details.

/pgfplots/faceted color={⟨*color name*⟩}   (initially `mapped color!80!black`)

Defines the color to be used for meshes of faceted surface plots.

Set `faceted color`=`none` to disable edge colors.

/pgfplots/mesh/interior colormap={⟨*map name*⟩}{⟨*colormap specification*⟩}
/pgfplots/mesh/interior colormap name={⟨*map name*⟩}

Allows to use a different `colormap` for the "other side" of the surface.

Each mesh has two sides: one which "points" to the view's origin and one which points away from it. This key allows to define a second `colormap` for the side which points away from the view's origin. The motivation is to distinguish between the outer side and the interior parts of a surface:
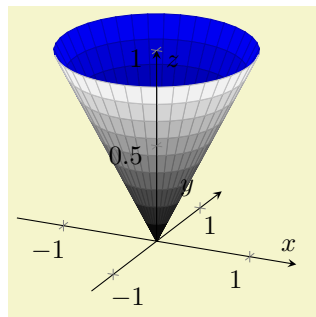

```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
\begin{axis}[
  axis lines=center,
  axis on top,
  xlabel={$x$}, ylabel={$y$}, zlabel={$z$},
  domain=0:1,
  y domain=0:2*pi,
  xmin=-1.5, xmax=1.5,
  ymin=-1.5, ymax=1.5, zmin=0.0,
  mesh/interior colormap=
      {blueblack}{color=(black) color=(blue)},
  colormap/blackwhite,
  samples=10,
  samples y=40,
  z buffer=sort,
 ]
  \addplot3[surf]
      ({x*cos(deg(y))},{x*sin(deg(y))},{x});
\end{axis}
\end{tikzpicture}
```

The `interior colormap` is often the one for the "'inner side". However, the orientation of the surface depends on its normal vectors: PGFPLOTS computes them using the right-hand-rule. The right-hand-rule applied to a triangle means to take the first encountered point, point the thumb in direction of the second point and the first finger in direction of the third point. Then, the normal for that triangle is the third finger (i.e. the cross–product of the involved oriented edges). For rectangular patches, PGFPLOTS uses the normal of one of its triangles[24]. Consequently, `mesh/interior colormap` will only work if the involved patch segments are consistently oriented.

A patch whose normal vector points into the same direction as the view direction uses the standard `colormap name`. A patch whose normal vector points into the opposite direction (i.e. in direction of the viewport) uses `mesh/interior colormap`.
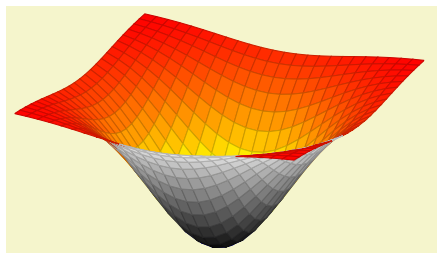

```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
\begin{axis}[
    hide axis,
    xlabel=$x$,ylabel=$y$,
    mesh/interior colormap name=hot,
    colormap/blackwhite,
]
  \addplot3[domain=-1.5:1.5,surf]
    {-exp(-x^2-y^2)};
\end{axis}
\end{tikzpicture}
```

The implementation of `mesh/interior colormap` works well for most examples; in particular, if the number of samples is large enough to resolve the boundary between inner and outer colormap. However, it might still produce spurious artifacts:
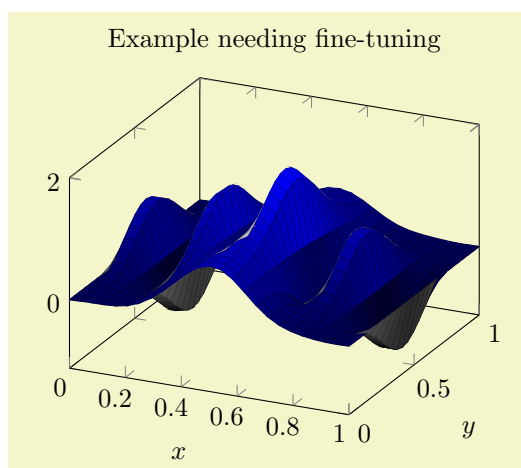

```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
\begin{axis}[
    title=Example needing fine-tuning,
    xlabel=$x$,
    ylabel=$y$]
\addplot3[surf,
  mesh/interior colormap=
    {blueblack}{color=(black) color=(blue)},
  colormap/blackwhite,
  domain=0:1]
    {sin(deg(8*pi*x))* exp(-20*(y-0.5)^2)
    + exp(-(x-0.5)^2*30
        - (y-0.25)^2 - (x-0.5)*(y-0.25))};
\end{axis}
\end{tikzpicture}
```

The previous example has need for improvement with respect to a couple of aspects: first, it has small overshoots near some of the meshes vertices (especially on top of the hills). These can be fixed using `miter limit`=1. Second, the boundary between blue and black is incorrect. This can be improved by means of an increased sampling density (`samples`=31). In addition, we can configure PGFPLOTS to move the boundary between the two colormaps in favor of the blue region using `mesh/interior colormap thresh` as follows:

---

[24]This may change in future versions.

Example of before with fine-tuning
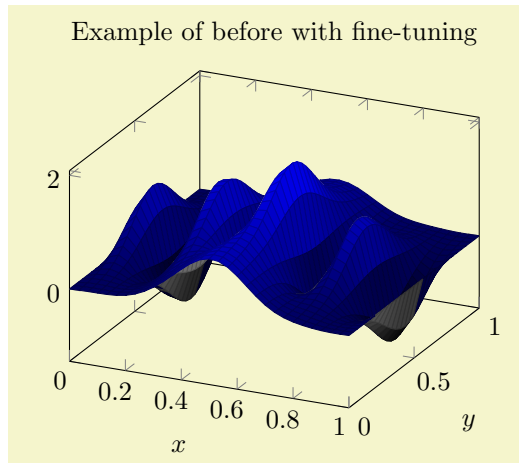
```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
\begin{axis}[
    title=Example of before with fine-tuning,
    xlabel=$x$,
    ylabel=$y$]
\addplot3[surf,
  mesh/interior colormap=
    {blueblack}{color=(black) color=(blue)},
  % slightly increase sampling quality (was 25):
  samples=31,
  % avoids overshooting corners:
  miter limit=1,
  % move boundary between inner and outer:
  mesh/interior colormap thresh=0.1,
  colormap/blackwhite,
  domain=0:1]
    {sin(deg(8*pi*x))* exp(-20*(y-0.5)^2)
    + exp(-(x-0.5)^2*30
        - (y-0.25)^2 - (x-0.5)*(y-0.25))};
\end{axis}
\end{tikzpicture}
```

This improves the display.

Call for volunteers: it would be nice if the fine–tuning of these keys would be unnecessary. If someone has well–founded suggestions (like knowledge and perhaps exhaustive experiments) on how to improve the feature, let me know.

Note that mesh/interior colormap cannot be combined with mesh/refines currently.

Note that mesh/interior colormap will increase compilation times due to the computation of normal vectors.

/pgfplots/**mesh/interior colormap thresh**={⟨*Number between* −1.0 *and* +1.0⟩}   (initially 0)

A threshold which moves the boundary between the colormap and interior colormap in favor of colormap (if the value is negative) or in favor of interior colormap (if the value is positive).

The extreme value −1 essentially deactivates interior colormap whereas the other extreme +1 deactivates colormap.

See above for an example.

/pgfplots/**surf shading/precision**=pdf|postscript|ps   (initially postscript)

A key to configure how the low level driver for shader=interp writes its data. The choice pdf uses 32 bit binary coordinates (which is lossless). The resulting .pdf files appear to be correct, but they can't be converted to postscript – the converter software always complains about an error.

The choice postscript (or, in short, ps) uses 24 bit truncated binary coordinates. This results in both, readable .ps and .pdf files. However, the truncation is lossy.

If anyone has ideas how to fix this problem: let me know. As far as I know, Postscript should accept 32 bit coordinates, so it might be a mistake in the shading driver.

4.6.7 Surface Plots with Explicit Color

The surface plots described in Section 4.6.6 are all based on colormaps. This section introduces a different type of surface plot. In fact, it uses the very same plot handlers: it applies to mesh, surf, and patch plots. However, the way colors are provided and the way PGFPLOTS interpolates colors is substantially different.

This section describes surface plots with explicit colors. These expect colors like red, green, or rgb=(0.5,0.2,1) for every vertex of the mesh – and interpolates smoothly between these vertices. This appears to be simpler, perhaps even more straight-forward than surface plots based on colormaps. It is not. Surface plots with explicit color are more difficult to define, and they are more difficult to read.

If you are in doubt of whether to use a surface colored by a colormap or explicit colors, you should prefer colormaps for reasons discussed below.

/pgfplots/**mesh/color input**=colormap|explicit|explicit mathparse   (initially colormap)

Allows to configure how PGFPLOTS expects color input for surface plots.

The choice `colormap` uses the standard colormaps. This particular choice expects scalar values of `point meta` which are mapped linearly into the colormap. It resembles the surface plots which are explained in more detail in Section 4.6.6. It is the default configuration and covers (probably) most common use–cases.

The choice `explicit` expects explicitly provided `point meta` of symbolic form: every coordinate of your input coordinate stream is supposed to have an explicitly defined color as `point meta`. Here, "explicitly provided" refers to `point meta`=explicit symbolic. This choice and the available color formats are explained in all detail in the following sub–sections.

The choice `explicit mathparse` is similar to `explicit`, but it allows to provide just one math expression which is evaluated for every coordinate. The math expression can be of the form `rgb`=x,y,0.5 in which case `x` is used to define the "red" component, `y` is used to define the "green" component and the "blue" component is fixed to 0.5. This key is also explained in more detail in the following sub–sections.

The main use–case of `mesh/color input`=`colormap` is to allow a map between the interpolated colors and some value of interest. This map can be shown as `colorbar`:

```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
% \usepgfplotslibrary{patchplots}
\begin{tikzpicture}
    \begin{axis}[small,view={0}{90}, colorbar]
    \addplot3[surf,shader=interp,patch type=bilinear]
    coordinates {
        (0,0,0) (1,0,0)

        (0,1,0) (1,1,1)
    };
    \end{axis}
\end{tikzpicture}
```
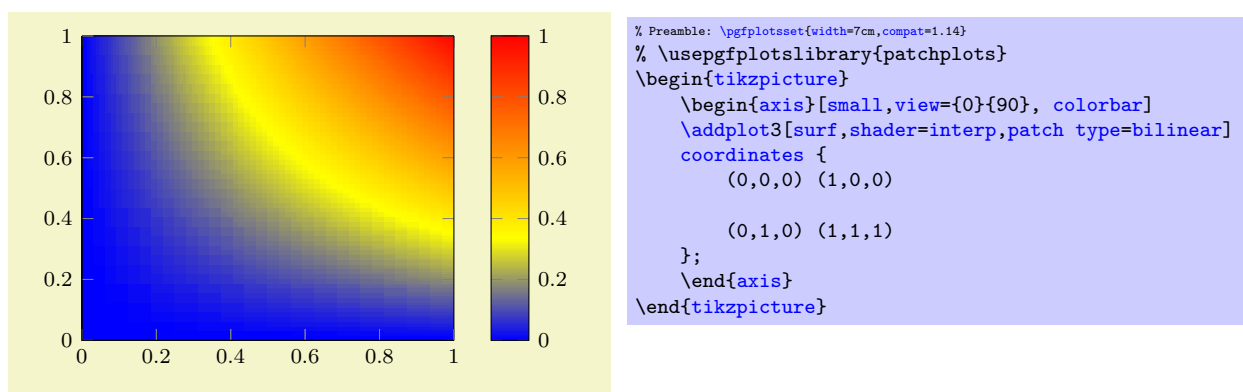
Note that the preceding example is a standard `surf` plot except for `patch type`=`bilinear` which controls how color is to be interpolated. There is a 2×2 matrix, and its z values are used as color data. Clearly, value $z = 0$ corresponds to blue and $z = 1$ corresponds to red – and all other colors in–between are not directly related to blue and red; they are taken from the colormap. The colormap defines which colors appear: those which make up the colormap and those which can occur as interpolated colors between the colors of the color map. The pairwise mixture of colors is a property of `mesh/color input`=`colormap`, not of `mesh/color input`=`explicit` (where more than two colors are mixed together). Furthermore, the surface indicates contours of constant z level. Take, for example, the yellow contour. We know that it has some value between 0.3 and 0.4, say 0.35. Since these shadings are continuous, we know that the point $z = 0.35$ occurs between $z = 0$ and $z = 1$ – at every point of the surface. Due to the colormap, each point on the surface which has $z = 0.35$ will receive the yellow color. This is because the interpolation is carried out on the scalar `point meta` value, which is afterwards mapped into the `colormap`. This contour–property is also unique for colormap surfaces.

The other two choices are explained in all detail in the next sub–sections.

Providing Colors Explicitly For Each Coordinate

Here is a simple approach with the same vertices as the colormap–example above, but with explicit colors:
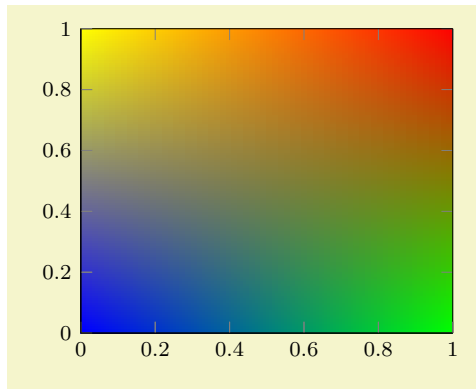
```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
% \usepgfplotslibrary{patchplots}
\begin{tikzpicture}
    \begin{axis}[small,view={0}{90}]
    \addplot3[surf,shader=interp,patch type=bilinear,
        mesh/color input=explicit]
    coordinates {
        (0,0,0) [color=blue] (1,0,0) [color=green]

        (0,1,0) [color=yellow] (1,1,1) [color=red]
    };
    \end{axis}
\end{tikzpicture}
```

The coordinates and the view is the same, even the way colors are being interpolated bilinearly. However, we have four different colors in the corners. We see these corners in the output, and we see that they are smoothly mixed together. However, the mix contains all four colors, not just two. As a direct consequence, there are no contour lines.

The absence of direct information how to map color information to "some information of the data visualization" implies that *if* you want to use surface plots with explicit color, you have to state clearly what you want to show. This is considerably simpler for colormaps.

The following example configures $z = 0$ to receive blue and $z = 1$ to receive red as in our preceding colormap example (see above) using mesh/color input=explicit.
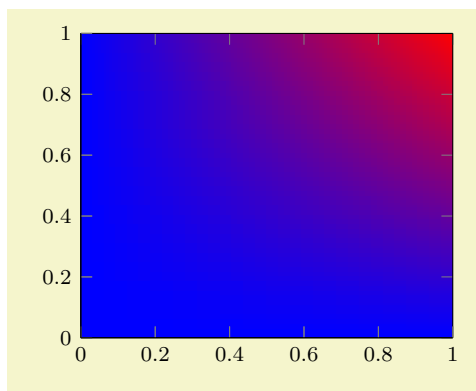

```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
% \usepgfplotslibrary{patchplots}
\begin{tikzpicture}
    \begin{axis}[small,view={0}{90}]
    \addplot3[surf,shader=interp,patch type=bilinear,
        mesh/color input=explicit]
    coordinates {
        (0,0,0) [color=blue] (1,0,0) [color=blue]

        (0,1,0) [color=blue] (1,1,1) [color=red]
    };
    \end{axis}
\end{tikzpicture}
```

We see the bilinear nature of the interpolation; it is related to that of mesh/color input=colormap above (compare the contour lines in–between). In most cases, you simply want to show some contour lines. And for such cases, a colormap is the way to go.

There might be cases where mesh/color input=explicit is adequate. However, you will need to think it through properly. And you need to explain clearly what you did because your audience will also have to think a lot before they make sense of any data visualization based on explicit color interpolation.

The choice mesh/color input=explicit expects a choice of point meta which results in symbolic values. In this context, "symbolic" refers to a special color definition:
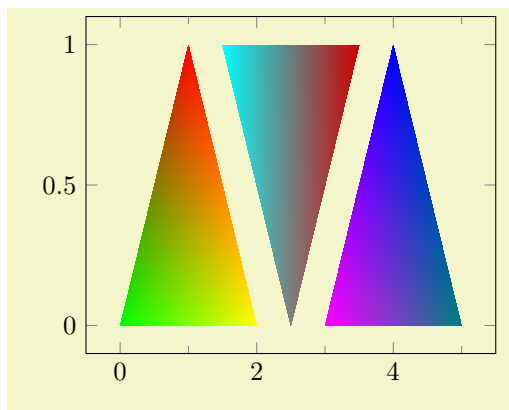
```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
\begin{axis}[minor x tick num=1]
    \addplot[
        patch,
        shader=interp,
        mesh/color input=explicit,
    ]
    table[meta=c] {
        x y c
        0 0 color=green
    % default color model is rgb:
        1 1 1,0,0
        2 0 1,1,0

        1.5 1 cmyk=1,0,0,0
        2.5 0 gray=0.5
        3.5 1 color=red!80!black

        3 0 1,0,1
        4 1 0,0,1
        5 0 rgb255=0,128,128
    };
\end{axis}
\end{tikzpicture}
```

The previous example defines a `patch` plot with three triangle patches, each made up of three vertices which are placed as–is into the input coordinate stream. Each vertex has its color data in column `c`. The format of color specifications is explained in more detail in the following paragraph.

As soon as you write `mesh/color input`=explicit, PGFPLOTS checks the current value of `point meta`. If the current value of `point meta` is `none`, it is set to `point meta`=explicit symbolic (that is what happened in our example above). If the current value of `point meta` is some choice which yields numeric output (like `point meta`=x or `point meta`=\thisrow{x}+1), it is set to `point meta`=explicit symbolic. If the current value of `point meta` is already of symbolic form, it is left unchanged.

Consequently, our example above sets `point meta`=explicit symbolic as soon as it encounters `mesh/-color input`=explicit. The explicit symbolic input handler in turn expects the coordinate stream to provide point meta data for every streamed coordinate. We use a table here, and a table reads its color data from the column name provided in the `table/meta` key.

The accepted format of colors is quite similar to that of Colormap definitions (compare Section 4.7.6 on page 192). The common format is ⟨*color model*⟩=⟨*arguments*⟩. In contrast to the similar input format inside of colormap definitions, the syntax here has no round braces and does not have the ⟨*length*⟩ argument. Nevertheless, the same ⟨*color model*⟩s with the same ⟨*arguments*⟩ are accepted. The choices are

`rgb`=⟨*red*⟩,⟨*green*⟩,⟨*blue*⟩ where each component is in the interval [0, 1],

`rgb255`=⟨*red*⟩,⟨*green*⟩,⟨*blue*⟩ is similar to `rgb` except that each component is expected in the interval [0,255],

`gray`=⟨*value*⟩ with ⟨*value*⟩ in the interval [0, 1],

`color`=⟨*named color*⟩ where ⟨*named color*⟩ is a predefined (named) color like '`red`' or a color expression like '`red!50`',

`cmyk`=⟨*cyan*⟩,⟨*magenta*⟩,⟨*yellow*⟩,⟨*black*⟩ where each component is in the interval [0, 1],

`cmyk255`=⟨*cyan*⟩,⟨*magenta*⟩,⟨*yellow*⟩,⟨*black*⟩ is the same as `cmyk` but expects components in the interval [0, 255],

`cmy`=⟨*cyan*⟩,⟨*magenta*⟩,⟨*yellow*⟩ where each component is in the interval [0, 1],

`hsb`=⟨*hue*⟩,⟨*saturation*⟩,⟨*brightness*⟩ where each component is in the interval [0, 1],

`Hsb`=⟨*hue*⟩,⟨*saturation*⟩,⟨*brightness*⟩ is the same as `hsb` except that ⟨*hue*⟩ is accepted in the interval [0, 360] (degree),

`HTML`=⟨*hex red*⟩⟨*hex green*⟩⟨*hex blue*⟩ where component is expected to be a hex number between 00 and FF (a variant of `rgb255`),

`wave`=⟨*wave length*⟩ which expects a single wave length as numeric argument in the range [363, 814].

/pgfplots/mesh/colorspace explicit color input=rgb|rgb255|cmy|cmyk|cmyk255|gray|wave|hsb
|Hsb|HTML   (initially rgb)

If the input color has *no color model*, the color components are interpreted as color in the color model specified as argument to this key.

This key has just one purpose: to omit the ⟨*color model*⟩ if it is the same for lots of points anyway.

/pgfplots/mesh/colorspace explicit color output=rgb|cmyk|gray   (initially rgb)

Any color which is encountered by the survey phase (i.e. while inspecting the point meta value) is immediately transformed into the color space configured as mesh/colorspace explicit color output.

Note that this option has *no effect* if you told xcolor to override the color space globally. More precisely, the use of

```
\usepackage[cmyk]{xcolor}
```

or, alternatively,

```
\selectcolormodel{cmyk}
```

will cause all colors to be converted to cmyk, and PGFPLOTS honors this configuration. Consequently, both these statements cause all colors to be interpolated in the desired color space, and all output colors will use this colorspace. This is typically exactly what you need.

The transformed color is used for any color interpolation. In most cases, this is done by the shader, but it applies to patch refines and patch to triangles as well.

Because the transformed color is used for color interpolation, the list of available *output* color spaces is considerably smaller than the available *input* color spaces. Only the device color spaces rgb, gray, and cmyk are available as value for mesh/colorspace explicit color output.

Any necessary colorspace transformations rely on the xcolor package[25]. Note that colorspace transformations are subject to nearest–color–matching, i.e. they are less accurate. This is typically far beyond pure rounding issues; it is caused by the fact that these color spaces are actually so different that transformations are hard to accomplish. If you can specify colors immediately in the correct color space, you can eliminate such transformations.

Here is the same shading, once with CMYK output and once with RGB output. Depending on your output media (screen or paper), you will observe slightly different colors when comparing the pictures.
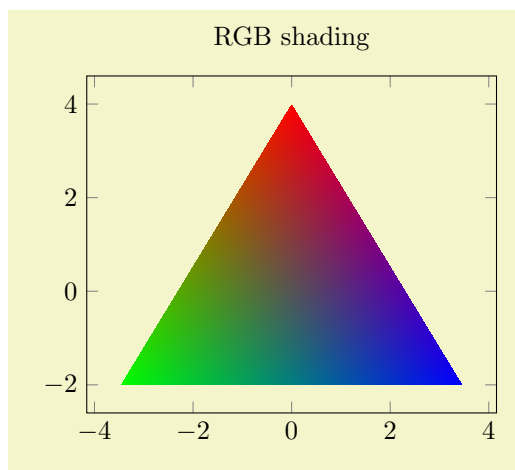

```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
\begin{axis}[title=RGB shading]
    \addplot[
        patch,
        shader=interp,
        mesh/color input=explicit,
        mesh/colorspace explicit color output=rgb,
        data cs=polar,
    ]
    coordinates {
        (90,4)  [color=red]
        (210,4) [color=green]
        (-30,4) [color=blue]
    };
\end{axis}
\end{tikzpicture}
```

---

[25]Colorspace transformations are unavailable for plain TEX and ConTEXt. For these cases, you have to ensure that input and output color model are the same.
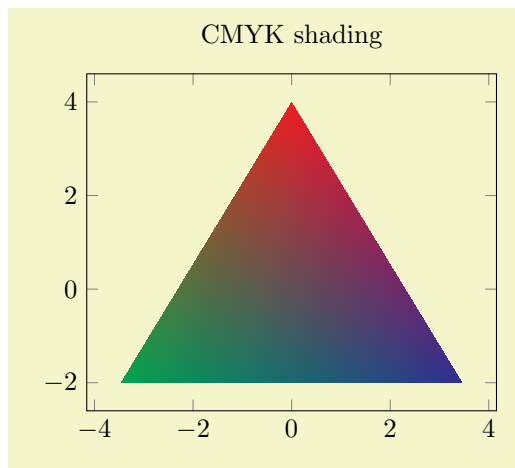
```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
\begin{axis}[title=CMYK shading]
    \addplot[
        patch,
        shader=interp,
        mesh/color input=explicit,
        mesh/colorspace explicit color output=cmyk,
        data cs=polar,
    ]
    coordinates {
        (90,4)  [color=red]
        (210,4) [color=green]
        (-30,4) [color=blue]
    };
\end{axis}
\end{tikzpicture}
```

This key is similar to the related key `colormap default colorspace`, although the values can be chosen independently.

Providing Color Components as Table

The previous section shows how to provide a single symbolic color expression for each coordinate, namely using `point meta`=explicit symbolic.

Another use–case might be to provide a table containing both the coordinate values and one column by color component. In order to assemble the color specification from the input table, you can provide a symbolic expression:
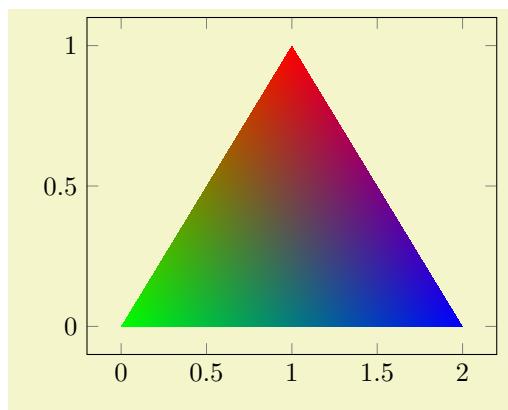
```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
\begin{axis}
    \addplot[
        patch,
        shader=interp,
        mesh/color input=explicit,
        point meta={symbolic=
            {\thisrow{R},\thisrow{G},\thisrow{B}}
        },
    ]
    table {
        x y R G B
        0 0 0 1 0
        1 1 1 0 0
        2 0 0 0 1
    };
\end{axis}
\end{tikzpicture}
```

The preceding example employs a `patch` plot with triangular elements as we have seen before. Furthermore, it uses explicit color input – but combined with `point meta`={symbolic={⟨*value*⟩}} (note the extra pair of braces). This choice accepts arbitrary symbols on input which will be reevaluated (expanded) for every coordinate. In our example, we simply read the values from table columns using `\thisrow`. Since the default input colorspace is RGB, this results in the expected triangle with red, green, and blue corners. The result has to form a valid color specification.

Note that the symbolic expression is purely string–based in this context. If you plan to use math expressions, you have to use `mesh/color input`=explicit mathparse as explained in the following section.

Providing Colors as Math Expression

The key `mesh/color input` has two choices for explicit color input. The choice `explicit` has been discussed in the preceding paragraphs, it expects one color specification for every node for which colors are needed. It also accepts a kind of string–based expressions to concatenate the expected color specification in a suitable way.

The second choice `mesh/color input`=`explicit mathparse` is almost the same – with one major difference: it allows to provide math expressions inside of the `point meta` value. However, the provided math expressions need to form a color specification which typically has more than one color component.

With this choice, the value of `point meta` is of symbolic form, but the color components are reevaluated with the math parser for every input point which has color data. The most convenient way to provide such expressions is `point meta`={symbolic={⟨R⟩,⟨G⟩,⟨B⟩}} (again, note the extra set of braces for the argument).
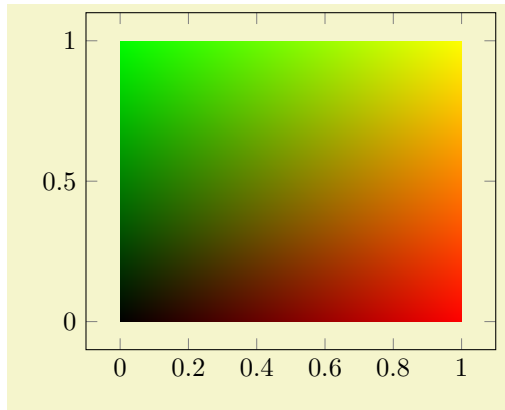

```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
\begin{axis}
    \addplot[
        surf,
        shader=interp,
        mesh/color input=explicit mathparse,
        point meta={symbolic={x,\thisrow{y},0}},
    ]
    table {
        x y
        0 0
        1 0

        0 1
        1 1
    };
\end{axis}
\end{tikzpicture}
```

The preceding example is a `surf`ace plot with a 2×2 input matrix. Note that the table has no explicit point meta data. The `point meta` data is acquired from a common math expression which uses the final x coordinate as ⟨*red*⟩ component, the value seen in the current row and column `y` as ⟨*green*⟩ value and constant value ⟨*blue*⟩$= 0$. Consequently, the output is black in the lower left corner since black is $(0, 0, 0)$, red in the lower right corner, green in the upper left corner, and a mixture of both along the diagonal.

The value provided as `point meta`={symbolic={⟨*value*⟩}} is of the same form as for `mesh/color input`=`explicit`, i.e. it is supposed to be of the form ⟨*color model*⟩=⟨*color components*⟩. If the ⟨*color model*⟩ is omitted, it defaults to `mesh/colorspace explicit color input` (which is `rgb` by default).

Since the math expression can be anything, it can safely be combined with plot by expression.

A potential use–case could be to show a surface with (x, y, z) and some two–dimensional quantity which is encoded as mixture of red and green. The following example relies on `mesh/color input`=`explicit mathparse` and `point meta`=`symbolic` to provide a vector of math expressions:
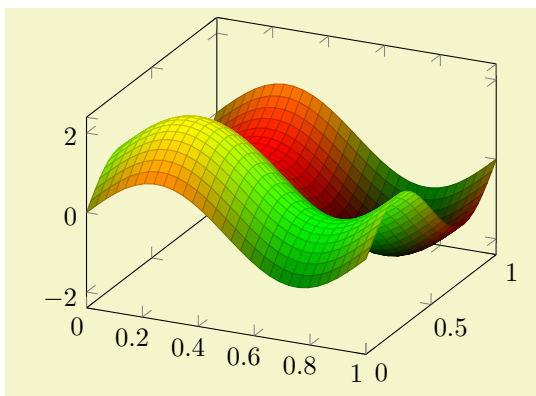

```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
% \usepgfplotslibrary{patchplots}
\begin{tikzpicture}
\begin{axis}
% this example burns colors if opacity
% is active in the document.
    \addplot3[
        patch,
        patch type=bilinear,
        mesh/color input=explicit mathparse,
        domain=0:1,
        samples=30,
        point meta={symbolic={%
            (sin(deg(x*pi*2))+1)/2,% R
            (sin(deg(y*pi*2))+1)/2,% G
            0% B
            }
        },
        ]
    {sin(deg(x*pi*2))+sin(deg(y*pi*2))};
\end{axis}
\end{tikzpicture}
```

Note that the preceding example suffers from color burning[26]: the green areas become too bright and the black areas become too dark. Note that the picture is entirely acceptable if it is written as stand–alone picture. But as soon as you import the picture (either as `.pdf` or as `.png`) into a document for which `opacity` is active, it suffers from burned colors.

The color burning is caused by the combination of RGB colorspace, the special color set in this example, and the color blending which is activated by `opacity`. Note that it is enough to activate `opacity` somewhere in the document.

In order to repair the problem for the picture at hand, one has to choose a different output colorspace:
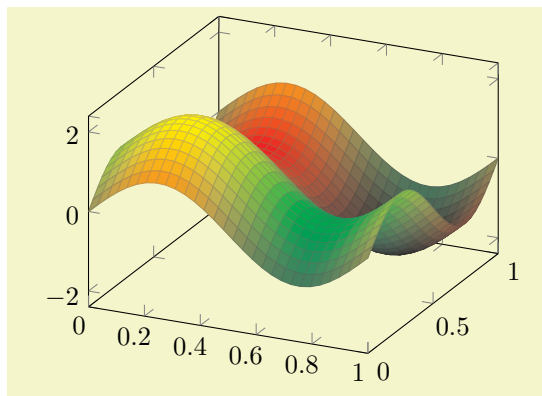
```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
% \usepgfplotslibrary{patchplots}
\begin{tikzpicture}
\begin{axis}
    \addplot3[
        patch,
        patch type=bilinear,
        mesh/color input=explicit mathparse,
        %
        % CMYK produces better quality here
        % since the manual has opacity enabled
        mesh/colorspace explicit color output=cmyk,
        domain=0:1,
        samples=30,
        point meta={symbolic={%
            (sin(deg(x*pi*2))+1)/2,% R
            (sin(deg(y*pi*2))+1)/2,% G
            0% B
            }
        },
        ]
    {sin(deg(x*pi*2))+sin(deg(y*pi*2))};
\end{axis}
\end{tikzpicture}
```

The key `mesh/colorspace explicit color output` transforms every input RGB color to a matching CMYK color. This, in turn, is a lossy transformation which seems to lack a trivial solution[27].

Math expressions can also be used for complicated input color spaces, for example the `wave` colorspace.
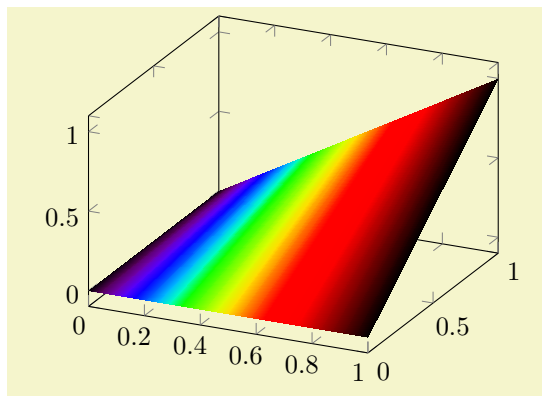
```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
\begin{axis}
    \addplot3[
        surf,
        shader=interp,
        mesh/color input=explicit mathparse,
        domain=0:1,
        samples y=2,
        point meta={symbolic={wave=363+x*(814-363)}},
        ]
    {x*y};
\end{axis}
\end{tikzpicture}
```

Note that you have to take care that the color components are within the expected bounds.

4.6.8   Contour Plots

PGFPLOTS supports visualization of contour plots whose coordinates have been computed by *external tools*. The `contour prepared` plot handler coming with PGFPLOTS takes precomputed contour line coordinates and handles their visualization (`contour/draw color`, `contour/labels` etc.). The `contour gnuplot` style takes matrix input in the same format as for `mesh` or `surf` (that includes any of the PGFPLOTS matrix input methods). It then writes the matrix data to a file and invokes `gnuplot` (or other, user customizable external programs) to compute contour coordinates. Finally, the computed contours are visualized with the `contour`

---

[26]At least in Acrobat Reader.

[27]If some expert in color space operations can contribute best–practices here, feel free to contact me.

prepared algorithm. Thus, external programs need to compute the contour coordinates and PGFPLOTS visualizes the result.

We discuss the high level interface to external programs first and continue with contour prepared later-on.

/pgfplots/contour gnuplot={⟨options with 'contour/' or 'contour external/' prefix⟩}

\addplot+[contour gnuplot={⟨options with 'contour/' or 'contour external/' prefix⟩}]

This is a high level contour plot interface. It expects matrix data in the same way as two dimensional surf or mesh plots do. It then computes contours and visualizes them.
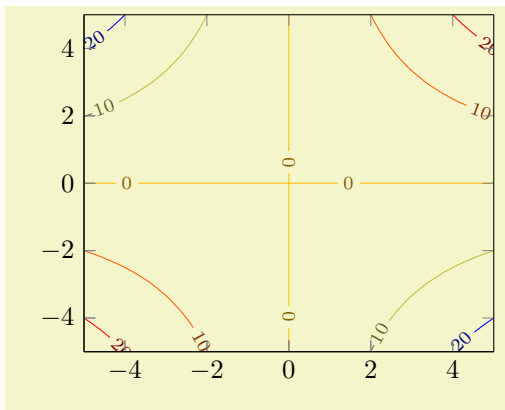

```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
    \begin{axis}[view={0}{90}]
    \addplot3[contour gnuplot]
        {x*y};
    \end{axis}
\end{tikzpicture}
```

The example uses \addplot3 together with expression plotting, that means the input data is of the form $(x_i, y_i, f(x_i, y_i))$. The view={0}{90} flag means "view from top", otherwise the contour lines would have been drawn as z value:
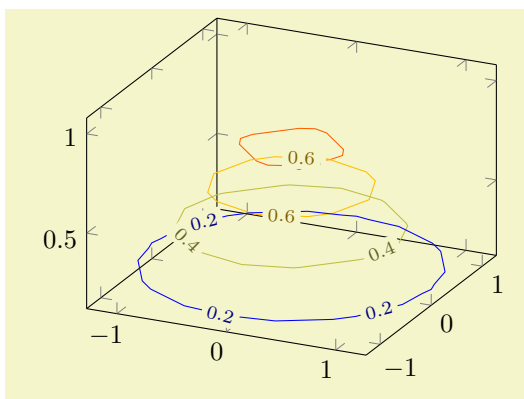

```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
    \begin{axis}
    \addplot3[contour gnuplot]
        {exp(0-x^2-y^2)};
    \end{axis}
\end{tikzpicture}
```

As mentioned, you can use any of the PGFPLOTS input methods as long as it yields matrix output. Thus, we can re-use our introductory example of matrix data, this time with inline data:
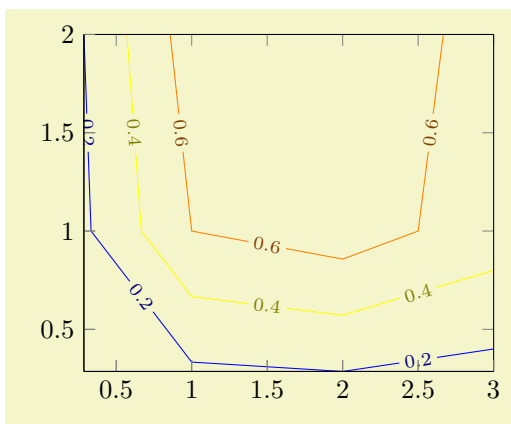

```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}%
\begin{tikzpicture}%
    \begin{axis}[view={0}{90}]%
    \addplot3[contour gnuplot]%
        coordinates {
            (0,0,0) (1,0,0)   (2,0,0)   (3,0,0)

            (0,1,0) (1,1,0.6) (2,1,0.7) (3,1,0.5)

            (0,2,0) (1,2,0.7) (2,2,0.8) (3,2,0.5)
        };
    \end{axis}%
\end{tikzpicture}%
```

What happens behind the scenes is that PGFPLOTS takes the input matrix and writes all encountered co-ordinates to a temporary file, including the end–of–scanline markers. Then, it generates a small gnuplot script and invokes gnuplot to compute the contour coordinates, writing everything into a temporary output file. Afterwards, it includes gnuplot's output file just as if you'd write \addplot3[contour prepared] file {⟨temporaryfile⟩};.

All this invocation of gnuplot, including input/output file management is transparent to the user. It only requires two things: first of all, it requires matrix data as input[28]. Second, it requires you to enable system calls. Consider the documentation for plot gnuplot for how to enable system calls.

Note that the z coordinate of the data which is communicated to gnuplot is the current value of point meta. This allows to generate contours on two columns only and has more freedom. See also the contour external/output point meta key.

The resulting data can be projected onto a separate slice, for example using z filter.
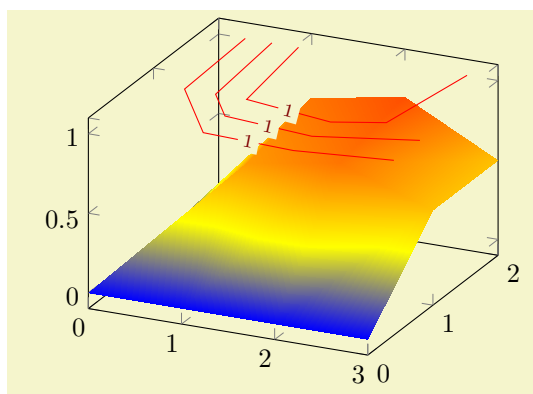

```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}%
\begin{tikzpicture}%
    \begin{axis}%
    \addplot3[surf,shader=interp]%
        coordinates {
            (0,0,0) (1,0,0)   (2,0,0)    (3,0,0)

            (0,1,0) (1,1,0.6) (2,1,0.7) (3,1,0.5)

            (0,2,0) (1,2,0.7) (2,2,0.8) (3,2,0.5)
        };
    \addplot3[
        contour gnuplot,
        z filter/.code={\def\pgfmathresult{1}},
    ]%
        coordinates {
            (0,0,0) (1,0,0)   (2,0,0)    (3,0,0)

            (0,1,0) (1,1,0.6) (2,1,0.7) (3,1,0.5)

            (0,2,0) (1,2,0.7) (2,2,0.8) (3,2,0.5)
        };
    \end{axis}%
\end{tikzpicture}%
```

An unexpected side–effect of a z filter combined with contour gnuplot is that the color information and the label sizes are essentially lost. To componsate this effect, we have to assign a new value for point meta. But since point meta defines the values for contour levels (see above), there is a special key named output point meta which can be used here:

---

[28]Note that contour gnuplot processes the input stream only once. Consequently, the temporary file will contain only information which was available before the first point has been seen. The example above works because it contains emptylines as end-of-scanline markers. If you do not provide such markers, you may need to provide two of the three options mesh/rows, mesh/cols, or mesh/num points.
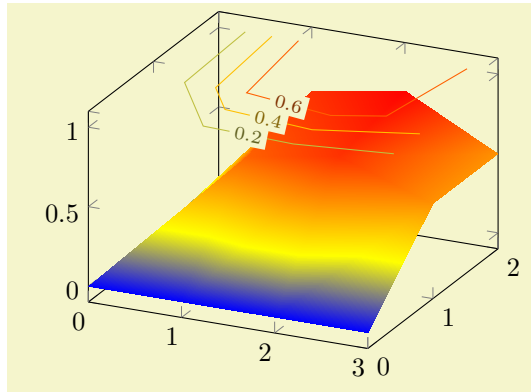
```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}%
\begin{tikzpicture}%
    \begin{axis}%
    \addplot3[surf,shader=interp]%
        coordinates {
            (0,0,0) (1,0,0)   (2,0,0)   (3,0,0)

            (0,1,0) (1,1,0.6) (2,1,0.7) (3,1,0.5)

            (0,2,0) (1,2,0.7) (2,2,0.8) (3,2,0.5)
        };
    \addplot3[
        contour gnuplot={
            output point meta=rawz,
        },
        z filter/.code={\def\pgfmathresult{1}},
    ]%
        coordinates {
            (0,0,0) (1,0,0)   (2,0,0)   (3,0,0)

            (0,1,0) (1,1,0.6) (2,1,0.7) (3,1,0.5)

            (0,2,0) (1,2,0.7) (2,2,0.8) (3,2,0.5)
        };
    \end{axis}%
\end{tikzpicture}%
```

Here, `output point meta`=`rawz` allows to assign point meta to the *output* of the contouring algorithm, i.e. something which is handed over to `contour prepared`. The choice `rawz` means to use the unfiltered z coordinate which is what we want here.

There are several fine-tuning parameters of the input/output file management, and it is even possible to invoke different programs than `gnuplot` (even `matlab`). These details are discussed at the end of this section, see below at page 162.

/pgfplots/contour/**number**={⟨*integer*⟩}   (initially 5)

Configures the number of contour lines which should be produced by any contouring algorithm. The value is applied to both `contour gnuplot` and `contour filled`.
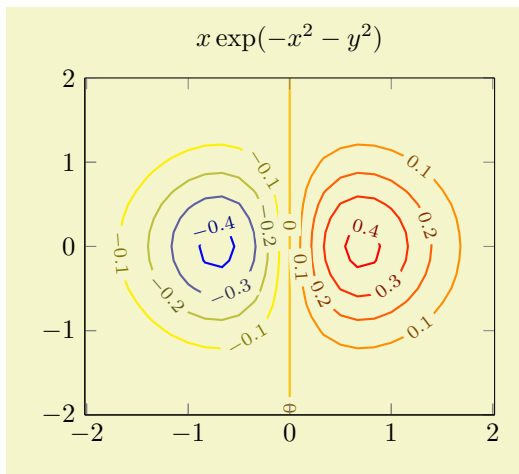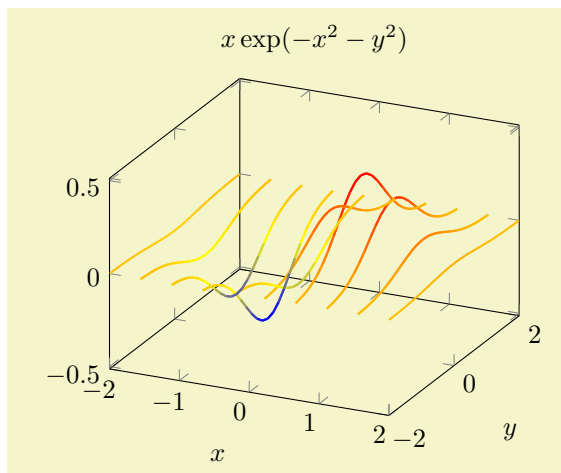


```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
    \begin{axis}[
        title={$x \exp(-x^2-y^2)$},
        domain=-2:2,enlarge x limits,
        view={0}{90},
    ]
    \addplot3[contour gnuplot={number=14},thick]
        {exp(-x^2-y^2)*x};
    \end{axis}
\end{tikzpicture}
```

It is also possible to change the `/pgf/number format` settings, see the documentation for the `contour/every contour label` style below.

Note that `contour/number` has no effect on `contour prepared`.

/pgfplots/contour/**levels**={⟨*list of levels*⟩}   (initially `empty`)

Configures the number of contour lines which should be produced by any contouring algorithm by means of a list of discrete levels.
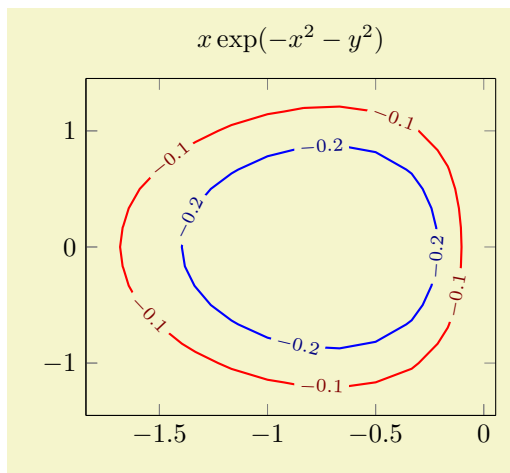
```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
    \begin{axis}[
        title={$x \exp(-x^2-y^2)$},
        domain=-2:2,
        enlargelimits,
        view={0}{90},
    ]
    \addplot3[
      contour gnuplot={levels={-0.1,-0.2,-0.6}},
        thick]
          {exp(-x^2-y^2)*x};
    \end{axis}
\end{tikzpicture}
```

It is also possible to change the /pgf/number format settings, see the documentation for the contour/every contour label style below.

This key has higher precedence than contour/number, i.e. if both are given, contour/levels will be active.

Note that contour/levels has no effect on contour prepared.

/pgfplots/contour/contour dir=x|y|z   (initially z)

Allows to generate contours with respect to another direction.
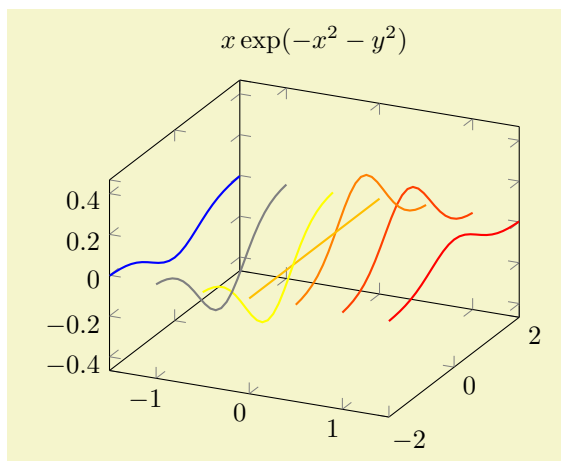

```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
    \begin{axis}[
        title={$x \exp(-x^2-y^2)$},
        domain=-2:2,
    ]
    \addplot3[
      contour gnuplot={
        contour dir=x,labels=false,number=15},
        thick]
          {exp(-x^2-y^2)*x};
    \end{axis}
\end{tikzpicture}
```

The input data is the same as before – it has to be given in matrix form.   The key contour dir configures the algorithm to compute contours along the provided direction.
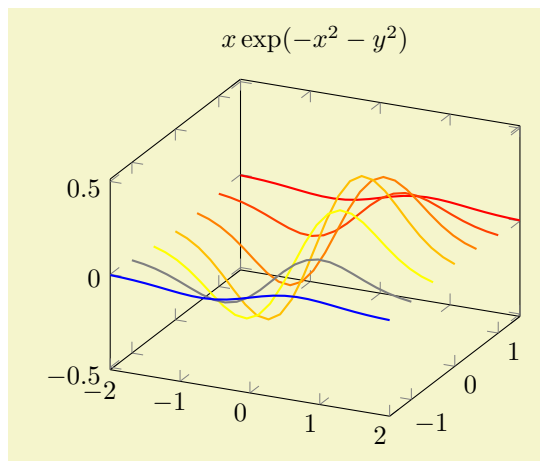

```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
    \begin{axis}[
        title={$x \exp(-x^2-y^2)$},
        domain=-2:2,
    ]
    \addplot3[
      contour gnuplot={
        contour dir=y,labels=false,number=15},
        thick]
          {exp(-x^2-y^2)*x};
    \end{axis}
\end{tikzpicture}
```

This function is also available for parameterized surfaces.
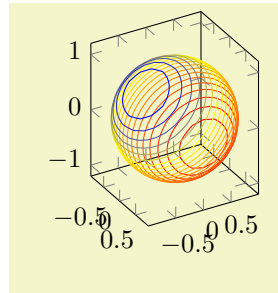
```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
\begin{axis}[view={60}{30}, axis equal image]
    \addplot3[
        contour gnuplot={
            contour dir=x,
            number=20,
            labels=false,
        },
        samples=30,domain=-1:1,y domain=0:2*pi]
        ({sqrt(1-x^2) * cos(deg(y))},
         {sqrt( 1-x^2 ) * sin(deg(y))},
          x);
\end{axis}
\end{tikzpicture}
```

Note, however, that each contour line receives a single color. This is what one expects for a contour plot: it has a single style, and a single contour level. Note furthermore that the color which is assigned to a contour plot with `contour dir`=x is *different* compared with the color assigned to a contour plot with `contour dir`=z: the argument of `contour dir` implicitly defines the argument for `point meta` (also known as color data). More precisely, a contour plot with `contour dir`=x has `point meta`=x whereas a contour plot with `contour dir`=z uses `point meta`=z.

If you would like to have individually colored segments inside of contours, you have to use a different plot handler. There is a simple alternative which works well in many cases: you can use a standard `mesh` plot combined with `patch type`=line:
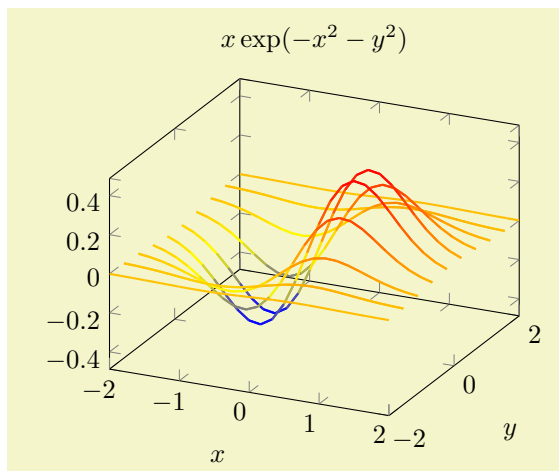

```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
    \begin{axis}[
        title={$x \exp(-x^2-y^2)$},
        domain=-2:2,
        xlabel=$x$, ylabel=$y$,
    ]
    \addplot3[
        samples y=10, samples=25,
      mesh, patch type=line,
        thick]
         {exp(-x^2-y^2)*x};
    \end{axis}
\end{tikzpicture}
```

Here, we did *not* generate a contour plot. We generated a `mesh` plot with `patch type`=line. The choice `patch type`=line causes an inherently one–dimensional plot as opposed to the default matrix–style visualization which would be generated by `mesh` in different cases. Since a mesh plot uses one color for every patch segment, we have a lot of freedom to color the segments. In the example above, we have the default configuration `point meta`=z, i.e. the z value defines the color.

The fact that a `mesh` plot with `patch type`=line yields almost the same output as `contour dir`=y is an artifact of the scanline encoding. Our example uses `\addplot`3 expression which relies on `mesh/ordering`=x varies. If we visualize the resulting matrix by means of `patch type`=line, the visualization follows the scanlines which vary along the x axis. In our example, we used `samples y`=10 to control the number of "contour lines".

A consequence of the previous paragraph is that we have a more challenging task at hand if we want to get the same effect as `contour dir`=x: we would need `mesh/ordering`=y varies. In our case, we would need to transpose the data matrix. For `\addplot`3 expression, this is relatively simple: we can exchange the meaning of `x` and `y` to get a transposition:

```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
    \begin{axis}[
        title={$x \exp(-x^2-y^2)$},
        domain=-2:2,
        xlabel=$x$, ylabel=$y$,
    ]
    \addplot3[
        samples y=10, samples=25,
     mesh, patch type=line,
        thick]
          (y,x,{exp(-x^2-y^2)*y});
    \end{axis}
\end{tikzpicture}
```

This is the same example as above – but as you noted, the meaning of x and y in the expression has been exchanged and the notation has been switched to a parametric plot. Such an approach is also possible for data files, but PGFPLOTS cannot transpose the matrix ordering on its own.

Coming back to contour dir, we can also use its output to generate several contour projections using coordinate filters.
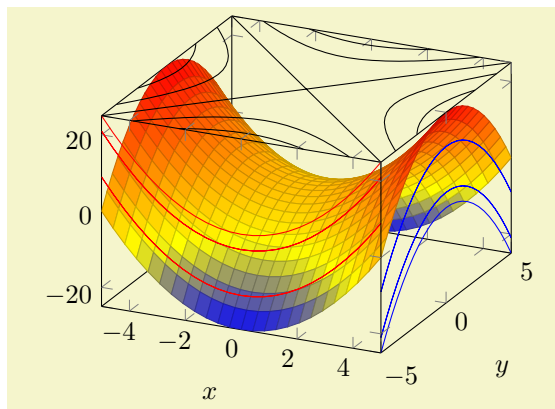

```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
\begin{axis}[
    xlabel=$x$,ylabel=$y$,
    enlargelimits=false,
    3d box=complete]
\addplot3[surf]
  {x^2-y^2};

\addplot3[
    contour gnuplot={contour dir=y,
        draw color=red,labels=false},
    y filter/.expression={-5}
] {x^2-y^2};

\addplot3[
    contour gnuplot={contour dir=x,
        draw color=blue,labels=false},
    x filter/.expression={5}
] {x^2-y^2};

\addplot3[
    contour gnuplot={contour dir=z,
        draw color=black,labels=false},
    z filter/.expression={25}
] {x^2-y^2};

\end{axis}
\end{tikzpicture}
```

The preceding example uses a fixed draw color combined with x filter, y filter, and z filter to fix the contours in one of the axis planes.

Technical background: This section is probably unnecessary and can be skipped. The key contour dir is implemented by means of coordinate permutations. Since contouring algorithms always support contour dir=z, it is relatively simple to compute z–contour lines from input matrixes X, Y, Z. The choice contour dir=z key simply takes the input as–is. The choice contour dir=x reorders the input coordinates to yzx. The choice contour dir=y reorders the input coordinates to xzy. All this reordering is applied before coordinates are handed over to the contouring algorithm (see contour external) and is undone when reading the results back from the contouring algorithm. That means that contour dir is also available for contour prepared. In this context, contour prepared is supposed to be the output of some contouring algorithm. Its input coordinates are automatically reordered according to the inverse permutation. This allows to draw x or y contours which are given in the prepared format.

/pgfplots/contour prepared={⟨options with 'contour/' prefix⟩}

\addplot+[contour prepared={⟨options with 'contour/' prefix⟩}]

A plot handler which expects already computed contours on input and visualizes them. It cannot compute contours on its own.

/pgfplots/contour prepared format=standard|matlab (initially standard)

There are two accepted input formats. The first is a long sequence of coordinates of the form (x, y, z) where all successive coordinates with the same z value make up a contour level (this is only part of complete truth, see below). The end–of–scanline markers (empty lines in the input) mark an interruption in one contour level.

For example, contour prepared format=standard could be[29]
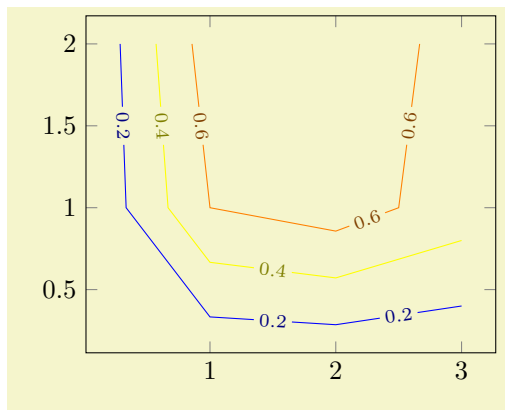

```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
    \begin{axis}
    \addplot[contour prepared]
        table {
            2   2   0.8

            0.857143   2   0.6
            1   1   0.6
            2   0.857143   0.6
            2.5   1   0.6
            2.66667   2   0.6

            0.571429   2   0.4
            0.666667   1   0.4
            1   0.666667   0.4
            2   0.571429   0.4
            3   0.8   0.4

            0.285714   2   0.2
            0.333333   1   0.2
            1   0.333333   0.2
            2   0.285714   0.2
            3   0.4   0.2
        };
    \end{axis}
\end{tikzpicture}
```

Note that the empty lines are not necessary in this case: empty lines make only a difference if they occur within the same contour level (i.e. if the same z value appears above and below of them).

The choice contour prepared format=matlab expects two–dimensional input data where the contour level and the number of elements of the contour line are provided as x and y coordinates, respectively, of a leading point. Such a format is used by matlab's contour algorithms, i.e. it resembles the output of the matlab commands data=contour(...) or data=contourc(...).

---

[29]This is actually the output from our \addplot3[contour gnuplot] coordinates example from above.
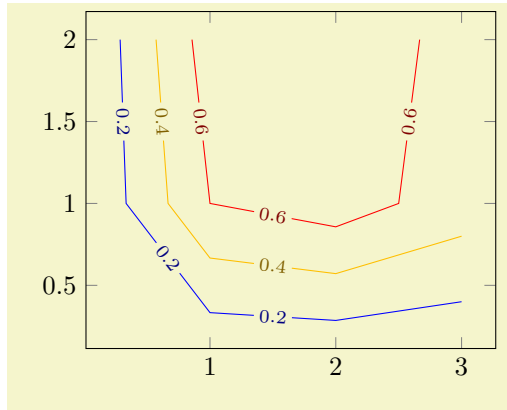
```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
    \begin{axis}
    \addplot[contour prepared,
        contour prepared format=matlab]
    table {
% (0.2,5) ==> contour '0.2' (x), 5 points follow (y):
        2.0000000e-01    5.0000000e+00
        3.0000000e+00    4.0000000e-01
        2.0000000e+00    2.8571429e-01
        1.0000000e+00    3.3333333e-01
        3.3333333e-01    1.0000000e+00
        2.8571429e-01    2.0000000e+00
% (0.4,5) ==> contour '0.4', consists of 5 points
        4.0000000e-01    5.0000000e+00
        3.0000000e+00    8.0000000e-01
        2.0000000e+00    5.7142857e-01
        1.0000000e+00    6.6666667e-01
        6.6666667e-01    1.0000000e+00
        5.7142857e-01    2.0000000e+00
% (0.6,6) ==> contour '0.6', has 6 points
        6.0000000e-01    6.0000000e+00
        2.6666667e+00    2.0000000e+00
        2.5000000e+00    1.0000000e+00
        2.0000000e+00    8.5714286e-01
        1.0000000e+00    1.0000000e+00
        1.0000000e+00    1.0000000e+00
        8.5714286e-01    2.0000000e+00
        };
    \end{axis}
\end{tikzpicture}
```

In case you use matlab, you can generate such data with

```
[x,y]=meshgrid(linspace(0,1,15));
data=contour(x,y,x.*y);
data=data';
save 'exporteddata.dat' data -ASCII
```

As already mentioned in the beginning, the z coordinate is not necessarily the coordinate used to delimit contour levels. In fact, the `point meta` data is acquired here, i.e. you are free to use whatever z coordinate you want as long as you have a correct `point meta` value. The example from above could be modified as follows:

Separating z from Color Value
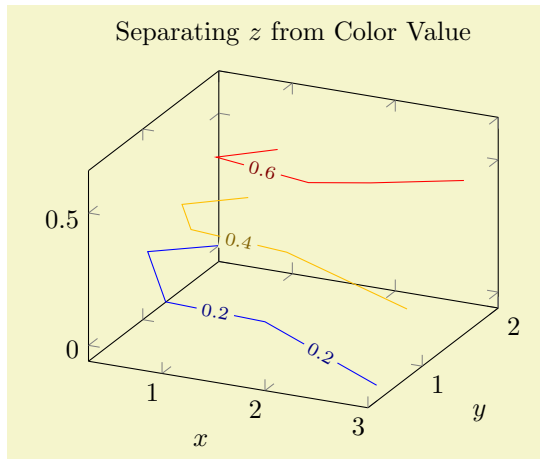
```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
    \begin{axis}[
        title=Separating $z$ from Color Value,
        xlabel=$x$,
        ylabel=$y$,
    ]
    \addplot3[contour prepared,
        point meta=\thisrow{level}]
        table {
    x        y    z   level
    0.857143  2   0.4 0.6
    1         1   0.6  0.6
    2  0.857143 0.6  0.6
    2.5  1      0.6  0.6
    2.66667  2  0.4  0.6

    0.571429  2   0.2 0.4
    0.666667  1   0.4 0.4
    1  0.666667  0.4 0.4
    2  0.571429  0.4 0.4
    3  0.8       0.2 0.4

    0.285714  2   0    0.2
    0.333333  1   0.2 0.2
    1  0.333333  0.2 0.2
    2  0.285714  0.2 0.2
    3  0.4       0    0.2
        };
    \end{axis}
\end{tikzpicture}
```

The example above uses different z coordinates for each first and each last point on contour lines. The contour lines as such are defined by the `level` column since we wrote `point meta=\thisrow{level}`. Such a feature also allows `contour prepared` for nonstandard axes, compare the examples for the `ternary` lib on page 509.

/pgfplots/contour/draw color={⟨*color*⟩}   (initially `mapped color`)

   Defines the draw color for every contour. Note that only `mapped color` actually depends on the contour level.

/pgfplots/contour/labels={⟨*true,false*⟩}   (initially `true`)

   Configures whether contour labels shall be drawn or not.

/pgfplots/contour/label distance={⟨*dimension*⟩}   (initially `70pt`)

   Configures the distance between adjacend contour labels within the same contour level.

/pgfplots/contour/every contour plot   (style, no value)

   A style which is installed as soon as either `contour` or `contour external` is set.

   The initial value is

```
\pgfplotsset{
    contour/every contour plot/.style={
        /pgfplots/legend image post style={sharp plot},
    },
}
```

/pgfplots/contour/every contour label   (style, no value)

   Allows to customize contour labels. The preferred way to change this style is the `contour label style`={⟨*options*⟩} method, see below.

   The initial value is

```
\pgfplotsset{
    contour/every contour label/.style={
        sloped,
        transform shape,
        inner sep=2pt,
        every node/.style={mapped color!50!black,fill=white},
        /pgf/number format/relative={\pgfplotspointmetarangeexponent},
    }
}
```

Note that `\pgfplotspointmetarangeexponent`= e where $\pm m \cdot 10^e$ is the largest occuring label value (technically, it is the largest occurring value of `point meta`).

The following example modifies the `/pgf/number format` styles for contour labels:
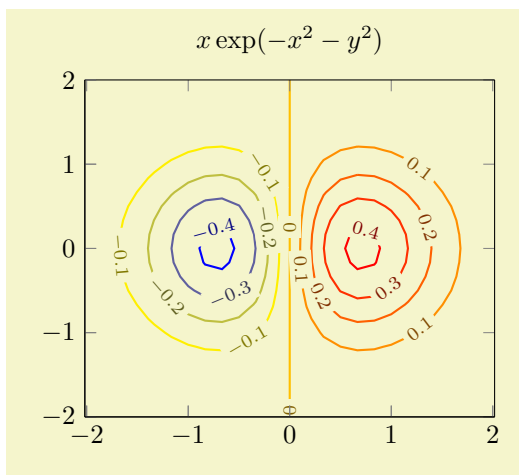

```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
    \begin{axis}[
        title={$x \exp(-x^2-y^2)$},
        domain=-2:2,enlarge x limits,
        view={0}{90},
    ]
    \addplot3[
            contour gnuplot={
              scanline marks=required,
                number=14,
                contour label style={
                    /pgf/number format/fixed,
                    /pgf/number format/precision=1,
                },
            },thick
        ]
            {exp(0-x^2-y^2)*x};
    \end{axis}
\end{tikzpicture}
```

/pgfplots/contour/contour label style=$\{\langle key\text{-}value\text{-}list\rangle\}$

An abbreviation for `contour/every contour label/.append style`=$\{\langle key\text{-}value\text{-}list\rangle\}$.

It appends options to the already existing style `contour/every contour label`.

/pgfplots/contour/labels over line   (style, no value)

A style which changes `every contour label` such that labels are right over the lines, without fill color.
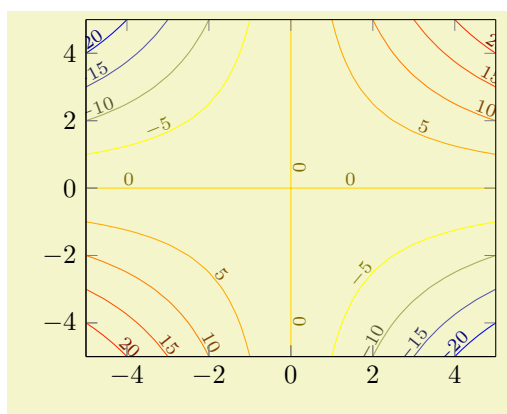

```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
    \begin{axis}[view={0}{90}]
    \addplot3[contour gnuplot={
        labels over line,number=9}]
        {x*y};
    \end{axis}
\end{tikzpicture}
```

/pgfplots/contour/handler   (style, no value)

Allows to modify the plot handler which connects the points of a single contour level.

The initial value is

```
\pgfplotsset{contour/handler/.style={/tikz/sharp plot}}
```

but a useful alternative might be the `smooth` handler:
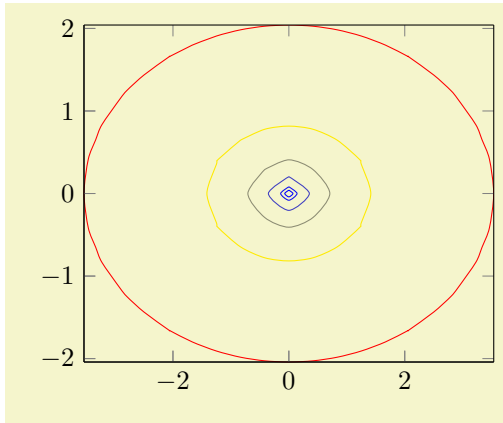
```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
\begin{axis}[view={0}{90}]
\addplot3[
    contour gnuplot={
        levels={0.1,0.2,0.5,1,2,5},
        labels=false,
        handler/.style=smooth,
    },
]
    {2*sqrt(x^2+y^2+(-0.5*(x^2-y^2)))};
\end{axis}
\end{tikzpicture}
```

Unfortunately, the TikZ handler `smooth` has its limitations for such plots, you may need to play around with the number of `samples`.

/pgfplots/contour/label node code/.code={⟨...⟩}

A lowlevel interface to modify how contour labels are placed.

The initial value is

```
\pgfplotsset{
    contour/label node code/.code={\node {\pgfmathprintnumber{#1}};}
}
```

/pgfplots/contour external={⟨options with 'contour/' or 'contour external/' prefix⟩}

\addplot+[contour external={⟨options with 'contour/' or 'contour external/' prefix⟩}]

This handler constitutes a generic interface to external programs to compute contour lines. The `contour gnuplot` method is actually a special case of `contour external`.

/pgfplots/contour external/file={⟨base file name⟩} (initially empty)

The initial configuration is to automatically generate a unique file name.

/pgfplots/contour external/scanline marks=false|if in input|required|true (initially `if in input`)

Controls how `contour external` writes end-of-scanline markers.

The choice `false` writes no such markers at all. In this case, `script` should contain `mesh/rows` and/or `mesh/cols`.

The choice `if in input` generates end-of-scanline markers if they appear in the provided input data (either as `empty line`s or if the user provided at least two of the three options `mesh/rows`, `mesh/cols`, or `mesh/num points` explicitly).

The choice `required` works like `if in input`, but it will fail unless there really was such a marker.

The choice `true` is an alias for `required`.

/pgfplots/contour external/script={⟨Code for external program⟩} (initially empty)

Provides template code to generate a script for the external program. Inside of ⟨*Code for external program*⟩, the placeholder `\infile` will expand to the temporary input file and `\outfile` to the temporary output file. The temporary `\infile` is a text file containing one point on each line, in the form `x y meta meta`, separated by tabstops. Whenever a scanline is complete, an `empty line` is issued (but only if these scanline markers are found in the input stream as well). The complete set of scanlines forms a matrix. There are no additional comments or extra characters in the file. The macro `\ordering` will expand to `0` if the matrix is stored in `mesh/ordering=x varies` and `\ordering` will be `1` for `mesh/ordering=y varies`.

Inside of ⟨*Code for external program*⟩, you can also use `\pgfkeysvalueof{/pgfplots/mesh/rows}` and `\pgfkeysvalueof{/pgfplots/mesh/cols}`; they expand to the matrix' size. Similarly, `\pgfkeysvalueof{/pgfplots/mesh/num points}` expands to the total number of points.

Inside of ⟨*Code for external program*⟩, the macro `\thecontournumber` is defined to be the value `\pgfkeysvalueof{/pgfplots/contour/number}` and `\thecontourlevels` contains the value `\pgfkeysvalueof{/pgfplots/contour/levels}`. These two macros simplify conditional code.

If you need one of the characters [`"|;:#''`] and some macro package already uses the character for other purposes, you can prepend them with a backslash, i.e. write `\"` instead of `"`.

/pgfplots/contour external/script extension=`{⟨extension⟩}`   (initially `script`)

The file name extension for the temporary script.

/pgfplots/contour external/cmd=`{⟨system call⟩}`   (initially `empty`)

A template to generate system calls for the external program. Inside of ⟨*system call*⟩, you may use `\script` as placeholder for the filename which contains the result of `contour external/script`.

/pgfplots/contour external/output point meta=`{⟨point meta read from result of external tool⟩}`
(initially `empty`)

Allows to customize the `point meta` configuration which is applied to the result of the external tool.

In `contour external`, the value of `point meta` is used to generate the *input z* coordinate for the external tool.

As soon as the external tool computed contour lines, its output is read and interpreted as contour lines – and the value of `output point meta` determines the value of `point meta` which will be used to visualize the result.

An empty value means to use the *z* coordinate returned by the external tool.

Any other value is interpreted as a valid choice of `point meta`.

/pgfplots/contour gnuplot   (style, no value)

The initial configuration is

```
\pgfplotsset{
    contour gnuplot/.style={
        contour external={
            script={
                unset surface;
                \ifx\thecontourlevels\empty
                set cntrparam levels \thecontournumber;
                \else
                set cntrparam levels discrete \thecontourlevels;
                \fi
                set contour;
                set table \"\outfile\";
                splot \"\infile\";
            },
            cmd={gnuplot \"\script\"},
            #1,%
        },
    }
}
```

Note that `contour gnuplot` requires explicit scanline markers in the input stream, and it assumes `mesh/ordering`=x varies.

Note that `contour external` lacks the intelligence to detect changes; it will always re-generate the output (unless the `-shell-escape` feature is not active).

4.6.9   Filled Contour Plots

PGFPLOTS is able to generate `contour filled` plots with its builtin arithmetics.

/pgfplots/contour filled=`{⟨options with 'contour/' prefix⟩}`

`\addplot+[contour filled=`{⟨options with 'contour/' prefix⟩}`]`

Beware: Viewer Limitations The following paragraph makes uses of PDF features which are un-supported by some free viewers (including `pdf.js` and `evince`). Please resort to a suitable viewer if you see unexpected results.

This plot handler visualizes patches or surfaces by means of filled segments: points on the surface will be colored based on their `point meta` value. The `point meta` value is mapped into a sequence of intervals, and each interval has its own color. The intervals, in turn, are part of a `colormap`.
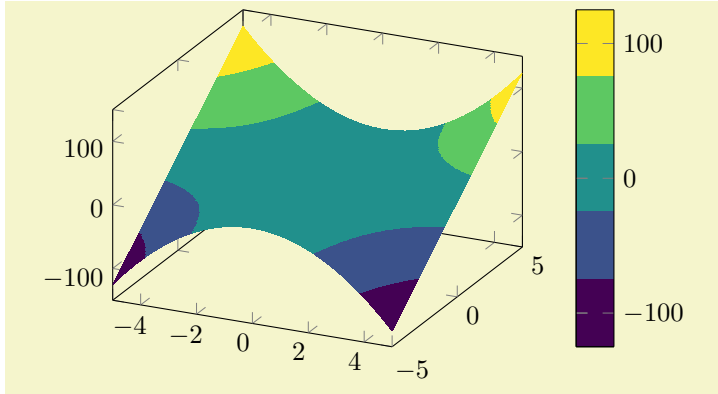

```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
    \begin{axis}[colormap name=viridis,colorbar]
    \addplot3[contour filled] {x^2*y};
    \end{axis}
\end{tikzpicture}
```

The number of contour levels is defined by means of `contour/number`, just as for `contour external`:
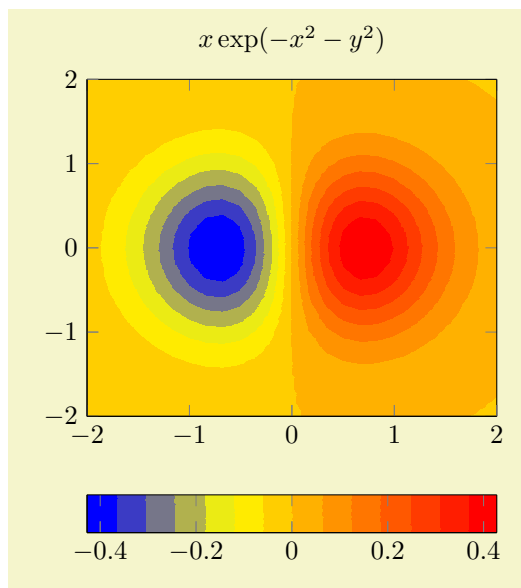

```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
    \begin{axis}[
        title={$x \exp(-x^2-y^2)$},
        domain=-2:2,
        view={0}{90},
        colorbar horizontal,
    ]
    \addplot3[contour filled={number=14}]
        {exp(-x^2-y^2)*x};
    \end{axis}
\end{tikzpicture}
```

In addition to selecting a `number` of contour levels, you can select a predefined list of `levels`:
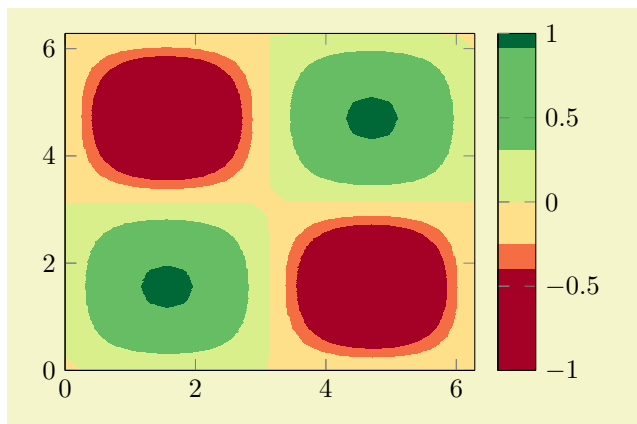
```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
    \begin{axis}[colormap/RdYlGn,colorbar, view={0}{90}]
    \addplot3[domain=0:2*pi,trig format plots=rad,
        contour filled={
            levels={-0.4,-0.25,0,0.3,0.9}}]
    {sin(x)*sin(y)};
    \end{axis}
\end{tikzpicture}
```

A filled contour plot merely affects the appearance of patch segments, so you can easily adopt axis options like `view`.

PGFPLOTS implements the plot handler `contour filled` in almost the same way as `surf`: it expects the very same input format (i.e. coordinates in matrix form from any supported coordinate input stream) and expects numeric `point meta`. In order to determine the correct color, PGFPLOTS evaluates `point meta` for each encountered vertex in the input matrix and interpolates any values of `point meta` on mesh segments. The interpolation scheme is normally linear, but you can write `patch type`=`bilinear` if you want bilinear interpolation of `point meta` (higher quality somewhat bigger output files; we come back to this at the end of this plot handler). Finally, each interpolated `point meta` is mapped into a `colormap` using `colormap access`=const.

The `colormap` in question is specific to `contour filled`: it is defined after the survey phase and is called `internal:contourfilled`. It is created using the `of colormap` functionality (see its reference for details). PGFPLOTS uses `target pos min` and `target pos max` to ensure that the resulting `colormap` fits into the range `point meta min`:`point meta max`.

/pgfplots/contour/`levels from colormap`={⟨*colormap definition*⟩}

Typically, `contour filled` will be customized either by means of a `number` of contour lines or by selecting a list of prescribed `levels`.

However, `levels from colormap` is another, highly flexible and more involved way of defining contour levels. It offers the most control over contour levels and the associated colors, namely by adding an entire ⟨*colormap definition*⟩. Such an argument must be a valid argument to `colormap`={⟨*name*⟩}{⟨*colormap definition*⟩}. Suppose we have a water depth profile and we want to visualize it as `contour filled`. In this case, we want a clear separation of "water" and "land", but the water depth and the land height may be asymmetric. In order to use different color maps for water and for land, we can add the following ⟨*colormap definition*⟩:
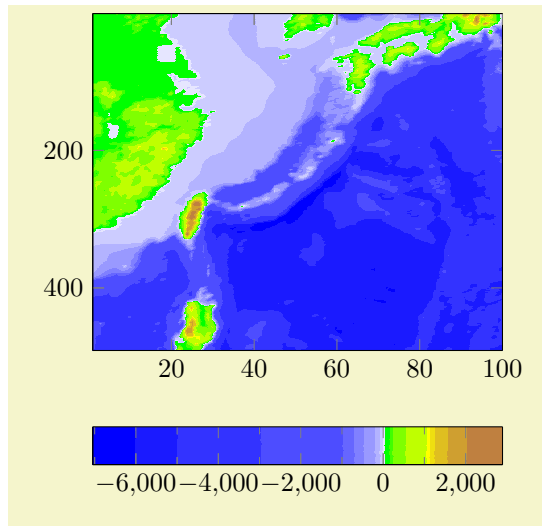
```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
\begin{axis}[view={0}{90},
    colormap={whiteblue}{color=(blue) color=(white)},
    colormap={gb}{color=(green) color=(yellow)
        color=(brown)},
    colorbar horizontal,
    colorbar style={minor x tick num=1},
    y dir=reverse,
]
\addplot3[contour filled={
    levels from colormap={
        of colormap={
            whiteblue,
            target pos max=,
            target pos={-12000,-10000,-6000,-5000,
                -3000,-1000,-750,-500,-250,-100,
                -50,0}
        },
        of colormap={
            gb,
            target pos min=,
            target pos={10,100,200,500,1000,1100,1200,
                1500,2000,4000,6000,8000}
        }
    }
},
]
table {plotdata/heightmap.dat};
\end{axis}
\end{tikzpicture}
```

The example above re-uses the colormap already explained in the documentation for `target pos min`: it concatenates two 'of colormap' specifications and assigns specific `target pos`itions. The data file `heightmap.dat` is shipped with PGFPLOTS.[30] The only special item here is that it *clears* `target pos max` (the right end) for the first part of the definition and `target pos min` (the left end) for the second part of the definition. This is because PGFPLOTS implicitly adds such limits in order to enforce the correct range. The colormap in question is essentially equivalent to
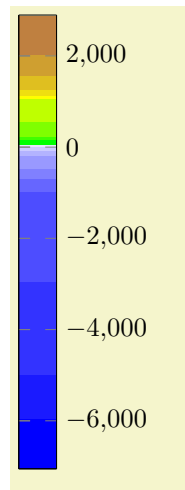
```
\pgfplotscolorbardrawstandalone[
    colormap={whiteblue}{color=(blue)
        color=(white)},
    colormap={gb}{color=(green)
        color=(yellow) color=(brown)},
    colorbar style={minor x tick num=1},
    point meta min=-7052,
    point meta max=2895,
    of colormap/target pos min*=-7052,
    of colormap/target pos max*=2895,
    of colormap/sample for=const,
    colormap access=const,
    colormap={CM}{
        of colormap={
            whiteblue,
            target pos max=,
            target pos={-12000,-10000,-6000,-5000,
                -3000,-1000,-750,-500,-250,-100,-50,0}
        },
        of colormap={
            gb,
            target pos min=,
            target pos={10,100,200,500,1000,1100,
                1200,1500,2000,4000,6000,8000}
        }
    }]
```

Note that this specific colormap would be more descriptive if each color had its specific legend. To this end, we could make use of `colorbar as legend`, i.e. using the following `colorbar`:

---

[30]Packed into the archive `doc/latex/pgfplots/pgfplots.doc.src.tar.bz2`. The file's content has been imported from [4]; the precise link location is referenced in the datafile itself.
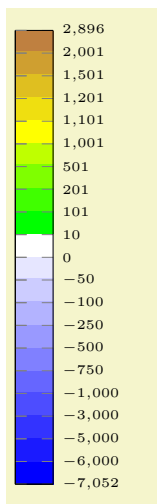
```
\pgfplotscolorbardrawstandalone[
    colormap={whiteblue}{color=(blue)
        color=(white)},
    colormap={gb}{color=(green)
        color=(yellow) color=(brown)},
    colorbar as legend,
    colorbar style={ticklabel style={font=\tiny}},
    point meta min=-7052,
    point meta max=2895,
    of colormap/target pos min*=-7052,
    of colormap/target pos max*=2895,
    of colormap/sample for=const,
    colormap access=const,
    colormap={CM}{
        of colormap={
            whiteblue,
            target pos max=,
            target pos={-12000,-10000,-6000,-5000,
                -3000,-1000,-750,-500,-250,-100,-50,0}
        },
        of colormap={
            gb,
            target pos min=,
            target pos={10,100,200,500,1000,1100,
                1200,1500,2000,4000,6000,8000}
        }
    }]
```

A `contour filled` plot comes with the following ways to define the contour limit positions:

1. Defining the number of contour levels using `contour/number`={⟨*number*⟩},

2. Defining a prescribed list of `contour/levels`={⟨*list*⟩},

3. Defining the levels in `levels from colormap` in a suitable ⟨*colormap definition*⟩,

4. Assigning empty values to all three of the items above in which case PGFPLOTS will use as many contour levels as there are distinct colors in the current colormap.

As already mentioned, `contour filled` makes use of the same routines as `mesh`, `surf`, and `patch` plots. In particular, it requires `z buffer`=sort for the same reason as the surface plots:
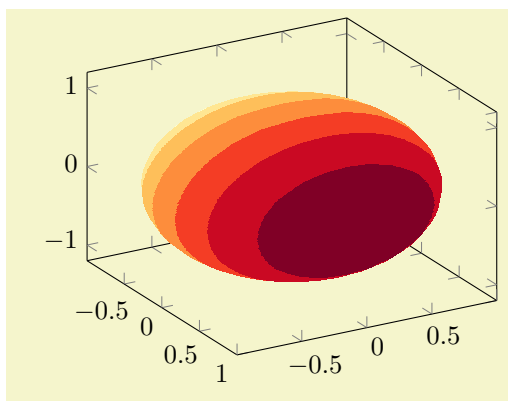
```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
\begin{axis}[view={60}{30},colormap/YlOrRd]
    \addplot3[
        contour filled={
            number=7,
        },
        point meta=x,
        z buffer=sort,
        samples=30,domain=-1:1,y domain=0:2*pi]
        ({sqrt(1-x^2) * cos(deg(y))},
         {sqrt( 1-x^2 ) * sin(deg(y))},
         x);
\end{axis}
\end{tikzpicture}
```

Note that `contour filled` *only* relies on `point meta` in order to determine contour levels. Consequently, it does not need `contour dir`; a simple `point meta`=x has the same effect (as is seen in the previous example).

A consequence of the fact that `contour filled` merely relies on `point meta` is that it supports two–dimensional plots as well, provided they have matrix structure and they provide `point meta`:
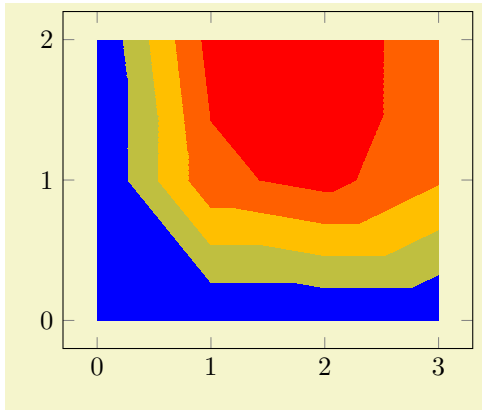
```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
\begin{axis}
\addplot[contour filled,point meta=explicit]
coordinates {
    (0,0) [0] (1,0) [0]   (2,0) [0]   (3,0) [0]

    (0,1) [0] (1,1) [0.6] (2,1) [0.7] (3,1) [0.5]

    (0,2) [0] (1,2) [0.7] (2,2) [0.8] (3,2) [0.5]
    };
\end{axis}
\end{tikzpicture}
```
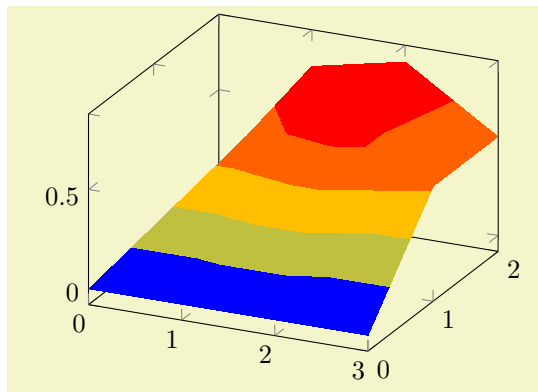


```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
\begin{axis}
\addplot3[contour filled]
    coordinates {
        (0,0,0) (1,0,0)   (2,0,0)   (3,0,0)

        (0,1,0) (1,1,0.6) (2,1,0.7) (3,1,0.5)

        (0,2,0) (1,2,0.7) (2,2,0.8) (3,2,0.5)
    };
\end{axis}
\end{tikzpicture}
```

Quality considerations. The results of `contour filled` always have smooth position interpolation at any resolution. Note that the quality of edges depends on the viewer application; Acrobat Reader appears to render results with high quality. Furthermore, the quality depends on the number of input samples (as always). However, `contour filled` plots of coarse grained input matrices can be improved by using a better color interpolation scheme: if you add `patch type`=`bilinear` for such plots, you typically get smoother results than the default triangle-based scheme:
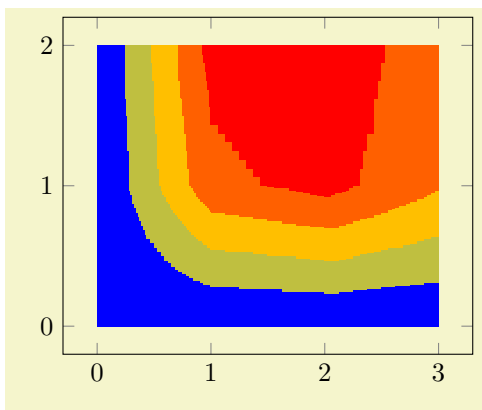

```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
% requires \usepgfplotslibrary{patchplots}
\begin{tikzpicture}
\begin{axis}
\addplot[contour filled,patch type=bilinear,
    point meta=explicit]
coordinates {
    (0,0) [0] (1,0) [0]   (2,0) [0]   (3,0) [0]

    (0,1) [0] (1,1) [0.6] (2,1) [0.7] (3,1) [0.5]

    (0,2) [0] (1,2) [0.7] (2,2) [0.8] (3,2) [0.5]
    };
\end{axis}
\end{tikzpicture}
```

Note that `patch type`=`bilinear` results in bigger output files and may take somewhat longer to render. It requires to load the `patchplots` library.

Limitations: `contour filled` supports no contour labels and no contour outlines. Furthermore, its contour lines differ from the contours computed by `contour gnuplot`.

4.6.10 Parameterized Plots

Parameterized plots use the same plot types as documented in the preceding sections: both `mesh` and `surf`ace plots are actually special parametrized plots where x and y are on cartesian grid points.

Parameterized plots just need a special way to provide the coordinates:
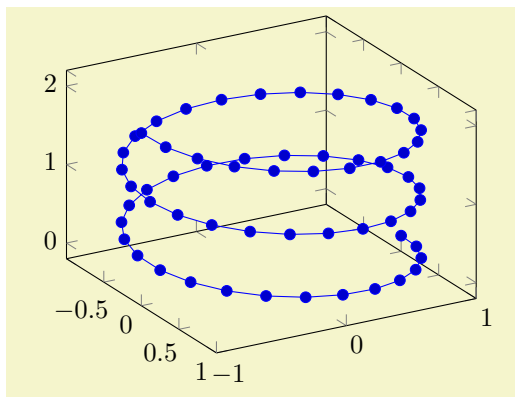

```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
    \begin{axis}[view={60}{30}]
    \addplot3+[domain=0:5*pi,samples=60,samples y=0]
        ({sin(deg(x))},
         {cos(deg(x))},
         {2*x/(5*pi)});
    \end{axis}
\end{tikzpicture}
```

The preceding example uses `samples y`=0 to indicate that a line shall be sampled instead of a matrix. The curly braces are necessary because TeX can't nest round braces. The single expressions here are used to parametrize the helix.

Another example follows. Note that `z buffer`=sort is a necessary method here.
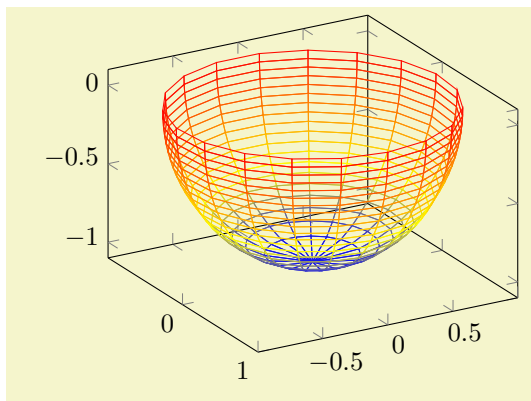

```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
\begin{axis}[view={60}{30}]
    \addplot3[mesh,z buffer=sort,
        samples=20,domain=-1:0,y domain=0:2*pi]
        ({sqrt(1-x^2) * cos(deg(y))},
         {sqrt( 1-x^2 ) * sin(deg(y))},
         x);
\end{axis}
\end{tikzpicture}
```
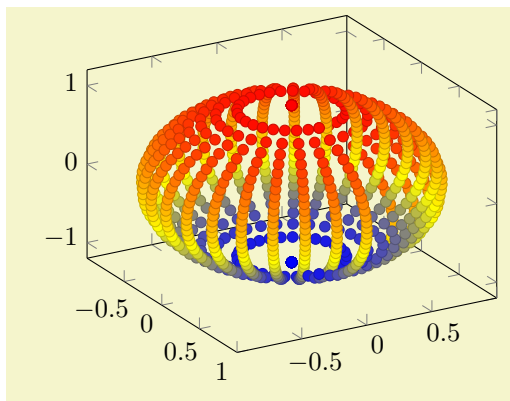


```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
\begin{axis}[view={60}{30}]
    \addplot3[mesh,z buffer=sort,
        scatter,only marks,scatter src=z,
        samples=30,domain=-1:1,y domain=0:2*pi]
        ({sqrt(1-x^2) * cos(deg(y))},
         {sqrt( 1-x^2 ) * sin(deg(y))},
         x);
\end{axis}
\end{tikzpicture}
```
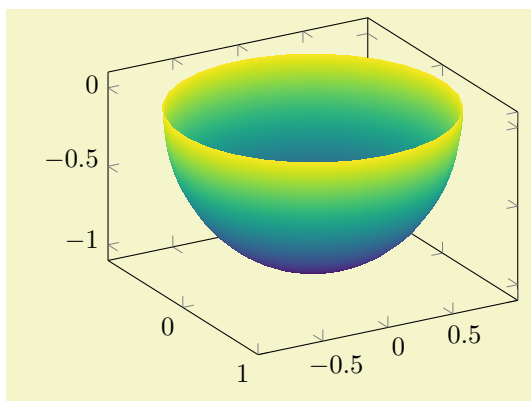


```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
\begin{axis}[view={60}{30},colormap/viridis]
    \addplot3[surf,shader=interp,z buffer=sort,
        samples=30,domain=-1:0,y domain=0:2*pi]
        ({sqrt(1-x^2) * cos(deg(y))},
         {sqrt( 1-x^2 ) * sin(deg(y))},
         x);
\end{axis}
\end{tikzpicture}
```
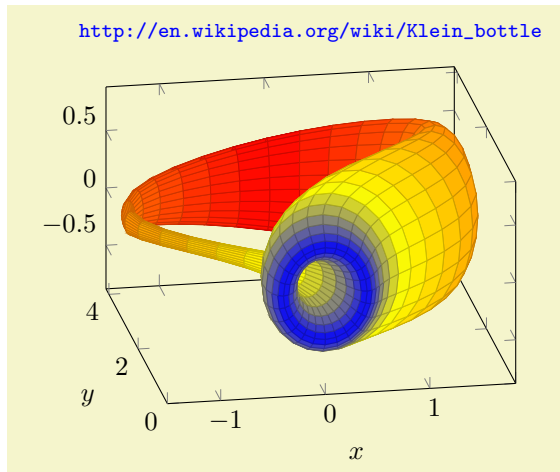
```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
    \begin{axis}[
        xlabel=$x$,
        ylabel=$y$,
        view/h=-10,
        title=\footnotesize
 \url{http://en.wikipedia.org/wiki/Klein_bottle},
        ]
    \addplot3[
        surf,
        z buffer=sort,
        colormap={periodic}{%
            color=(blue)
                color=(yellow)
                    color=(orange)
                        color=(red)
                    color=(orange)
                color=(yellow)
            color=(blue)},
        domain=0:180, domain y=0:360,
        samples=41, samples y=25,
        variable=\u, variable y=\v,
        point meta=u,
        ]
        ({-2/15 * cos(u) * (
            3*cos(v) - 30*sin(u)
          + 90 *cos(u)^4 * sin(u)
          - 60 *cos(u)^6 * sin(u)
          + 5 * cos(u)*cos(v) * sin(u))
         },
         {-1/15 * sin(u) * (3*cos(v)
           - 3*cos(u)^2 * cos(v)
           - 48 * cos(u)^4*cos(v)
           + 48*cos(u)^6 *cos(v)
           - 60 *sin(u)
           + 5*cos(u)*cos(v)*sin(u)
           - 5*cos(u)^3 * cos(v) *sin(u)
           - 80*cos(u)^5 * cos(v)*sin(u)
           + 80*cos(u)^7 * cos(v) * sin(u))
         },
         {2/15 * (3 + 5*cos(u) *sin(u))*sin(v)});
    \end{axis}
\end{tikzpicture}
```

4.6.11 3D Quiver Plots (Arrows)

Three dimensional `quiver` plots are possible with the same interface as their two-dimensional counterparts, simply provide the third coordinate using `quiver/w`. Please refer to Section 4.5.8 for details and examples.

4.6.12 Image (Matrix) Plots

/pgfplots/matrix plot   (no value)

\addplot+[matrix plot]

> A matrix plot is very similar to a `surf`ace plot in that it produces a filled lattice of shaded rectangles. The key difference is that a `surf`ace plot expects the *corners* as input whereas a `matrix plot` expects the *cell mid points* as input:
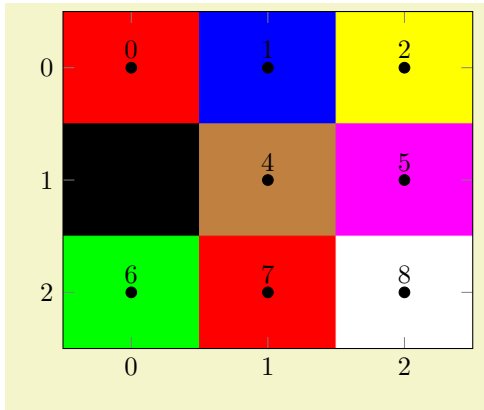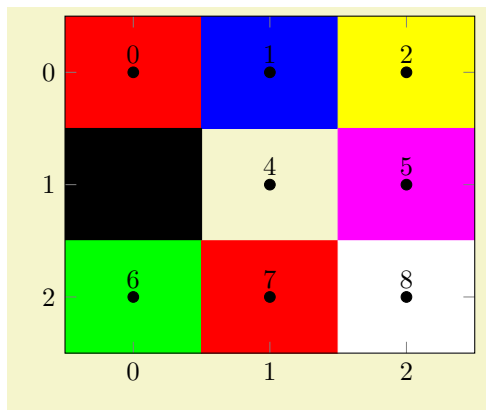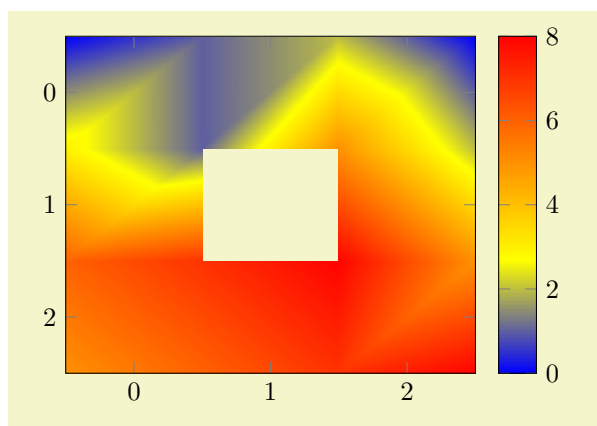
```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
\begin{axis}[enlargelimits=false]

\addplot[
    matrix plot,
    mark=*,nodes near coords=\coordindex,
    mesh/color input=explicit]
coordinates {
  % row 0 1 2:
  (0,0) [color=red] (1,0) [color=blue]
  (2,0) [color=yellow]

  % row 3 4 5
  (0,1) [color=black] (1,1) [color=brown]
  (2,1) [color=magenta]

  % row 6 7 8
  (0,2) [color=green] (1,2) [color=red]
  (2,2) [color=white]
};

\end{axis}
\end{tikzpicture}
```

The example above shows a matrix plot along with the associated node near coords. The input coordinates resemble the cell mid points, and the color given according to the format mesh/color input=explicit defines the cell's color. Note that a surface plot would connect the input vertices, but here we have one cell for every mid point.

The size of each cell is determined according to the distance of adjacent cell mid points and cells are always connected with each other; it is an interpolation scheme for adjacent cells.

A matrix plot is implemented using the same routines as surf, which means that it supports all of the options associated with a surface plot. A standard application is to visualize the matrix using a colormap:
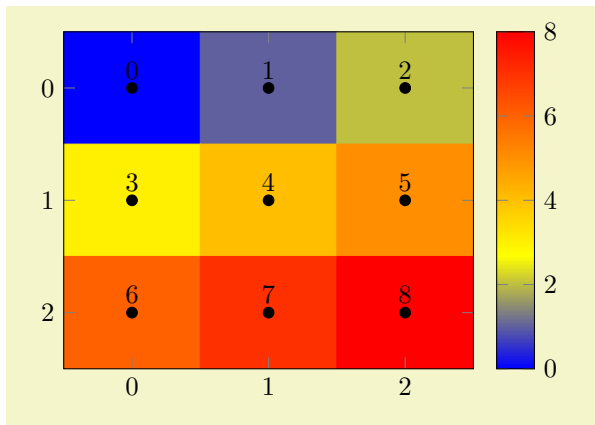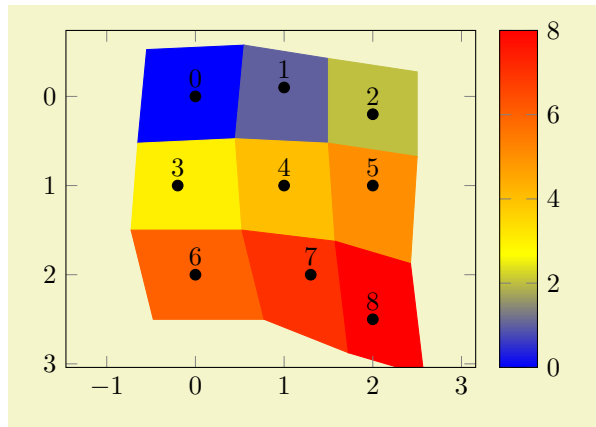


```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
\begin{axis}[enlargelimits=false,colorbar]

\addplot[matrix plot,
    nodes near coords=\coordindex,mark=*,
    point meta=explicit]
coordinates {
(0,0) [0] (1,0) [1] (2,0) [2]

(0,1) [3] (1,1) [4] (2,1) [5]

(0,2) [6] (1,2) [7] (2,2) [8]
};
\end{axis}
\end{tikzpicture}
```

Note that matrix plot uses shader=flat corner by default. This ensures that the colors are taken from the inputs, i.e. from the cell mid points. Use shader=faceted or shader=interp to interpolate the colors. Similarly, other options which apply to surface plots (like faceted color, mesh/color input, or mesh/ordering) can be combined with matrix plot as well.

Note that a matrix plot has one major difference to almost all other plot handlers: providing matrix plot to one of the \addplot commands in an axis will reconfigure the entire axis such that its display fits. More precisely, a matrix plot implicitly sets the options

```
\pgfplotsset{
    y dir=reverse,
    axis on top
}
```

in the assumption that the matrix "coordinate" $(0,0)$ is typically the upper left corner (as opposed to the lower left corner as for standard axes). This reconfiguration of the axis overrides any user options

for `y dir` and `axis on top`. If you prefer other values, you can and should use the starred version `matrix plot*` which does not reconfigure the axis in any way.

A `matrix plot` automatically updates axis limits to match those of the cell corners.
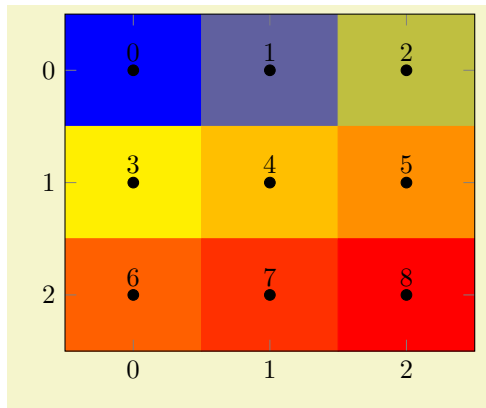

```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
\begin{axis}[enlargelimits=false]

\addplot[
    matrix plot,
    nodes near coords=\coordindex,mark=*,
    mesh/cols=3,
    point meta=explicit]
table[meta=C] {
 x y  C
 0 0  0
 1 0  1
 2 0  2
 0 1  3
 1 1  4
 2 1  5
 0 2  6
 1 2  7
 2 2  8
};
\end{axis}
\end{tikzpicture}
```

Limitations: Due to current implementational restrictions, `matrix plot` can only update axis limits successfully if the length of the matrix scanlines is known in advance. The example above contains `mesh/cols`=3, and a "scanline" is a row (with 3 columns each). Consequently, the example above works fine. However, If `mesh/cols`=3 would be unknown in advance, the current implementation assumes that end–of–scanline markers are given in the input file according to `empty line`=scanline. As a rule of thumb, you have to follow the following guidelines when using `matrix plot`:

1. The input matrix should have an `empty line` whenever one line of input is finished.

2. If there is no `empty line`, the length of each scanline must be given. For the standard configuration `mesh/ordering`=x varies, PGFPLOTS expects `mesh/cols`. For the alternative choice `mesh/ordering`=y varies, PGFPLOTS expects `mesh/rows` to be set.

3. The input matrix must have at least 2 rows and at least 2 columns. This allows PGFPLOTS to interpolate/extrapolate the vertices in a well-defined way.

If both of the first two conditions are violated, PGFPLOTS fails to update the limits correctly and generates the warning

```
Package pgfplots Warning: Automatic computation of axis limits for 'matrix plot' is INACCURATE.
Please add the key 'mesh/cols=3'. You can also ignore this warning and deal with axis limits manually
```

If you encounter this warning, you should proceed according to the guidelines above or ignore the warning and configure `ymin` and `ymax` manually.

A `matrix plot` expects a complete matrix on input; it is forbidden to leave holes in it. However, it supports "invisible" cells: provide unbounded values for `point meta` in order to produce a "hole" in the lattice:
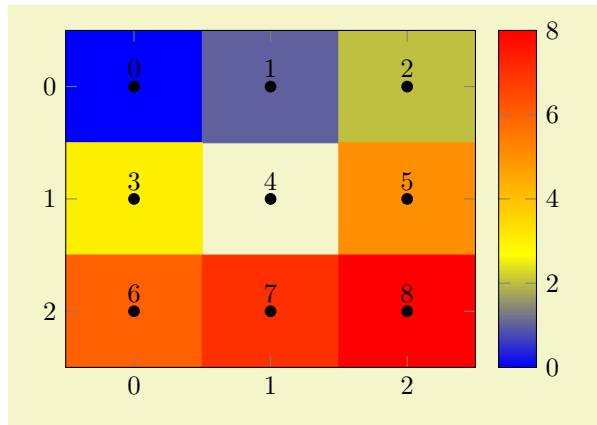
```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
\begin{axis}[enlargelimits=false,colorbar]

\addplot[matrix plot,
    nodes near coords=\coordindex,mark=*,
    point meta=explicit]
coordinates {
(0,0) [0] (1,0) [1] (2,0) [2]

(0,1) [3] (1,1) [nan] (2,1) [5]

(0,2) [6] (1,2) [7] (2,2) [8]
};
\end{axis}
\end{tikzpicture}
```

Here, "unbounded" means a color value which is `nan` (not a number), `inf`, or `-inf`. In case of `mesh/color input`=explicit, you can simply provide an empty explicit color to achieve the same effect:


```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
\begin{axis}[enlargelimits=false]

\addplot[
    matrix plot,
    mark=*,nodes near coords=\coordindex,
    mesh/color input=explicit]
coordinates {
(0,0) [color=red] (1,0) [color=blue]
  (2,0) [color=yellow]

(0,1) [color=black] (1,1) []
  (2,1) [color=magenta]

(0,2) [color=green] (1,2) [color=red]
  (2,2) [color=white]
};

\end{axis}
\end{tikzpicture}
```

This feature works for `shader`=flat mean or `shader`=interp as well. However, these shaders require color interpolation in order to determine the correct color for the *visible* cells. In this case, the missing cell will be replaced by the lowest possible point meta (or by black in case of `mesh/color input`=explicit), resulting in the following output:


```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
\begin{axis}[enlargelimits=false,colorbar]

\addplot[matrix plot,
    shader=interp,
    point meta=explicit]
coordinates {
(0,0) [0] (1,0) [1] (2,0) [2]

(0,1) [3] (1,1) [nan] (2,1) [5]

(0,2) [6] (1,2) [7] (2,2) [8]
};
\end{axis}
\end{tikzpicture}
```

A `matrix plot` will always be connected, even if the vertices form a distorted mesh. The input must be a complete matrix, but its x and y coordinates (or maybe even z coordinates) can still be different from what one expects from a matrix. The resulting cells are produced using interpolation/extrapolation:

```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
\begin{axis}[enlargelimits=0.2,colorbar]

\addplot[
    matrix plot,
    nodes near coords=\coordindex,mark=*,
    point meta=\coordindex]
table {
 x y
 0 0
 1 -0.1
 2 0.2

 -0.2 1
 1 1
 2 1

 0 2
 1.3 2
 2 2.5
};
\end{axis}
\end{tikzpicture}
```

Note that the expected usage of `matrix plot` is to have something which is at least close to a matrix, and the axis limits may become inaccurate if the input forms a highly irregular mesh. In particular, the axis limits in z direction are highly inaccurate for matrix plots, but the visualization is precise. Applying `matrix plot` to a three–dimensional input might also need `z buffer`=`auto` since `matrix plot` disables `z buffer` by default (in order to ensure correct color associations, i.e. to avoid reorderings). If you really need three–dimensional `matrix plot`s, you may want to specify `surf`,`mesh input`=image directly, and you may need to adopt axis limits manually. The main use–case of `matrix plot` is for input which looks roughly like an image.

Technically, `matrix plot` is a style which configures `y dir`=`reverse` and `axis on top` as outlined above, and which installes `matrix plot*` afterwards.

See also `colormap access`=direct for examples how to use `matrix plot` in conjunction with bitmap graphics.

/tikz/**matrix plot*** (no value)

\addplot+[**matrix plot***]

The same as `matrix plot` except that `matrix plot*` does not reconfigure the axis. As outlined above, `matrix plot` reconfigures the axis for

```
y dir=reverse,
axis on top,
```

These options are missing for `matrix plot*`:
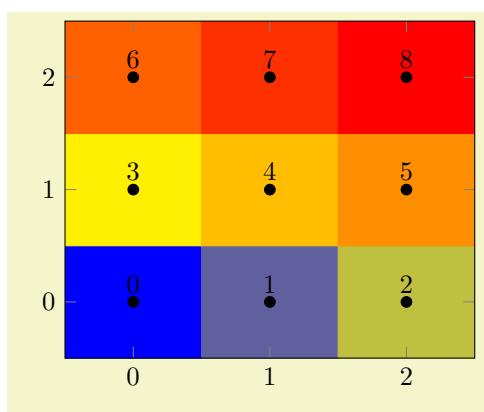

```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
\begin{axis}[enlargelimits=false, axis on top]

\addplot[matrix plot*,
    nodes near coords=\coordindex,mark=*,
    point meta=explicit]
coordinates {
(0,0) [0] (1,0) [1] (2,0) [2]

(0,1) [3] (1,1) [4] (2,1) [5]

(0,2) [6] (1,2) [7] (2,2) [8]
};
\end{axis}
\end{tikzpicture}
```

Actually, `matrix plot*` is a style which is implemented as

```
\pgfplotsset{
    matrix plot*/.style={%
        surf,
        mesh input=image,
        shader=flat corner,
        z buffer=none,
    },
}
```

Where the most important key is `mesh input`. Note that `z buffer=none` avoids reorderings which might affect the color association. Use `z buffer=auto` if you have a need to apply reorderings. Be aware that `z buffer` reorders the color data.

/tikz/`imagesc`   (no value)

`\addplot+[imagesc]`

A pure alias for `matrix plot` because `imagesc` is the reference to this type of plot in other applications.

/tikz/`imagesc*`   (no value)

`\addplot+[imagesc*]`

A pure alias for `matrix plot*`.

4.6.13   Patch Plots

/pgfplots/`patch`   (no value)

`\addplot+[patch]`

Patch plots are similar to `mesh` and `surf` plots in that they describe a filled area by means of a geometry.

However, `patch` plots are defined by *explicitly* providing the elements of the geometry: they expect a sequence of triangles (or other `patch type`s) which make up the mesh.

There are two dimensional and three dimensional patch plots, both with the same interfaces which are explained in the following sections.

The standard input format (constituted by `mesh input=patches`) is to provide a sequence of coordinates (either two– or three–dimensional) as usual. Each consecutive set of points makes up a patch element, which is often a triangle:
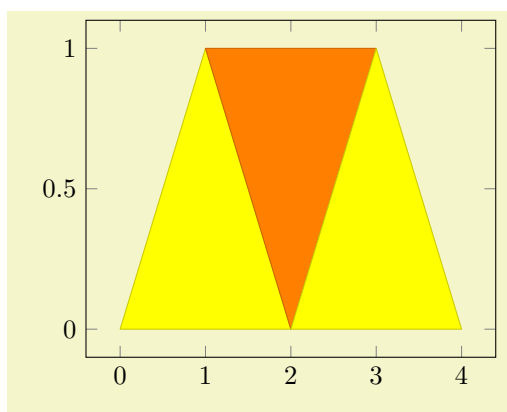
```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
    \begin{axis}
    \addplot[patch]
    table {
        x y
        0 0
        1 1
        2 0
% empty lines do not hurt, they are ignored here:

        1 1
        2 0
        3 1

        2 0
        3 1
        4 0

    };
    \end{axis}
\end{tikzpicture}
```

Patch plots use `point meta` to determine fill colors. In its initial configuration, `point meta` will be set to the y coordinate (or the z coordinate for three dimensional `patch` plots). Set `point meta` somehow to color the patches:
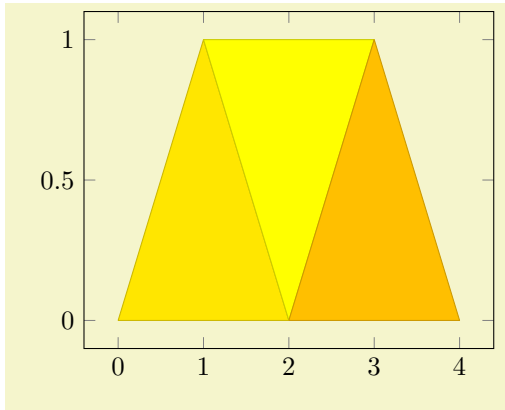
```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
    \begin{axis}
    \addplot[patch]
    table[point meta=\thisrow{c}] {
        x y c
        0 0 0.2
        1 1 0
        2 0 1

        1 1 0
        2 0 1
        3 1 0

        2 0 1
        3 1 0
        4 0 0.5
    };
    \end{axis}
\end{tikzpicture}
```

Patch plots make use of the `mesh` configuration, including the `shader`. Thus, the example above uses the initial `shader=faceted` (which uses the *mean* color data to determine a triangle's color and a related stroke color). The `shader=interp` yields the following result:
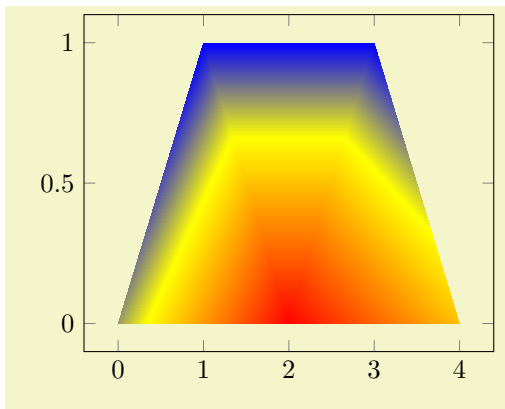
```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
    \begin{axis}
    \addplot[patch,shader=interp]
    table[point meta=\thisrow{c}] {
        x y c
        0 0 0.2
        1 1 0
        2 0 1

        1 1 0
        2 0 1
        3 1 0

        2 0 1
        3 1 0
        4 0 0.5
    };
    \end{axis}
\end{tikzpicture}
```

For triangles, `shader=interp` results in linearly interpolated `point meta` values throughout each individual triangle, which are then mapped to the color map (a technique also known as Gouraud shading).

The color data does not need to be continuous, it is associated to triangle vertices. Thus, changing some of the color values allows individually shaded regions:
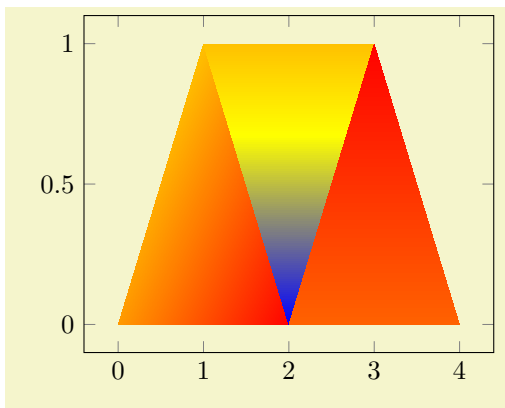
```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
    \begin{axis}
    \addplot[patch,shader=interp]
    table[point meta=\thisrow{c}] {
        x y c
        0 0 0.2
        1 1 0
        2 0 1

        1 1 0
        2 0 -1
        3 1 0

        2 0 0.5
        3 1 1
        4 0 0.5
    };
    \end{axis}
\end{tikzpicture}
```

Two dimensional `patch` plots simply draw triangles in their order of appearance. In three dimensions, single elements are sorted according to their view depth, with foreground elements drawn on top of background elements ("Painter's algorithm", see `z buffer`=`sort`).

/pgfplots/**patch table**={⟨*table file name or inline table*⟩}   (initially `empty`)
/pgfplots/**patch table with point meta**={⟨*table file name or inline table*⟩}   (initially `empty`)
/pgfplots/**patch table with individual point meta**={⟨*table file name or inline table*⟩} (initially `empty`)

Allows to provide patch connectivity data stored in an input table.

A non–empty argument for `patch table` enables patch input mode. Now, the standard input stream is a long list of vertices which are stored in an array using their `\coordindex` as key. Each row of ⟨*table file name or inline table*⟩ makes up one patch, defined by indices into the vertex array:
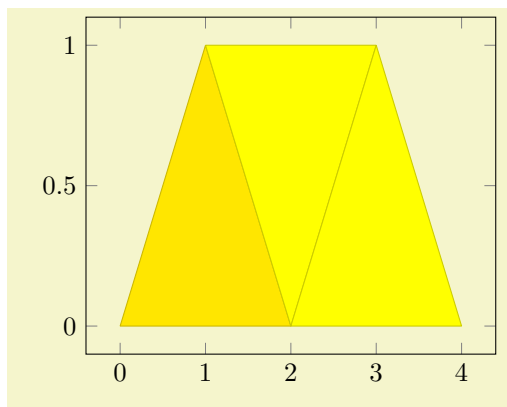

```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
    \begin{axis}
    \addplot[patch,table/row sep=\\,patch table={%
        0 1 2\\
        1 2 3\\
        4 3 5\\
    }]
    table[row sep=\\,point meta=\thisrow{c}] {
        x y c  \\
        0 0 0.2\\% 0
        1 1 0   \\% 1
        2 0 1   \\% 2
        3 1 0   \\% 3
        2 0 0.5\\% 4
        4 0 0.5\\% 5
    };
    \end{axis}
\end{tikzpicture}
```

The example consists of *two separate* tables. The `patch table` argument is a table, provided inline where rows are separated by `\\` (which is the purpose of the `row sep`=`\\` key as you guessed[31]). The `patch table` here declares three triangles: the triangle made up by vertex #0, #1 and #2, the triangle made up by #1, #2 and #3 and finally the one using the vertices #4, #3 and #5. The vertices as such are provided using the standard input methods of PGFPLOTS; in our case using a table as well. The standard input simply provides coordinates (and `point meta`) which are stored in the vertex array; you could also have used `plot coordinates` to provide them (or `plot expression`).

The argument to `patch table` needs to be a table – either a file name or an inline table as in the example above. The first n columns of this table are assumed to contain indices into the vertex array (which is made up using all vertices of the standard input as explained in the previous paragraph). The entries in this table can be provided in floating point, just make sure they are not rounded. The variable n is the number of vertices required to make up a single patch. For triangular patches, it is $n = 3$, for `patch type`=`bilinear` it is $n = 4$ and similar for other choices of `patch type`.

The alternative `patch table with point meta` is almost the same as `patch table` – but it allows to provide (a single) `point meta` (color data) per patch instead of per vertex. Here, a further column of the argument table is interpreted as color data:

---

[31]Note that the choice `row sep`=`\\` is much more robust here: newlines would be converted to spaces by TEX before PGFPLOTS had a chance to see them.
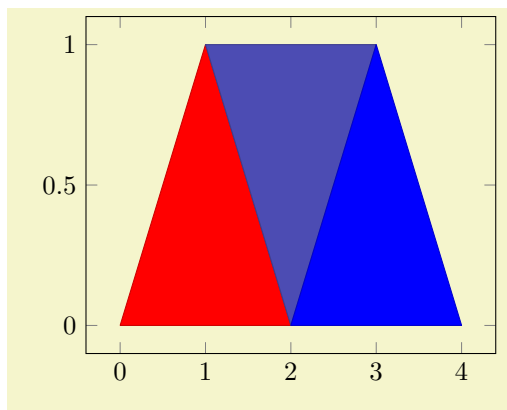
```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
    \begin{axis}
    % this uses per-patch color data:
    \addplot[patch,table/row sep=\\,
    patch table with point meta={%
        0 1 2 100\\
        1 2 3 10\\
        4 3 5 0\\
    }]
    table[row sep=\\] {
        x y \\
        0 0 \\% 0
        1 1 \\% 1
        2 0 \\% 2
        3 1 \\% 3
        2 0 \\% 4
        4 0 \\% 5
    };
    \end{axis}
\end{tikzpicture}
```

The `patch table with point meta` always prefers `point meta` data from the provided table argument. However, it is still supported to write `point meta=\thisrow{⟨colname⟩}` or similar constructs – but now, ⟨colname⟩ refers to the provided table argument. More precisely, `point meta` is evaluated in a context where the patch connectivity has been resolved and the `patch table with point meta` is loaded.

The other alternative `patch table with individual point meta` is very similar, but instead of a flat color per patch, it allows to write one color value for every patch:
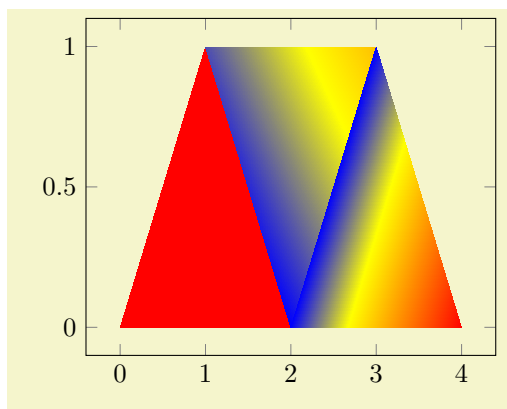

```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
    \begin{axis}
    % this uses n per-patch color values:
    \addplot[patch,shader=interp,
    table/row sep=\\,
    patch table with individual point meta={%
        0 1 2 100 100 100\\% V_0 V_1 V_2 C_0 C_1 C_2
        1 2 3 10 0 50\\
        4 3 5 0 0 100\\
    }]
    table[row sep=\\] {
        x y \\
        0 0 \\% 0
        1 1 \\% 1
        2 0 \\% 2
        3 1 \\% 3
        2 0 \\% 4
        4 0 \\% 5
    };
    \end{axis}
\end{tikzpicture}
```

To find the `point meta` data for vertex $\#i, i = 0, 1, 2$, PGFPLOTS searches in column $i + n$ where n is the number of vertices for `patch type` (in our case, $n = 3$).

Technical remark: The key `patch table with individual point meta` automatically installs `point meta`=explicit as well. It might be confusing to override the value of `point meta` here (although it is allowed).

The `patch table` input type allows to reduce the size of geometries since vertices are stored just once. PGFPLOTS unpacks them into memory into the redundant format in order to work with single patch elements[32]. In case you experience TeX memory problems with this connectivity input, consider using the redundant format. It uses other types of memory limits.

A more involved example is shown below; it uses `\addplot3[patch]` to visualize a three dimensional `patch` plot, provided by means of a long sequence of patches:

---

[32]The reason for such an approach is that TeX doesn't really know what an array is – and according to my experience, arrays implemented by macros tend to blow up TeX's memory limits even faster than the alternative.
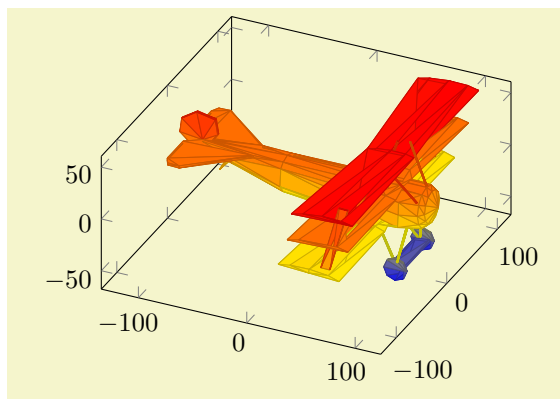
```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
\begin{axis}[axis equal]
% FokkerDrI_layer_0.patches.dat contains:
% # each row is one vertex; three consecutive
% # vertices make one triangle (patch)
% 105.577    -19.7332    2.85249
% 88.9233    -21.1254    13.0359
% 89.2104    -22.1547    1.46467
% # end of facet 0
% 105.577    -19.7332    2.85249
% 105.577    -17.2161    12.146
% 88.9233    -21.1254    13.0359
% # end of facet 1
\addplot3[patch]
    file
    {plotdata/FokkerDrI_layer_0.patches.dat};
\end{axis}
\end{tikzpicture}
```

The ordering in which triangles are specified is irrelevant, three–dimensional patch plots use z buffer=sort to sort patches according to their depth (defined as mean depth over each vertex), where foreground patches are drawn on top of background patches. This so–called "Painter's algorithm" works well for most meshes. If it fails, consider using patch refines=1 or patch refines=2 to split larger elements into small ones automatically.

The drawing color associated to single vertices can be changed using the point meta key (which is the common method to configure color data in PGFPLOTS). The initial configuration is point meta=z for three dimensional patch plots, i.e. to use the z coordinate also as color data. Use point meta=\thisrow{⟨colname⟩} in conjunction with \addplot3[patch] table to load a selected table column.

Patch plots are (almost) the same as mesh or surf plots, they only have more freedom in their input format (and a more complicated geometry). Actually, "patch" is just a style for surf,mesh input=patches. In other words, patch *is* the same as surf, it even shares the same internal implementation. Thus, most of the keys to configure mesh or surf plots apply to patch as well, especially shader and z buffer. As already mentioned, \addplot3[patch] automatically activates z buffer=sort to ensure a good drawing sequence. The shader can be used to modify the appearance:
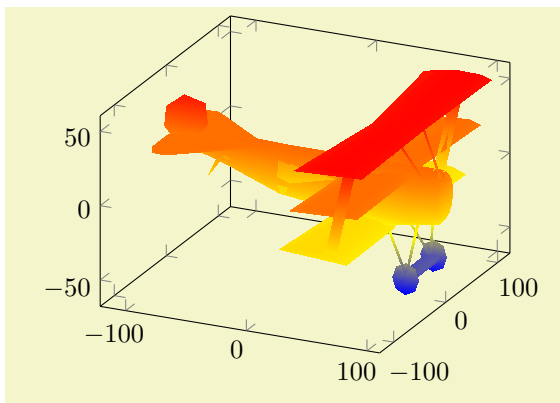

```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
\begin{axis}
% FokkerDrI_layer_0.facetIdx.dat contains:
% # each row makes up one facet; it
% # consists of 0-based indices into
% # the vertex array
% 0    1    2 % triangle of vertices #0,#1 and #2
% 0    3    1 % triangle of vertices #0,#3 and #1
% 3    4    1
% 5    6    7
% 6    8    7
% 8    9    7
% 8    10    9
% ...
% while FokkerDrI_layer_0.vertices.dat contains
% 105.577    -19.7332    2.85249    % vertex #0
% 88.9233    -21.1254    13.0359    % vertex #1
% 89.2104    -22.1547    1.46467    % vertex #2
% 105.577    -17.2161    12.146
% 105.577    -10.6054    18.7567
% 105.577    7.98161    18.7567
% 105.577    14.5923    12.146
% ...
\addplot3[patch,shader=interp,
    patch table=
        {plotdata/FokkerDrI_layer_0.facetIdx.dat}]
    file
    {plotdata/FokkerDrI_layer_0.vertices.dat};
\end{axis}
\end{tikzpicture}
```

See the description of `shader`=`interp` for details and remarks. The example above makes use of the alternative syntax to provide a geometry: the `patch table` input. It allows to provide vertices separate from patch connectivity, where each patch is defined using three indices into the vertex array as discussed above.
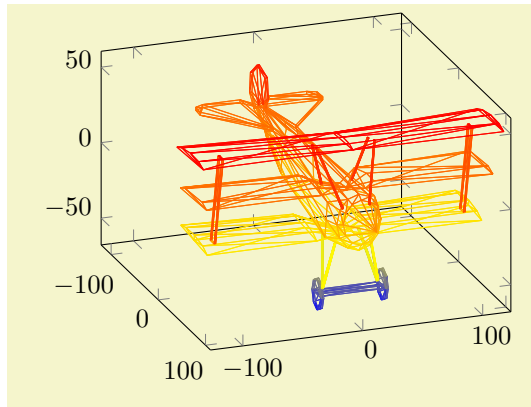

```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
\begin{axis}[view/h=70]
% FokkerDrI_layer_0.patches.dat contains:
% # each row is one vertex; three consecutive
% # vertices make one triangle (patch)
% 105.577    -19.7332     2.85249
% 88.9233    -21.1254    13.0359
% 89.2104    -22.1547     1.46467
% # end of facet 0
% 105.577    -19.7332     2.85249
% 105.577    -17.2161    12.146
% 88.9233    -21.1254    13.0359
% # end of facet 1
\addplot3[patch,mesh]
    file
    {plotdata/FokkerDrI_layer_0.patches.dat};
\end{axis}
\end{tikzpicture}
```

/pgfplots/mesh input=lattice|patches|image

This key controls how input coordinates are decoded to get patches. It is used only if `patch table` is empty (`patch table` has its own way to decode input coordinates). Usually, you won't need to bother with this key as it is set implicitly.

The choice `mesh input`=`lattice` is the initial configuration for `mesh` and `surf` plots: it expects input in a compact matrix form as described at the beginning of this section starting with page 122 and requires a `mesh/ordering` and perhaps end–of–scanline markers. It yields patches with exactly four corners and is compatible with `patch type`=`rectangle` and `patch type`=`bilinear` (the latter requiring to load the `patchplots` library). In this case, the input stream contains the *vertices*.

The choice `mesh input`=`patches` is implicitly set when you use the `patch` style (remember that `surf` is actually some sort of patch plot on its own). It expects the input format as described for `patch` plots, i.e. n consecutive coordinates make up the vertices of a single patch where n is the expected number of vertices for the configured `patch type`.

The choice `mesh input`=`image` implements `matrix plot`: it expects input in the same technical format as for `mesh input`=`lattice` (i.e. using end–of–scanline markers, `mesh/ordering`, etc), but the coordinates are interpreted as patch *mid points*. It yields patches with exactly four corners and is compatible with `patch type`=`rectangle` and `patch type`=`bilinear`. The patches are generated by interpolating the coordinates between adjacent cell mid points. Vertices which have only one adjacent cell mid point are extrapolated. This choice is unsupported for one–dimensional inputs, i.e. for lines or for $1 \times n$ or $n \times 1$ matrices. See `matrix plot` for more details.

Note that a non–empty `patch table` implies `mesh input`=`patches`.

/pgfplots/patch type=default|rectangle|triangle|line   (initially `default`)

Defines the type of patch.

The initial configuration `patch type`=`default` checks the configuration of `mesh input`: for `mesh input`=`patches`, it uses `triangle`. For `mesh input`=`lattice`, it checks if there is just one row or just one col and uses `patch type`=`line` in such a case, otherwise it uses `patch type`=`rectangle`.

The choice `patch type`=`rectangle` expects $n = 4$ vertices. The vertices can be either encoded as a matrix or, using `mesh input`=`patches`, in the sequence in which you would connect the vertices:
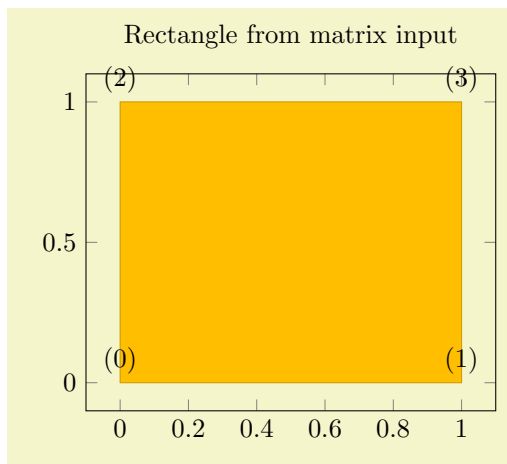
Rectangle from matrix input

```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
    \begin{axis}[nodes near coords={(\coordindex)},
        title=Rectangle from matrix input]
    % note that surf implies 'patch type=rectangle'
    \addplot[surf,mesh/rows=2,patch type=rectangle]
    coordinates {
        (0,0) (1,0)
        (0,1) (1,1)
    };
    \end{axis}
\end{tikzpicture}
```
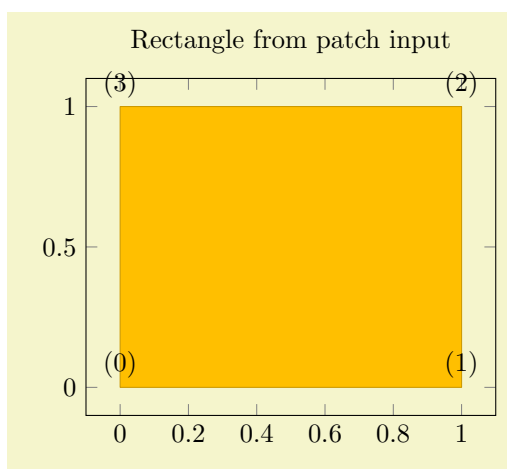
Rectangle from patch input

```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
    \begin{axis}[nodes near coords={(\coordindex)},
        title=Rectangle from patch input]
    \addplot[patch,patch type=rectangle]
    coordinates {
        (0,0) (1,0) (1,1) (0,1)
    };
    \end{axis}
\end{tikzpicture}
```

As for all other `patch type` values, the vertices can be arbitrary two– or three–dimensional points, there may be even two on top of each other (resulting in a triangle). When used together with `shader`=`interp`, `patch type`=`rectangle` is visualized using two Gouraud shaded triangles (see below for `triangle`). It is the *most efficient* representation for interpolated shadings together with `mesh input`=`lattice` since the input lattice is written directly into the pdf. Use `patch type`=`rectangle` if you want rectangular elements and perhaps "some sort" of smooth shading. Use `patch type`=`bilinear` of the `patchplots` library in case you need real bilinear shading. Examples of such shadings can be found in Section 5.9.1.

The choice `patch type`=`triangle` expects $n = 3$ vertices which make up a triangle. The ordering of the vertices is irrelevant:
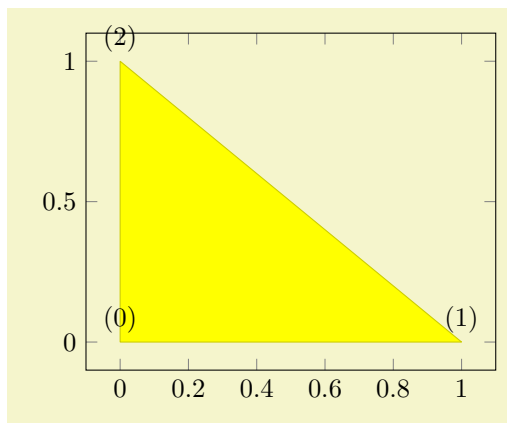
```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
    \begin{axis}[nodes near coords={(\coordindex)}]
    \addplot[patch,patch type=triangle]
    coordinates {
        (0,0) (1,0) (0,1)
    };
    \end{axis}
\end{tikzpicture}
```

The use of `shader`=`interp` is implemented by means of linear interpolation of the three color values (specified with the `point meta` key) between the corners; the resulting interpolated `point meta`

values are then mapped into the actual `colormap`. This type of interpolation is called Gouraud shading. Examples of such shadings can be found in Section 5.9.1.

The choice `patch type=line` expects $n = 2$ vertices which make up a line. It is used for one-dimensional `mesh` plots (see Section 4.5.13 for examples).

There are more values for `patch type` like `bilinear`, `triangle quadr`, `biquadratic`, `coons`, `polygon` and `tensor bezier`. Please refer to the separate `patchplots` library in Section 5.9.

/pgfplots/every patch   (style, no value)

This style will be installed as soon as the `patch` plot handler is activated.

The initial configuration is

```
\pgfplotsset{
    every patch/.style={miter limit=1}
}
```

which improves display of sharp triangle corners significantly (see the TikZ manual for details about `miter limit` and line join parameters).

There is much more to say about patch plots, like `patch type` which allows triangles, bilinear elements, quadratic triangles, biquadratic quadrilaterals, coons patches; the `patch refines` key which allows automatic refinement, `patch to triangles` which triangulates higher order elements; how matrix data can be used for rectangular shapes and more. These details are subject of the `patchplots` library in Section 5.9.

4.6.14 About 3D Const Plots and 3D Bar Plots

There are currently *no* equivalents of `const plot` and its variants or the bar plot types like `ybar` for three dimensional axes, sorry.

4.6.15 Mesh/Surface Plots with Holes
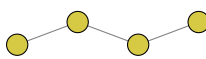
Please refer to Section 4.5.14 for interrupted plots.

4.7 Markers, Linestyles, (Background-) Colors and Colormaps
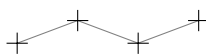
The following options of TikZ are available to plots.

4.7.1 Markers

This list is copied from [7, section 29]:
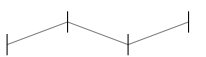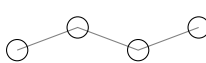
And with `\usetikzlibrary{plotmarks}`:
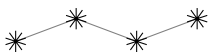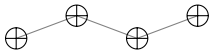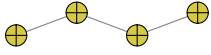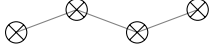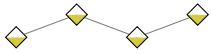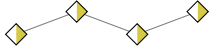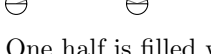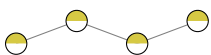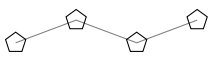
mark=10-pointed star

mark=oplus

mark=oplus*

mark=otimes

mark=otimes*

mark=square

mark=square*

mark=triangle

mark=triangle*

mark=diamond

mark=diamond*

mark=halfdiamond*

mark=halfsquare*

mark=halfsquare right*

mark=halfsquare left*

mark=Mercedes star

mark=Mercedes star flipped

mark=halfcircle

One half is filled with white (more precisely, with `mark color`).

mark=halfcircle*

One half is filled with white (more precisely, with `mark color`) and the other half is filled with the actual `fill` color.

mark=pentagon

mark=pentagon*

mark=ball

This marker is special and can easily generate big output files if there are lots of them. It is also special in that it needs `ball color` to be set (in our case, it is `ball color=yellow!80!black`.

mark=text

This marker is special as it can be configured freely. The character (or even text) used is configured by a set of variables, see below.

mark=cube
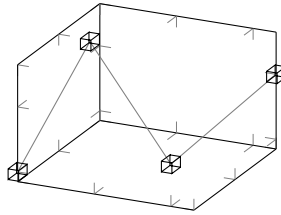
This marker is only available inside of a PGFPLOTS axis, it draws a cube with axis parallel faces. Its dimensions can be configured separately, see below.

mark=cube*
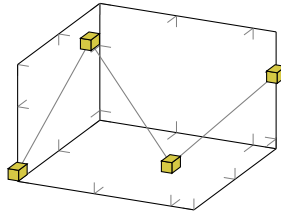
User defined It is possible to define new markers with `\pgfdeclareplotmark`, see below.

All these options have been drawn with the additional options

```
\draw[
    gray,
    thin,
    mark options={%
        scale=2,fill=yellow!80!black,draw=black
    }
]
```

Please see Section 4.7.5 for how to change `draw` and `fill` colors. Note that each of the provided marks can be rotated freely by means of `mark options`={rotate=90} or `every mark/.append style`={rotate=90}.

/tikz/**mark size**={⟨*dimension*⟩}   (initially 2pt)

This TikZ option allows to set marker sizes to ⟨*dimension*⟩. For circular markers, ⟨*dimension*⟩ is the radius, for other plot marks it is about half the width and height.

/pgfplots/**cube/size x**={⟨*dimension*⟩}   (initially \pgfplotmarksize=2pt)
/pgfplots/**cube/size y**={⟨*dimension*⟩}   (initially \pgfplotmarksize=2pt)
/pgfplots/**cube/size z**={⟨*dimension*⟩}   (initially \pgfplotmarksize=2pt)

Sets the size for `mark`=cube separately for every axis.

/tikz/**every mark**   (no value)

This TikZ style can be reconfigured to set marker appearance options like colors or transformations like scaling or rotation. PGFPLOTS appends its `cycle list` options to this style.
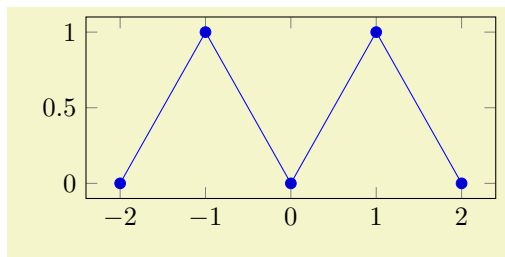
```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
\begin{axis}[y=2cm]
    \addplot coordinates
        {(-2,0) (-1,1) (0,0) (1,1) (2,0)};
\end{axis}
\end{tikzpicture}
```
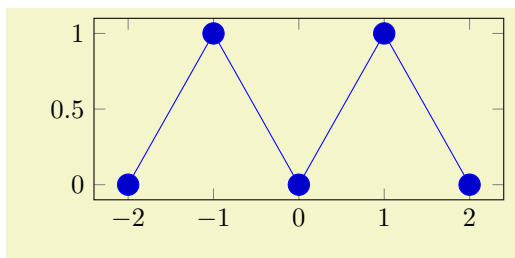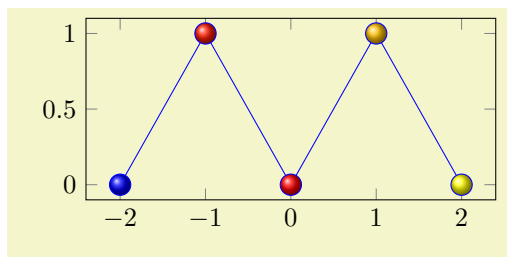
```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\tikzset{every mark/.append style={scale=2}}
\begin{tikzpicture}
\begin{axis}[y=2cm]
    \addplot coordinates
        {(-2,0) (-1,1) (0,0) (1,1) (2,0)};
\end{axis}
\end{tikzpicture}
```
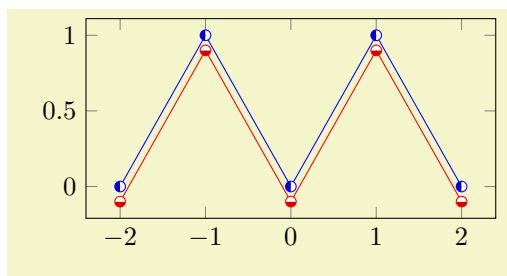
```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
\begin{axis}[y=2cm]
  \addplot+[
    mark=halfcircle*,
    every mark/.append style={rotate=90}]
  coordinates
    {(-2,0) (-1,1) (0,0) (1,1) (2,0)};

  \addplot+[
    mark=halfcircle*,
    every mark/.append style={rotate=180}]
  coordinates
    {(-2,-0.1) (-1,0.9) (0,-0.1) (1,0.9) (2,-0.1)};
\end{axis}
\end{tikzpicture}
```

Note that `every mark` is kind of static in the sense that it is evaluated once only. If you need individually colored markes as part of a `scatter` plot, you will need to resort to `scatter/use mapped color`.

```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
\begin{axis}[y=2cm]
  \addplot+[
    mark=ball,
    mark size=4pt,
    scatter,% enable scatter
    scatter src=rand,% the "color data"
    % configure individual appearances:
    scatter/use mapped color=
      {ball color=mapped color}]
  coordinates
    {(-2,0) (-1,1) (0,0) (1,1) (2,0)};

\end{axis}
\end{tikzpicture}
```

/pgfplots/no markers   (style, no value)

A key which overrides any `mark` value set by `cycle list` of option lists after `\addplot`.

If this style is provided as argument to a complete axis, it is appended to `every axis plot post` such that it disables markers even for `cycle list`s which contain markers.

/tikz/mark repeat={⟨integer⟩}   (initially empty)

Allows to draw only each nth `mark` where n is provided as ⟨integer⟩.

/tikz/mark phase={⟨integer p⟩}   (initially 1)

This option allows to control which markers are drawn. It is primarily used together with the TikZ option `mark repeat`=r: it tells TikZ that the first mark to be draw should be the pth, followed by the $(p + r)$th, then the $(p + 2r)$th, and so on.
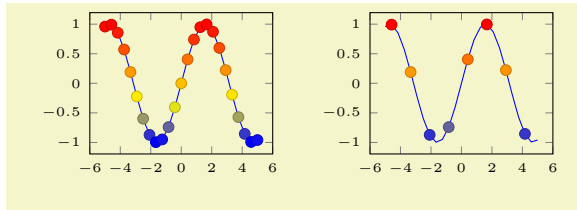
```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
    \begin{axis}[tiny]
    \addplot+[scatter] {sin(deg(x))};
    \end{axis}
\end{tikzpicture}
\begin{tikzpicture}
    \begin{axis}[tiny]
    \addplot+[scatter,
      mark repeat=3,mark phase=2]
      {sin(deg(x))};
    \end{axis}
\end{tikzpicture}
```

Here, $p = 1$ is the first point (the one with `\coordindex` = 0).

/tikz/mark indices={⟨*index list*⟩}   (initially `empty`)

Allows to draw only the marker whose index numbers are in the argument list.

/pgf/mark color={⟨*color*⟩}   (initially `empty`)

Defines the *additional* fill color for the `halfcircle`, `halfcircle*`, `halfdiamond*` and `halfsquare*` markers. An empty value uses `white` (which is the initial configuration). The value `none` disables filling for this part.

These markers have two distinct fill colors, one is determined by `fill` as for any other marker and the other one is `mark color`.
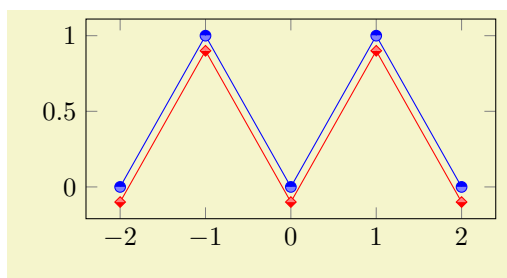
```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
\begin{axis}[y=2cm]
  \addplot[
    blue,mark color=blue!50!white,
    mark=halfcircle*]
  coordinates
    {(-2,0) (-1,1) (0,0) (1,1) (2,0)};

  \addplot[
    red,mark color=red!50!white,
    mark=halfsquare*]
  coordinates
    {(-2,-0.1) (-1,0.9) (0,-0.1) (1,0.9) (2,-0.1)};
\end{axis}
\end{tikzpicture}
```

Note that this key requires PGF 2.10 or later.

/tikz/mark options={⟨*options*⟩}

Resets `every mark` to {⟨*options*⟩}.

/pgf/text mark={⟨*text*⟩}   (initially `p`)

Changes the text shown by `mark=text`.

With **/pgf/text mark**=m:

With **/pgf/text mark**=A:

There is no limitation about the number of characters or whatever. In fact, any TeX material can be inserted as ⟨*text*⟩, including images.

/pgf/text mark style={⟨*options for* `mark=text`⟩}

Defines a set of options which control the appearance of `mark=text`.

If **/pgf/text mark as node**=false (the default), ⟨*options*⟩ is provided as argument to `\pgftext` – which provides only some basic keys like `left`, `right`, `top`, `bottom`, `base` and `rotate`.

If **/pgf/text mark as node**=true, ⟨*options*⟩ is provided as argument to `\node`. This means you can provide a very powerful set of options including `anchor`, `scale`, `fill`, `draw`, `rounded corners` etc.

/pgf/text mark as node=true|false   (initially false)

>   Configures how mark=text will be drawn: either as \node or as \pgftext.

>   The first choice is highly flexible and possibly slow, the second is very fast and usually enough.

\pgfdeclareplotmark{⟨plot mark name⟩}{⟨code⟩}

>   Defines a new marker named ⟨plot mark name⟩. Whenever it is used, ⟨code⟩ will be invoked. It is supposed to contain (preferrable PGF basic level) drawing commands. During ⟨code⟩, the coordinate system's origin denotes the coordinate where the marker shall be placed.

>   Please refer to [7] section "Mark Plot Handler" for more detailed information.

/pgfplots/every axis plot post   (style, initially)

>   The every axis plot post style can be used to overwrite parts (or all) of the drawing styles which are assigned for plots.
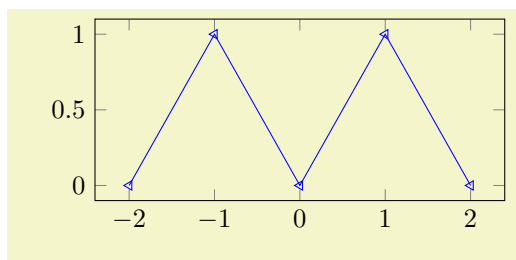
```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
% Overwrite any cycle list:
\pgfplotsset{
  every axis plot post/.append style={
    mark=triangle,
    every mark/.append style={rotate=90}}}
\begin{tikzpicture}
\begin{axis}[y=2cm]
    \addplot coordinates
        {(-2,0) (-1,1) (0,0) (1,1) (2,0)};
\end{axis}
\end{tikzpicture}
```

>   Markers paths are not subjected to clipping as other parts of the figure. Markers are either drawn completely or not at all.

>   TikZ offers more options for marker fine tuning, please refer to [7] for details.

4.7.2   Line Styles

The following line styles are predefined in TikZ.

/tikz/solid   (style, no value)
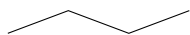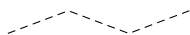
/tikz/dotted   (style, no value)
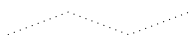
/tikz/densely dotted   (style, no value)

/tikz/loosely dotted   (style, no value)

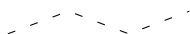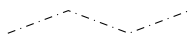/tikz/dashed   (style, no value)

/tikz/densely dashed   (style, no value)

/tikz/loosely dashed   (style, no value)

/tikz/dashdotted   (style, no value)

/tikz/**densely dashdotted** (style, no value)

/tikz/**loosely dashdotted** (style, no value)
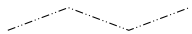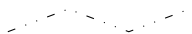
/tikz/**dashdotdotted** (style, no value)

/tikz/**densely dashdotdotted** (style, no value)

/tikz/**loosely dashdotdotted** (style, no value)

since these styles apply to markers as well, you may want to consider using

```
\pgfplotsset{
    every mark/.append style={solid}
}
```

in marker styles.

Besides linestyles, PGF also offers (a lot of) arrow heads. Please refer to [7] for details.

4.7.3 Edges and Their Parameters

When PGFPLOTS connects points, it relies on PGF drawing parameters to create proper edges (and it only changes them in the **every patch** style).

It might occasionally be necessary to change these parameters:

/tikz/**line cap**=round|rect|butt (initially butt)
/tikz/**line join**=round|bevel|miter (initially miter)
/tikz/**miter limit**=⟨*factor*⟩ (initially 10)

These keys control how lines are joined at edges. Their description is beyond the scope of this manual, so interested readers should consult [7].

Here is just an example illustrating why it might be of interest to study these parameters:
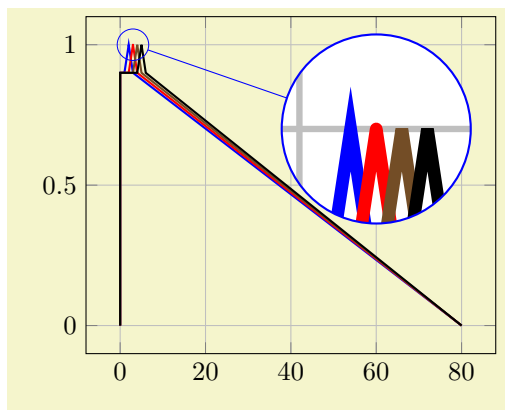

```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
% requires \usetikzlibrary{spy}
\begin{tikzpicture}[spy using outlines=
    {circle, magnification=6, connect spies}]
\begin{axis}[no markers,grid=major,
    every axis plot post/.append style={thick}]
\addplot  coordinates
 {(0, 0.0) (0, 0.9) (1, 0.9) (2, 1) (3, 0.9) (80, 0)};
\addplot +[line join=round] coordinates
 {(0, 0.0) (0, 0.9) (2, 0.9) (3, 1) (4, 0.9) (80, 0)};
\addplot +[line join=bevel] coordinates
 {(0, 0.0) (0, 0.9) (3, 0.9) (4, 1) (5, 0.9) (80, 0)};
\addplot +[miter limit=5] coordinates
 {(0, 0.0) (0, 0.9) (4, 0.9) (5, 1) (6, 0.9) (80, 0)};

  \coordinate (spypoint) at (3,1);
  \coordinate (magnifyglass) at (60,0.7);
\end{axis}

\spy [blue, size=2.5cm] on (spypoint)
   in node[fill=white] at (magnifyglass);
\end{tikzpicture}
```

4.7.4   Font Size and Line Width

Often, one wants to change line width and font sizes for plots. This can be done using the following options of TikZ.

/tikz/**font**={⟨*font name*⟩}   (initially \normalfont)

Sets the font which is to be used for text in nodes (like tick labels, legends or descriptions).

A font can be any LaTeX argument like \footnotesize or \small\bfseries[33].

It may be useful to change fonts only for specific axis descriptions, for example using

```
\pgfplotsset{
    tick label style={font=\small},
    label style={font=\small},
    legend style={font=\footnotesize}
}
```

See also the predefined styles normalsize, small and footnotesize in Section 4.10.2.

/tikz/**line width**={⟨*dimension*⟩}   (initially 0.4pt)

Sets the line width. Please note that line widths for tick lines and grid lines are predefined, so it may be necessary to override the styles every tick and every axis grid.

The line width key is changed quite often in TikZ. You should use

```
\pgfplotsset{every axis/.append style={line width=1pt}}
```

or

```
\pgfplotsset{every axis/.append style={thick}}
```

to change the overall line width. To also adjust ticks and grid lines, one can use

```
\pgfplotsset{every axis/.append style={
    line width=1pt,
    tick style={line width=0.6pt}}}
```

or styles like

```
\pgfplotsset{every axis/.append style={
    thick,
    tick style={semithick}}}
```

The 'every axis plot' style can be used to change line widths for plots only.

/tikz/**thin**   (no value)
/tikz/**ultra thin**   (no value)
/tikz/**very thin**   (no value)
/tikz/**semithick**   (no value)
/tikz/**thick**   (no value)
/tikz/**very thick**   (no value)
/tikz/**ultra thick**   (no value)

These TikZ styles provide different predefined line widths.

---

[33]ConTeXt and plain TeX users need to provide other statements, of course.
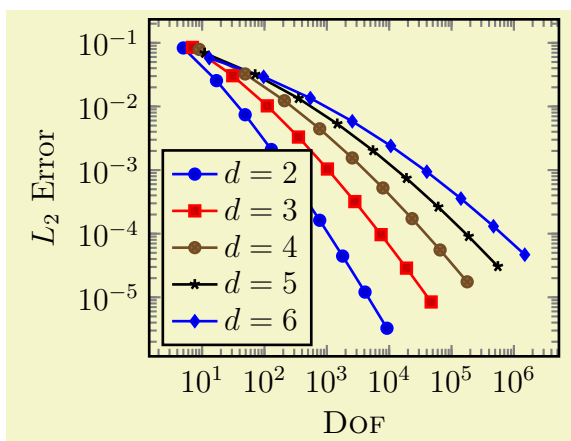
```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\pgfplotsset{every axis/.append style={
    font=\large,
    line width=1pt,
    tick style={line width=0.8pt}}}
\begin{tikzpicture}
\begin{loglogaxis}[
    legend style={at={(0.03,0.03)},
        anchor=south west},
    xlabel=\textsc{Dof},
    ylabel=$L_2$ Error
]
\addplot coordinates {
    (5,8.312e-02)   (17,2.547e-02)   (49,7.407e-03)
    (129,2.102e-03) (321,5.874e-04)  (769,1.623e-04)
    (1793,4.442e-05) (4097,1.207e-05) (9217,3.261e-06)
};

\addplot coordinates{
    (7,8.472e-02)   (31,3.044e-02)   (111,1.022e-02)
    (351,3.303e-03) (1023,1.039e-03) (2815,3.196e-04)
    (7423,9.658e-05) (18943,2.873e-05)
    (47103,8.437e-06)};

\addplot coordinates{
    (9,7.881e-02)    (49,3.243e-02)   (209,1.232e-02)
    (769,4.454e-03)  (2561,1.551e-03)
    (7937,5.236e-04) (23297,1.723e-04)
    (65537,5.545e-05) (178177,1.751e-05)};

\addplot coordinates{
    (11,6.887e-02)   (71,3.177e-02)   (351,1.341e-02)
    (1471,5.334e-03) (5503,2.027e-03)
    (18943,7.415e-04) (61183,2.628e-04)
    (187903,9.063e-05) (553983,3.053e-05)};

\addplot coordinates{
    (13,5.755e-02)   (97,2.925e-02)   (545,1.351e-02)
    (2561,5.842e-03) (10625,2.397e-03)
    (40193,9.414e-04) (141569,3.564e-04)
    (471041,1.308e-04) (1496065,4.670e-05)};
\legend{$d=2$,$d=3$,$d=4$,$d=5$,$d=6$}
\end{loglogaxis}
\end{tikzpicture}
```

The preceding example defines data which is used a couple of times throughout this manual; it is referenced by `\plotcoords`.
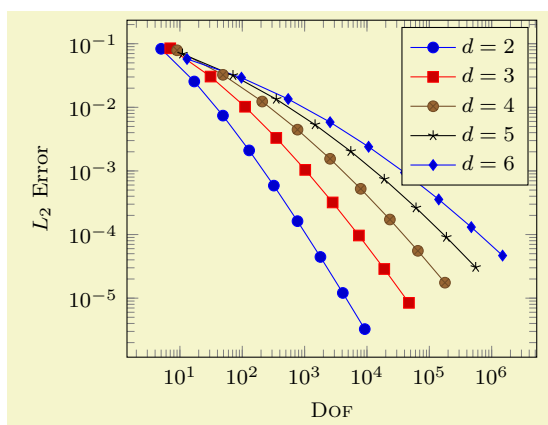

```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\pgfplotsset{every axis/.append style={
    font=\footnotesize,
    thin,
    tick style={ultra thin}}}
\begin{tikzpicture}
    \begin{loglogaxis}[
        xlabel=\textsc{Dof},
        ylabel=$L_2$ Error
    ]
    % see above for this macro:
    \plotcoords
    \legend{$d=2$,$d=3$,$d=4$,$d=5$,$d=6$}
    \end{loglogaxis}
\end{tikzpicture}
```

4.7.5 Colors

PGF uses the color support of `xcolor`. Therefore, the main reference for how to specify colors is the `xcolor` manual [3]. The PGF manual [7] is the reference for how to select colors for specific purposes like drawing, filling, shading, patterns etc. This section contains a short overview over the specification of colors in [3] (which is not limited to PGFPLOTS).

The package `xcolor` defines a set of predefined colors, namely ■ red, ■ green, ■ blue, ■ cyan, ■ magenta, ■ yellow, ■ black, ■ gray, □ white, ■ darkgray, ■ lightgray, ■ brown, ■ lime, ■ olive, ■ orange, ■ pink, ■ purple, ■ teal, ■ violet.
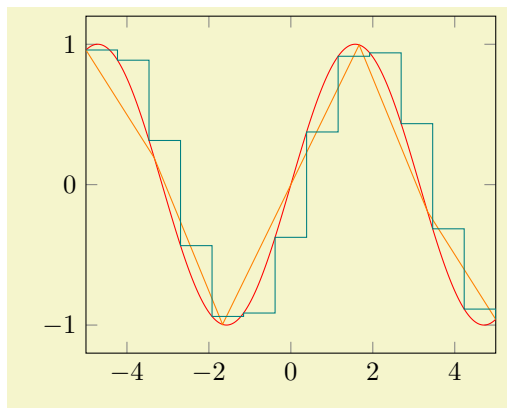
```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
    \begin{axis}[enlarge x limits=false]
    \addplot[red,samples=500] {sin(deg(x))};

    \addplot[orange,samples=7] {sin(deg(x))};

    \addplot[teal,const plot,
        samples=14] {sin(deg(x))};
    \end{axis}
\end{tikzpicture}
```

Besides predefined colors, it is possible to *mix* two (or more) colors. For example, ■ red!30!white contains 30% of ■ red and 70% of □ white. Consequently, one can build ■ red!70!white to get 70% red and 30% white or □ red!10!white for 10% red and 90% white. This mixing can be done with any color, for example ■ red!50!green, ■ blue!50!yellow or ■ green!60!black.

A different type of color mixing is supported, which allows to take 100% of *each* component. For example, ■ rgb,2:red,1;green,1 will add 1/2 part ■ red and 1/2 part ■ green and we reproduced the example from above. Using the denominator 1 instead of 2 leads to ■ rgb,1:red,1;green,1 which uses 1 part ■ red and 1 part ■ green. Many programs allow to select pieces between $0, \ldots, 255$, so a denominator of 255 is useful. Consequently, ■ rgb,255:red,231;green,84;blue,121 uses 231/255 red, 84/255 green and 121/255. This corresponds to the standard RGB color $(231, 84, 121)$. Other examples are ■ rgb,255:red,32;green,127;blue,43, ■ rgb,255:red,178;green,127;blue,43, ■ rgb,255:red,169;green,178;blue,43.

It is also possible to use RGB values, the HSV color model, the CMY (or CMYK) models, or the HTML color syntax directly. However, this requires some more programming. I suppose this is the fastest (and probably the most uncomfortable) method to use colors. For example,

```
\definecolor{color1}{rgb}{1,1,0}
\tikz \fill[color1]
    (0,0) rectangle (1em,0.6em);
```

creates the color with 100% ■ red, 100% ■ green and 0% ■ blue;

```
\definecolor{color1}{cmyk}{0.6,0.9,0.5,0.1}
\tikz \fill[color1]
    (0,0) rectangle (1em,0.6em);
```

creates the color with 60% ■ cyan, 90% ■ magenta, 50% ■ yellow and 10% ■ black;

```
\definecolor{color1}{HTML}{D0B22B}
\tikz \fill[color1]
    (0,0) rectangle (1em,0.6em);
```

creates the color with 208/255 pieces red, 178/255 pieces green and 43 pieces blue, specified in standard HTML notation. Please refer to the `xcolor` manual [3] for more details and color models.

The `xcolor` package provides even more methods to combine colors, among them the prefix '-' (minus) which changes the color into its complementary color (□ -black, ■ -white, ■ -red) or color wheel calculations. Please refer to the `xcolor` manual [3].

/tikz/color={⟨*a color*⟩}
/tikz/draw={⟨*stroke color*⟩}
/tikz/fill={⟨*fill color*⟩}

These keys are (generally) used to set colors. Use `color` to set the color for both drawing and filling. Instead of `color`={⟨*color name*⟩} you can simply write ⟨*color name*⟩. The `draw` and `fill` keys only set colors for stroking and filling, respectively.

Use `draw=none` to disable drawing and `fill=none` to disable filling[34].

Since these keys belong to TikZ, the complete documentation can be found in the TikZ manual [7, Section "Specifying a Color"].

Color Spaces

Since PGFPLOTS relies on `xcolor`, all mechanisms of `xcolor` to define color spaces apply here as well.

One of the most useful approaches is global color space conversion: if you want a document which contains only colors in the `cmyk` color spaces, you can say

```
\usepackage[cmyk]{xcolor}
\usepackage{pgfplots}
```

in order to convert all colors of the entire document (including all shaded) to `cmyk`.

The same can be achieved by means of the `xcolor` statement `\selectcolormodel`.

```
\selectcolormodel{cmyk}
```

4.7.6 Color Maps

A "color map" is a sequence of colors with smooth transitions between them. Color maps are often used to visualize "color data" in plots: in this case, a plot has the position coordinates (x, y) and some additional scalar value (`point meta`) which can be used as "color data". The smallest encountered `point meta` is then mapped to the first color of a `colormap`, the largest encountered value of `point meta` is mapped to the last color of a `colormap`, and interpolation happens in-between.

`/pgfplots/colormap name={⟨color map name⟩}` (initially `hot`)

Changes the current color map to the already defined map named ⟨*color map name*⟩. The predefined color maps are

The definition can be found in the documentation for `colormap/hot` and `colormap/viridis`, respectively. These, and further color maps, are described below.

Color maps can be used, for example, in `scatter` plots and `surf`ace plots.

You can use `colormap` to create new color maps (see below).

`/pgfplots/colormap={⟨name⟩}{⟨color specification⟩}`

Defines a new colormap named ⟨*name*⟩ according to ⟨*color specification*⟩ and activates it using `colormap name={⟨name⟩}`.

A simple ⟨*color specification*⟩ is just a sequence of color definitions of type

⟨*color type*⟩=(⟨*color value*⟩)

separated by either white spaces or semicolon or comma:

```
\pgfplotsset{colormap={CM}{rgb=(0,0,1) color=(black) rgb255=(238,140,238)}}
```


Here, the three input colors form the left end, middle point, and right end of the interval, respectively. A couple of ⟨*color type*⟩s are available, the ⟨*color value*⟩ depends on the actual ⟨*color type*⟩ which is shown below in all detail. Most `colormap` definitions use the simple form and merely list suitable color definitions.

---

[34]Up to now, plot marks always have a stroke color (some also have a fill color). This restriction may be lifted in upcoming versions.

A more advanced ⟨*color specification*⟩ is one which defines both colors and positions in order to define the place of each color. In this case, PGFPLOTS offers the syntax

⟨*color type*⟩(⟨*offset*⟩)=(⟨*color value*⟩):

```
\pgfplotsset{colormap={CM}{rgb(-500)=(0,0,1) color(0)=(black) rgb255(1500)=(238,140,238)}}
```

This syntax allows to distribute colors over the interval using non-uniform distances.

Compatibility note : PGFPLOTS up to and including version 1.13 offered just rudimentary support for non-uniform color maps. You need to write `compat`=1.14 or higher in order to make use of non-uniform color maps.

The positions can be arbitrary numbers[35] (or dimensions), but each new color must come with a larger position than its preceding one. The position can be omitted in which case it will be deduced from the context: if the first two colors have no position, the first will receive position 0 and the second will receive position "1cm". All following ones receive the last encountered mesh width. Note that non-uniform positions make a real difference in conjunction with `colormap access`=piecewise const.

The precise input format is described in the following section.

Colormap Input Format Reference

Each entry in ⟨*color specification*⟩ has the form

⟨*color model*⟩(⟨*position*⟩)=(⟨*arguments*⟩) or

⟨*special mode*⟩(⟨*position*⟩)=(⟨*argument*⟩ `of` ⟨*colormap name*⟩)

where the most common form is to specify a color using a ⟨*color model*⟩ like `rgb`=(0,0.5,1). The ⟨*special mode*⟩s are discussed later in Section 4.7.6 on page 198; they are useful to access colors of existing colormaps. The ⟨*position*⟩ argument is optional and defaults to 0 for the first color, 1cm for the second, and an automatically deduced mesh grid for all following ones. The number range of ⟨*position*⟩ is arbitrary. Note that PGFPLOTS merely remembers the relative distances of the ⟨*positions*⟩, not their absolute values. Consequently, a color map with positions $0, 1, 2$ is equivalent to one with $0, 10, 20$ or $-10, 0, 10$ or $-1100, -1000, -900$. PGFPLOTS maps the input positions to the range $[0, 1000]$ internally and works with these numbers. Each new color must have a ⟨*position*⟩ which is larger than the preceding one.

Available choices for ⟨*color model*⟩ are

`rgb` which expects ⟨*arguments*⟩ of the form (⟨*red*⟩,⟨*green*⟩,⟨*blue*⟩) where each component is in the interval $[0, 1]$,

`rgb255` which is similar to `rgb` except that each component is expected in the interval [0,255],

`gray` in which case ⟨*arguments*⟩ is a single number in the interval $[0, 1]$,

`color` in which case ⟨*arguments*⟩ contains a predefined (named) color like '`red`' or a color expression like '`red!50`',

`cmyk` which expects ⟨*arguments*⟩ of the form (⟨*cyan*⟩,⟨*magenta*⟩,⟨*yellow*⟩,⟨*black*⟩) where each component is in the interval $[0, 1]$,

`cmyk255` which is the same as `cmyk` but expects components in the interval $[0, 255]$,

`cmy` which expects ⟨*arguments*⟩ of the form (⟨*cyan*⟩,⟨*magenta*⟩,⟨*yellow*⟩) where each component is in the interval $[0, 1]$,

`hsb` which expects ⟨*arguments*⟩ of the form (⟨*hue*⟩,⟨*saturation*⟩,⟨*brightness*⟩) where each component is in the interval $[0, 1]$,

`Hsb` which is the same as `hsb` except that ⟨*hue*⟩ is accepted in the interval $[0, 360]$ (degree),

`HTML` which is similar to `rgb255` except that each component is expected to be a hex number between `00` and `FF`,

---

[35]Note that PGFPLOTS up to and including version 1.13 only supported ranges $[0, 16300]$.

`wave` which expects a single wave length as numeric argument in the range $[363, 814]$.
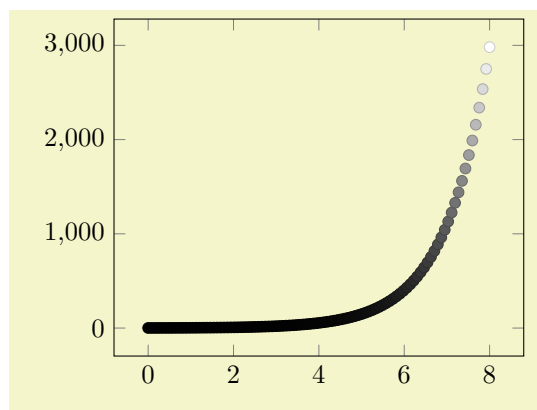
```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
    \begin{axis}[
        colormap={bw}{gray(0cm)=(0); gray(1cm)=(1)}]
    \addplot+[scatter,only marks,
        domain=0:8,samples=100]
        {exp(x)};
    \end{axis}
\end{tikzpicture}
```

The choice of ⟨*positions*⟩ influences the processing time: a uniform distance between the ⟨*positions*⟩ allows more efficient lookup than non-uniform distances. If there is no visual difference and it does not hurt with respect to the number of data points, prefer color maps with uniform distances over non-uniform maps. Note that non-uniform maps make a huge difference in conjunction with `colormap access`=piecewise constant. PGFPLOTS provides a simple way to map a non-uniform color definition to a uniform one: write the target mesh width as *first item* in the specification. PGFPLOTS will perform this interpolation automatically, provided all encountered ⟨*positions*⟩ can be mapped to the target grid:

```
% non uniform spacing example: the mesh width is provided as first
% part of the specification.
\pgfplotsset{colormap={violetnew}%
    {[1cm] rgb255(0cm)=(25,25,122) color(1cm)=(white) rgb255(5cm)=(238,140,238)}}
```

In this last example, the mesh width has been provided explicitly and PGFPLOTS interpolates the missing grid points on its own. It is an error if the provided positions are no multiple of the mesh width.

The Colorspace of a Colormap

Attention: this section is essentially superfluos if you have configured the `xcolor` package to override color spaces globally (for example by means of `\usepackage[cmyk]{xcolor}` before loading PGFPLOTS), see the end of this sub–section.

Even though a `colormap` accepts lots of color spaces on *input* (in fact, it accepts most or all that `xcolor` provides), the *output* color of a colorspace has strict limitations. The output colorspace is the one in which PGFPLOTS interpolates between two other colors. To this end, it transforms input colors to the output color space. The output colorspace is also referred to as "the colorspace of a colormap".

There are three supported color spaces for a `colormap`: the GRAY, RGB, and CMYK color spaces. Each access into a `colormap` requires linear interpolation which is performed in its color space. Color spaces make a difference: colors in different color spaces may be represented differently, depending on the output device. Many printers use CMYK for color printing, so providing CMYK colors might improve the printing quality on a color printer. The RGB color space is often used for display devices. The predefined `colormap`s in PGFPLOTS all use RGB.

Whenever a new `colormap` is created, PGFPLOTS determines an associated color space. Then, each color in this specific `colormap` will be represented in its associated color space (converting colors automatically if necessary). Furthermore, every access into the `colormap` will be performed in its associated color space and every returned `mapped color` will be represented with respect to this color space. Furthermore, every shading generated by `shader`=`interp` will be represented with respect to the `colormap`'s associated color space.

The color space is chosen as follows: in case `colormap default colorspace`=`auto` (the initial configuration), the color space depends on the *first* encountered color in ⟨*color specification*⟩. For `rgb` or `gray`

or `color`, the associated color space will be RGB (as it was in all earlier versions of PGFPLOTS). For `cmyk`, the associated color space will be CMYK. If `colormap default colorspace` is either `gray`, `rgb` or `cmyk`, this specific color space is used and every color is converted automatically.

/pgfplots/colormap default colorspace=auto|gray|rgb|cmyk   (initially `auto`)

> Allows to set the color space of every *newly created* `colormap`. The choices are explained in the previous paragraph.
>
> It is impossible to change the color space of an existing `colormap`; re-create it if conversion is required.
>
> The macro `\pgfplotscolormapgetcolorspace`{⟨*name*⟩} defines `\pgfplotsretval` to contain the color space of an existing `colormap name`, if you are in doubt.
>
> Note that this option has *no effect* if you told `xcolor` to override the color space globally. More precisely, the use of

```
\usepackage[cmyk]{xcolor}
```

> or, alternatively,

```
\selectcolormodel{cmyk}
```

> will cause all colors to be converted to `cmyk`, and PGFPLOTS honors this configuration. Consequently, both these statements cause all colors to be interpolated in the desired color space, and all output colors will use this colorspace. This is typically exactly what you need.

Predefined Colormaps

Available color maps are shown below.

/pgfplots/colormap/viridis   (style, no value)

> A style which installs the colormap "viridis" which has been defined by Stéfan van der Walt and Nathaniel Smith for `Matplotlib`. It is designated to be the default `colormap` for `Matplotlib` starting with version 2.0 and is released under the CC0[36].
>
> The choice `viridis` is a downsampled copy included in PGFPLOTS.

```
\pgfplotsset{
    colormap name=viridis,
}
```

> This `colormap` has considerably better properties compared to other choices:
>
> - its color distribution is perceptually uniform (compare the definition in the link below),
> - it is suitable for moderate forms of color blindness,
> - it is still good when printed in black and white.
>
> Details about these properties can be found in http://bids.github.io/colormap.
>
> Please use the the choice `colormap name`=`viridis` as this makes uses of the predefined colormap whereas `colormap/viridis` will redefine it.
>
> There is also a high resolution copy of `viridis` which is called `colormap/viridis high res` in the `colormaps` library. It resembles the original resolution of the authors, but it is visually almost identically to `viridis` and requires less resources in TeX.

/pgfplots/colormap/hot   (style, no value)

> A style which installs the colormap

---

[36]https://creativecommons.org/about/cc0

```
\pgfplotsset{
    colormap={hot}{color(0cm)=(blue); color(1cm)=(yellow); color(2cm)=(orange); color(3cm)=(red)}
}
```

This is a preconfigured color map.

/pgfplots/colormap/hot2   (style, no value)

A style which is equivalent to

```
\pgfplotsset{
    /pgfplots/colormap={hot2}{[1cm]rgb255(0cm)=(0,0,0) rgb255(3cm)=(255,0,0)
        rgb255(6cm)=(255,255,0) rgb255(8cm)=(255,255,255)}
}
```

Note that this particular choice ships directly with PGFPLOTS, you do not need to load the colormaps library for this value.

This colormap is similar to one shipped with Matlab (Ⓡ) under a similar name.

/pgfplots/colormap/jet   (style, no value)

A style which is equivalent to

```
\pgfplotsset{
    /pgfplots/colormap={jet}{rgb255(0cm)=(0,0,128) rgb255(1cm)=(0,0,255)
        rgb255(3cm)=(0,255,255) rgb255(5cm)=(255,255,0) rgb255(7cm)=(255,0,0) rgb255(8cm)=(128,0,0)}
}
```

This colormap is similar to one shipped with Matlab (Ⓡ) under a similar name.

/pgfplots/colormap/blackwhite   (style, no value)

A style which is equivalent to

```
\pgfplotsset{
    colormap={blackwhite}{gray(0cm)=(0); gray(1cm)=(1)}
}
```

/pgfplots/colormap/bluered   (style, no value)

A style which is equivalent to

```
\pgfplotsset{
    colormap={bluered}{
        rgb255(0cm)=(0,0,180); rgb255(1cm)=(0,255,255); rgb255(2cm)=(100,255,0);
        rgb255(3cm)=(255,255,0); rgb255(4cm)=(255,0,0); rgb255(5cm)=(128,0,0)}
}
```
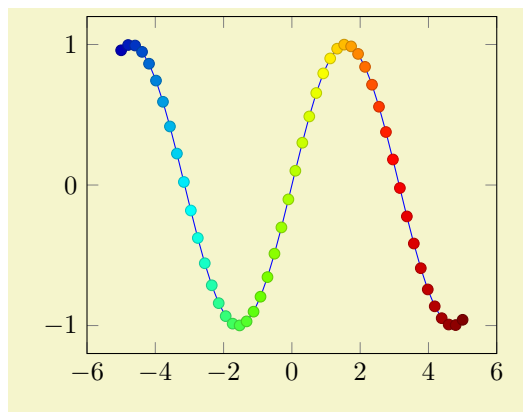
```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
    \begin{axis}[colormap/bluered]
    \addplot+[scatter,
        scatter src=x,samples=50]
        {sin(deg(x))};
    \end{axis}
\end{tikzpicture}
```

Remark: The style `bluered` (re-)defines the color map and activates it. TEX will be slightly faster if you call `\pgfplotsset{colormap/bluered}` in the preamble (to create the color map once) and use `colormap name`=bluered whenever you need it. This remark holds for every color map style which follows. But you can simply ignore this remark.

/pgfplots/**colormap/cool**   (style, no value)

A style which is equivalent to

```
\pgfplotsset{
    colormap={cool}{rgb255(0cm)=(255,255,255); rgb255(1cm)=(0,128,255); rgb255(2cm)=(255,0,255)}
}
```


/pgfplots/**colormap/greenyellow**   (style, no value)

A style which is equivalent to

```
\pgfplotsset{
    colormap={greenyellow}{rgb255(0cm)=(0,128,0); rgb255(1cm)=(255,255,0)}
}
```


/pgfplots/**colormap/redyellow**   (style, no value)

A style which is equivalent to

```
\pgfplotsset{
    colormap={redyellow}{rgb255(0cm)=(255,0,0); rgb255(1cm)=(255,255,0)}
}
```


/pgfplots/**colormap/violet**   (style, no value)

A style which is equivalent to

```
\pgfplotsset{
    colormap={violet}{rgb255=(25,25,122) color=(white) rgb255=(238,140,238)}
}
```

\pgfplotscolormaptoshadingspec{⟨*colormap name*⟩}{⟨*right end size*⟩}{⟨*macro*⟩}

A command which converts a colormap into a PGF shading's color specification. It can be used in commands like **\pgfdeclare*shading** (see the PGF manual [7] for details).

The first argument is the name of a (defined) colormap, the second the rightmost dimension of the specification. The result will be stored in ⟨*macro*⟩.


```
% convert 'hot' -> \result
\pgfplotscolormaptoshadingspec{hot}{8cm}\result
% define and use a shading in pgf:
\def\tempb{\pgfdeclarehorizontalshading{tempshading}{1cm}}%
% where '\result' is inserted as last argument:
\expandafter\tempb\expandafter{\result}%
\pgfuseshading{tempshading}%
```

The usage of the result ⟨*macro*⟩ is a little bit low–level.

Attention: PGF shadings are always represented with respect to the RGB color space. Consequently, even CMYK ⟨*colormap name*⟩s will result in an RGB shading specification when using this method[37].

\pgfplotscolorbardrawstandalone[⟨*options*⟩]

A command which draws a `tikzpicture` and a `colorbar` using the current color bar settings inside of it. Its purpose is to simplify the documentation.

Since this `colorbar` is a "standalone" picture, it defines the following options

```
point meta min=0,
point meta max=1000,
parent axis width/.initial=6cm,
parent axis height/.initial=6cm,
```

before it evaluates ⟨*options*⟩ and draws the colorbar.

\pgfplotscolormaptodatafile[⟨*options*⟩]{⟨*colormap name*⟩}{⟨*output file*⟩}

Allows to export `colormap` data to a file.
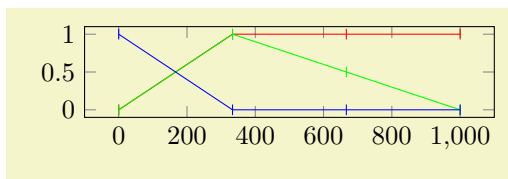

```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
    \begin{axis}[y=1cm,table/col sep=comma]
    \pgfplotscolormaptodatafile{hot}{hot.dat}
    \addplot[red,mark=|] table[y index=1] {hot.dat};
    \addplot[green,mark=|] table[y index=2] {hot.dat};
    \addplot[blue,mark=|] table[y index=3] {hot.dat};
    \end{axis}
\end{tikzpicture}
```
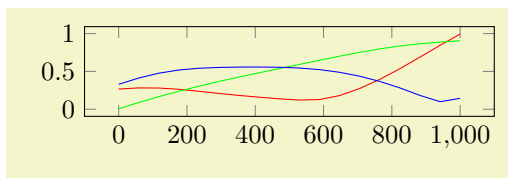


```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
    \begin{axis}[y=1cm,table/col sep=comma]
    \pgfplotscolormaptodatafile{viridis}{viridis.dat}
    \addplot[red] table[y index=1] {viridis.dat};
    \addplot[green] table[y index=2] {viridis.dat};
    \addplot[blue] table[y index=3] {viridis.dat};
    \end{axis}
\end{tikzpicture}
```

Valid ⟨*options*⟩ are

/pgfplots/**/pgfplots/colormap/output each nth**=⟨*num*⟩ (initially 1)

Allows to downsample the color map by writing only each ⟨*num*⟩'s entry.

---

[37]In case PGF should someday support CMYK shadings and you still see this remark, you can add the macro definition
\def\pgfplotscolormaptoshadingspectorgb{0} to your preamble.

/pgfplots/**/pgfplots/colormap/output format**=cvs|native   (initially `csv`)

>   The choice `csv` generates a csv file where the first column is the offset of the color map and all
>   following are the color components.
>
>   The choice `native` generates a TEX file which can be `\input` in order to define the colormap for
>   use in PGFPLOTS.

Note that there are *more available choices* of colormaps in the associated libraries, name in
the colorbrewer library and in the colormaps library which need to be loaded by means of
`\usepgfplotslibrary{colorbrewer,colormaps}`.

Building Colormaps based on other Colormaps

A colormap definition of sorts colormap=`{⟨name⟩}{⟨color specification⟩}` typically consists of ⟨*color
specifications*⟩ made up from single colors, each with its own ⟨*color model*⟩. As outlined in Section 4.7.6,
each entry in ⟨*color specification*⟩ has the form

⟨*color model*⟩(⟨*position*⟩)=(⟨*arguments*⟩) or
⟨*special mode*⟩(⟨*position*⟩)=(⟨*argument*⟩ of ⟨*colormap name*⟩).

This section explains how to make use of ⟨*special mode*⟩ in order to build colormaps based on existing
colormaps. To this end, PGFPLOTS offers the following values inside of a ⟨*color specification*⟩:

1. `samples of colormap`(⟨*position*⟩)=(⟨*number*⟩ `of` ⟨*colormap name*⟩) or
    `samples of colormap`(⟨*position*⟩)=(⟨*number*⟩) or
    `samples of colormap`(⟨*position*⟩)={⟨*number*⟩ `of` ⟨*colormap name*⟩, ⟨*options*⟩}

    This method takes a ⟨*colormap name*⟩ on input, samples ⟨*number*⟩ colors from it (using a uniform
    mesh width) and inserts it into the currently built colormap. It is equivalent to the choice colors of
    colormap(⟨*position*⟩)=(0,h,...,1000) with `h` chosen such that you get ⟨*number*⟩ samples positioned
    at an equidistant grid.
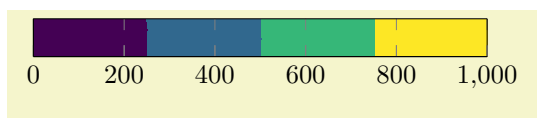
    ```
    \pgfplotscolorbardrawstandalone[
        colormap={example}{%
            samples of colormap=(4 of viridis)
        },
        colorbar horizontal,
        colormap access=const]
    ```
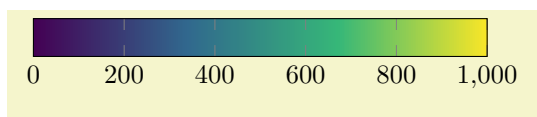
    ```
    \pgfplotscolorbardrawstandalone[
        colormap={example}{%
            samples of colormap=(4 of viridis)
        },
        colorbar horizontal,
        colormap access=map]
    ```

    The special suffix " `of` ⟨*colormap name*⟩" is optional; it defaults to the current value of colormap
    name:
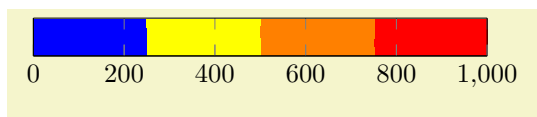
    ```
    \pgfplotscolorbardrawstandalone[
        colormap={example}{%
            samples of colormap=(4)
        },
        colorbar horizontal,
        colormap access=const]
    ```
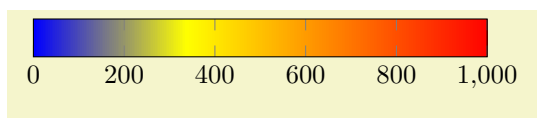
    ```
    \pgfplotscolorbardrawstandalone[
        colormap={example}{%
            samples of colormap=(4)
        },
        colorbar horizontal,
        colormap access=map]
    ```

    The argument can be surrounded by round braces or curly braces, both is accepted. PGFPLOTS also
    accepts a sequence of options inside of the argument and curly braces are best applied if options are
    needed:
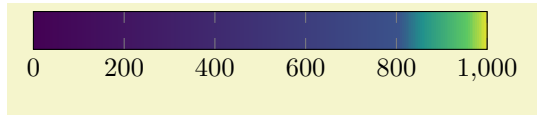
```
\pgfplotscolorbardrawstandalone[
    colormap={example}{%
        samples of colormap={
            5 of viridis,
            target pos={0,800,850,950,1000},
        }
    },
    colorbar horizontal,
    colormap access=map]
```
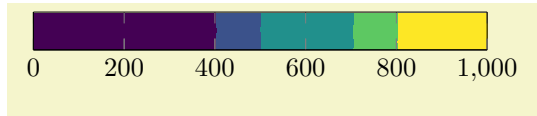
```
\pgfplotscolorbardrawstandalone[
    colormap={example}{%
        % simpler alternative:
        % of colormap={viridis,target pos={...}}
        samples of colormap={
            5 of viridis,
            target pos={0,400,500,700,800,1000},
            sample for=const,
        }
    },
    colorbar horizontal,
    colormap access=const]
```

The use of options inside of the argument is discussed in the next sub-section, see `of colormap` and `target pos`.

As with normal color definitions, the ⟨*position*⟩ argument is optional and can be omitted. If it is given, it is used for the first encountered item in the list, all others are deduced automatically. If both `target pos` and ⟨*position*⟩ are given, ⟨*position*⟩ is ignored.

Note that PGFPLOTS offers a special syntax for `target pos` and a sampled colormap:
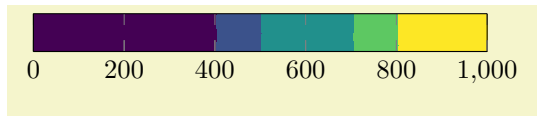
```
\pgfplotscolorbardrawstandalone[
    colormap={example}{%
        of colormap={
            viridis,
            target pos={0,400,500,700,800,1000},
            sample for=const,
        }
    },
    colorbar horizontal,
    colormap access=const]
```

This syntax also samples colors from the source colormap (`viridis` here). It chooses enough samples to satisfy the given `target pos`; see the documentation for '`of colormap`' for details.

2. `index of colormap(`⟨*position*⟩`)=(`⟨*index*⟩ `of` ⟨*colormap name*⟩`)` or
   `index of colormap(`⟨*position*⟩`)=(`⟨*index*⟩`)`

   This key allows to identify a *single* color of ⟨*colormap name*⟩ and use it as part of ⟨*color specification*⟩. The ⟨*index*⟩ is a numeric index $0, 1, \ldots, N-1$ where N is the size of ⟨*colormap name*⟩.
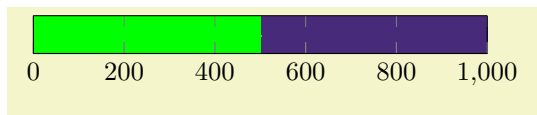
```
\pgfplotscolorbardrawstandalone[
    colormap={example}{%
        color=(green),
        index of colormap=(2 of viridis)
    },
    colorbar horizontal,
    colormap access=const]
```

Note that `index of colormap` is also available as key for drawing operations.

All special remarks of `samples of colormap` (like curly braces, option list support, positions) apply here as well.

3. `indices of colormap(`⟨*position*⟩`)=(`⟨*list of indices*⟩ `of` ⟨*colormap name*⟩`)` or
   `indices of colormap(`⟨*position*⟩`)=(`⟨*list of indices*⟩`)`

   A convenience key which is equivalent to a sequence of `index of colormap(`⟨*position*⟩`)`, one for each element in ⟨*list*⟩. The ⟨*list*⟩ is evaluated using `\foreach`. Note that you need round braces around the argument.
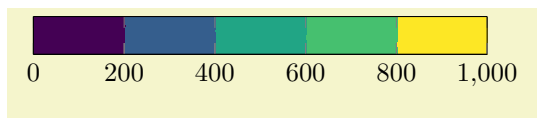
```
\pgfplotscolorbardrawstandalone[
    colormap={example}{%
        indices of colormap=(0,5,10,12,
            \pgfplotscolormaplastindexof{viridis}
            of viridis)
    },
    colorbar horizontal,
    colormap access=const]
```

All special remarks of `samples of colormap` (like curly braces, option list support, positions) apply here as well.

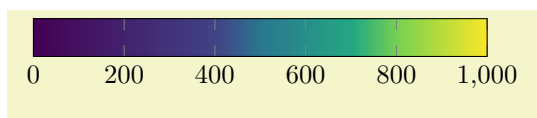4. `color of colormap`(⟨*position*⟩)=(⟨*value*⟩ of ⟨*colormap name*⟩) or
   `color of colormap`(⟨*position*⟩)=(⟨*value*⟩)

   This key allows to interpolate a color within ⟨*colormap name*⟩ and use the result as part of ⟨*color specification*⟩. The interpolation point is a floating point number in the range $[0, 1000]$ and is interpolated using `colormap access`=map (i.e. using piecewise linear interpolation).

   Note that `color of colormap` is also available as key for drawing operations.

   All special remarks of `samples of colormap` (like curly braces, option list support, positions) apply here as well.

5. `colors of colormap`(⟨*position*⟩)=(⟨*list*⟩ of ⟨*colormap name*⟩) or
   `colors of colormap`(⟨*position*⟩)=(⟨*list*⟩) or
   `colors of colormap`(⟨*position*⟩)={⟨*list*⟩ of ⟨*colormap name*⟩, ⟨*options*⟩}

   A convenience key which is equivalent to a sequence of `color of colormap`(⟨*position*⟩), one for each element in ⟨*list*⟩. The ⟨*list*⟩ is evaluated using `\foreach`. Note that you need round braces around the argument.
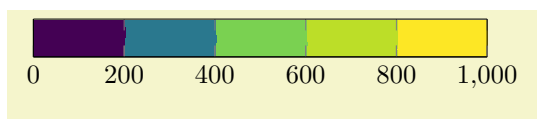
```
\pgfplotscolorbardrawstandalone[
    colormap={example}{%
      colors of colormap=(0,400,800,900,
          1000 of viridis)
    },
    colorbar horizontal,
    colormap access=const]
```

   Note that `colors of colormap` is also available during `cycle list` definitions.

   All special remarks of `samples of colormap` (like curly braces, option list support, positions) apply here as well.

6. `of colormap`(⟨*position*⟩)=(⟨*colormap name*⟩, ⟨*options*⟩)

   Builds a new `colormap` by *sampling* enough colors from the input `colormap name`. This mode is one of two methods which samples colors from another `colormap`; it is to be preferred if you want to assign `target pos`. See also `samples of colormap`; it is simpler if you just want to specify a number of samples.

   The syntax '`of colormap`=' is most useful if you want to draw samples from another colormap *at specific positions*:

```
\pgfplotscolorbardrawstandalone[
    colormap={example}{%
        of colormap={
            viridis,
            target pos={0,400,500,700,800,1000},
        }
    },
    colorbar horizontal,
    colormap access=map]
```

   Here, PGFPLOTS parses the ⟨*options*⟩. Each unidentified option is treated as either a value of '`colormap name`' or as a style argument which defines a `colormap` like `colormap/PuOr`. The previous example identifies `colormap name`=viridis (since `viridis` is no known option) and assigns `target pos`. There are 6 samples which make up the colormap, these are drawn from `viridis`. Note that you do not need

to specify a ⟨*colormap name*⟩ in this context. If it is missing, the current value of `colormap name` (i.e. the current colormap) will be used.
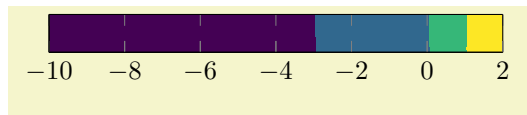
Similarly, '`of colormap`' can sample a `colormap` for use with `colormap access`=const:
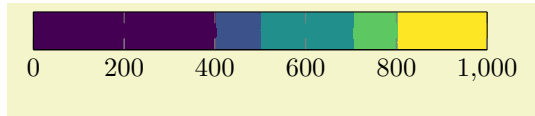
```
\pgfplotscolorbardrawstandalone[
    colormap={example}{%
        of colormap={
            viridis,
            target pos={0,400,500,700,800,1000},
            sample for=const,
        }
    },
    colorbar horizontal,
    colormap access=const]
```

Note that you *need* to write `sample for`=const in this context such that PGFPLOTS knows that the result is to be used in conjunction with `colormap access`=const. The details are specified below.

As with all colormap building blocks, the `target pos` can have an arbitrary number range. However, the absolute values are meaningless; they are always mapped to the range $[0, 1000]$. Only their relative distances are of importance when it comes to the `colormap` as such:
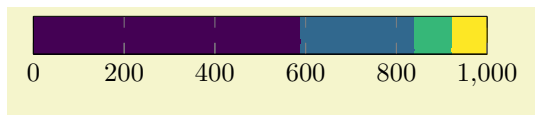
```
\pgfplotscolorbardrawstandalone[
    colormap={example}{%
        of colormap={viridis,
            target pos={-10,-3,0,1,2},
            sample for=const,
        }
    },
    colorbar horizontal,
    colormap access=const]
```

However, if the `point meta` range equals the colormap definition range, you see that they fit exactly:

```
\pgfplotscolorbardrawstandalone[
    colormap={example}{%
        of colormap={viridis,
            target pos={-10,-3,0,1,2},
            sample for=const,
        }
    },
    point meta min=-10,point meta max=2,
    colorbar horizontal,
    colormap access=const]
```

Note that you can use `xtick`=data or `ytick`=data inside of the `colorbar` styles in order to place tick labels at the `colormap`'s positions:
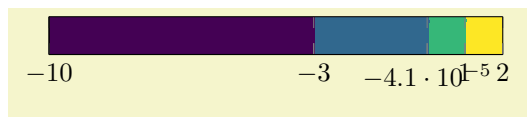
```
\pgfplotscolorbardrawstandalone[
    colormap={example}{%
        of colormap={viridis,
            target pos={-10,-3,0,1,2},
            sample for=const,
        }
    },
    point meta min=-10,point meta max=2,
    colorbar horizontal,
    colorbar style={xtick=data},
    colormap access=const]
```

Finally, '`of colormap`' can be used to *copy* another `colormap`: if there are no suitable hints how to build a new `colormap`, PGFPLOTS copies the input map:
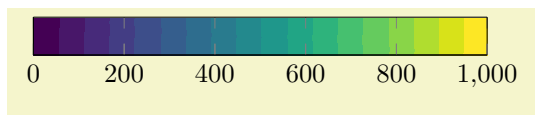
```
\pgfplotscolorbardrawstandalone[
    colormap={example}{%
        of colormap={viridis},
    },
    colorbar horizontal,
    colormap access=const]
```

The ⟨*options*⟩ are accepted by all colormap building blocks: you can also specify them after `samples of colormap` or `colors of colormap` if needed.

The following options are available:

`/pgfplots/of colormap/target pos`={⟨*position(s)*⟩}   (initially `empty`)

Allows to define the ⟨*position*⟩ for zero, one, or more of the involved colors. An empty value means to use the argument in round braces '(⟨*position*⟩)' in the definition, for example the value 100 in `color of colormap(100)=(4)`. This is sufficient if there is just one color involved. However, if `target pos` has a non-empty value, it overrides the (⟨*position*⟩) argument.

The key `target pos` is primarily intended to provide positions for more than one color definition, in particular in the context of '`of colormap`'. In this context, as many ⟨*position(s)*⟩ as specified are used.

If you have `colors of colormap` and a non-empty value of `target pos`, PGFPLOTS will use as many `target pos`itions as available. If there are too few to cover all involved colors, the remaining ones are deduced automatically. More precisely: PGFPLOTS will use the current mesh width as distance to the previous position. The "current mesh width" is defined as the smallest difference between adjacent positions. Excess positions will be ignored (and a warning is written into the log file).

Note that `target pos` requires attention when used together with `colormap access`=const: in this case, there are *intervals* with constant color and the positions become interval boundaries. Consequently, N elements in `target pos` make up $N - 1$ different colors!

Note that `target pos` as option to `samples of colormap` is also possible. However, you have to specify all required positions and it is an error if the number does not match. If you also combine this case with `sample for`=const, you need $N + 1$ positions for N samples.

`/pgfplots/of colormap/sample for`=default|const   (initially `default`)

This key allows to configure `samples of colormap` such that the resulting `colormap` is suitable for dedicated values of `colormap access`.

In particular, it allows to optimize ⟨*colormap definitions*⟩ which rely on *sampling* for the case `colormap access`=const.

Note that the case `colormap access`≠const typically requires no modification to this key and works best with the defaults.

The strategy `colormap access`=const means that colors are associated with entire *intervals* and no longer with single positions in the `colormap`. In this context, you have to write `sample for`=const such that PGFPLOTS handles that correctly.

Here is the reference of `colormap`s and their significance with respect to `sample for`:

- In general, a `colormap` can be used with any value of `colormap access`. If there are no positions in the ⟨*colormap definition*⟩ (neither in round braces nor in `target pos`), this works out of the box without any special attention.
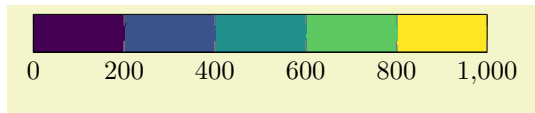

- As soon as there are positions, PGFPLOTS has a conflict if the colormap is used in the context of `colormap access`=const: it cannot enlarge the displayed limit, but it cannot respect both the given positions *and* the required number of colors! It has the choice to either omit one color, or to add an artifical position and rescale all other positions.
- The default strategy in PGFPLOTS in the presence of `colormap access`=const and input positions is: PGFPLOTS chooses to keep the input positions and omit one color.
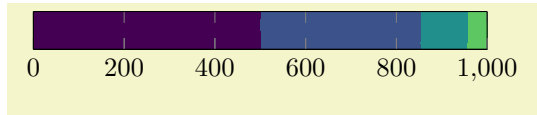
```
\pgfplotscolorbardrawstandalone[
    colormap={example}{%
        of colormap={
            viridis,
            target pos={0,500,850,950,1000},
        }
    },
    colorbar horizontal,
    colormap access=const]
```

Technically, this means that it implicitly sets `colormap access/extra interval width`=0 (the default is `colormap access/extra interval width`=h). The color associated with 1000 has no interval and is essentially invisible.

Restoring `colormap access/extra interval width`=h results in rescaled positions which is typically not what you want:
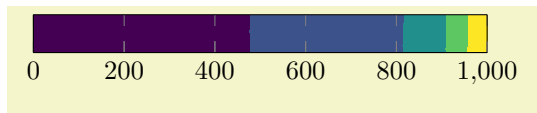
```
\pgfplotscolorbardrawstandalone[
    colormap={example}{%
        samples of colormap={
            5 of viridis,
            target pos={0,500,850,950,1000},
        }
    },
    colormap access/extra interval width=h,
    colorbar horizontal,
    colormap access=const]
```

- Finally, PGFPLOTS offers `sample for`=const.
  Applying `sample for`=const to '`of colormap`' ensures that any given positions are respected. To this end, it reduces the number of available colors, but modifies the sampling procedure such that the entire input color range is visible in the result:
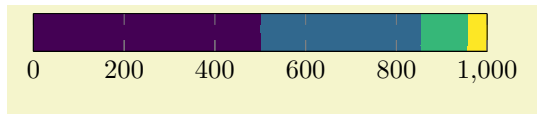
```
\pgfplotscolorbardrawstandalone[
    colormap={example}{%
        of colormap={
            viridis,
            target pos={0,500,850,950,1000},
            sample for=const,
        }
    },
    colorbar horizontal,
    colormap access=const]
```

Here, the result has 4 colors, but the rightmost color is also the rightmost color of the input map `viridis`. Note that `of colormap` has assigned an invisible color to the position 1000: this dummy color is defined to be the rightmost color of `viridis`. That means that if you define a `colormap` with `sample for`=const and use it with `colormap access`=map, the right end of the interval will be longer than expected:
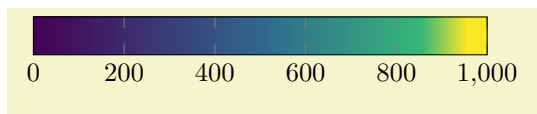
```
\pgfplotscolorbardrawstandalone[
    colormap={example}{%
        of colormap={
            viridis,
            target pos={0,500,850,950,1000},
            sample for=const,
        }
    },
    colorbar horizontal,
    colormap access=map]
```

The strategy `sample for`=const applied to `samples of colormap` works in a similar way. Keep in mind that this combination requires to either omit `target pos` or to add *exactly* $N + 1$ target positions:
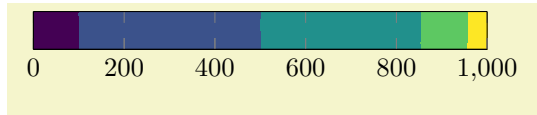
```
\pgfplotscolorbardrawstandalone[
    colormap={example}{%
        samples of colormap={
            5 of viridis,
            target pos={0,100,500,850,950,1000},
            sample for=const,
        }
    },
    colorbar horizontal,
    colormap access=const]
```

This results in correctly respected positions and a fully respected range of the input colormap.

The key `sample for` applies whenever a ⟨*colormap definition*⟩ involves sampling (that means: only for `of colormap` and `samples of colormap`). It does not apply for explicitly fixed colors. Its effect is that the number of samples is reduced by 1 and the last provided sample is replicated once.

See also `colormap access/extra interval width`.

/pgfplots/**of colormap/colormap access**={⟨*argument*⟩}

An alias for **/pgfplots/colormap access**={⟨*argument*⟩}.

/pgfplots/**of colormap/source range**={⟨*min:max*⟩}   (initially `0:1000`)

Defines the source range for interpolation-based specifications, i.e. for `color of colormap` and `const color of colormap`. It defaults to `0:1000` which means that only values in the interval [0, 1000] can be provided.

Changing the value allows to use any number range in order to identify numbers.
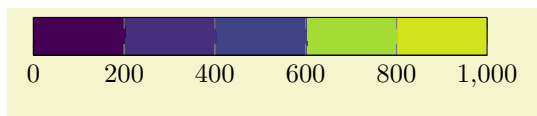
```
\pgfplotscolorbardrawstandalone[
    colormap={example}{%
      colors of colormap={
        -30000,-10000,0,100000,110000 of viridis,
        source range=-30000:120000}
      },
      colorbar horizontal,
      colormap access=const]
```

Note that these building blocks can be combined as often as needed. This allows to combine different colormaps:
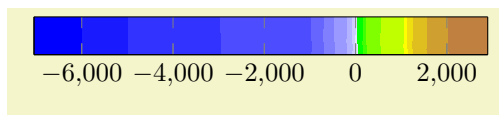
```
\pgfplotscolorbardrawstandalone[
    point meta min=-7046,
    point meta max=2895,
    colormap={whiteblue}{color=(blue) color=(white)},
    colormap={gb}{color=(green) color=(yellow)
        color=(brown)},
    colormap={CM}{
        of colormap={
            whiteblue,
            target pos={-7046,-6000,-5000,-3000,
                -1000,-750,-500,-250,-100,-50,0},
            sample for=const,
        },
        of colormap={
            gb,
            target pos={10,100,200,500,1000,1100,
                1200,1500,2000,2895},
            sample for=const,
        }
    },
    colorbar horizontal,
    colormap access=const]
```

The previous example first defines the two simple colormaps `whiteblue` and `gb`. These are merely used as building blocks; they are not used for the visualization. Finally, the colormap `CM` consists of two `of colormap` specifications which resample the building blocks and assign specific `target pos`itions.

/pgfplots/**of colormap/target pos min**={⟨*lower limit*⟩}   (initially `empty`)
/pgfplots/**of colormap/target pos min***={⟨*lower limit*⟩}   (initially `empty`)
/pgfplots/**of colormap/target pos max**={⟨*upper limit*⟩}   (initially `empty`)
/pgfplots/**of colormap/target pos max***={⟨*upper limit*⟩}   (initially `empty`)

These keys allow to *modify* the argument of `target pos`. Their primary use is to simplify writing style definitions. Consequently, most users may want to ignore these keys and skip their documentation. The keys are unnecessary if the argument of `target pos` is used directly.

The versions without star (`target pos min` and `target pos max`) discard all elements of `target pos` which are outside of the bounds. The starred versions (`target pos min*` and `target pos max*`) also discard all which do not fit, but they ensure that the limit is part of `target pos` after the filtering.

These filtering limits come in handy if you want to select matching positions from a previously defined `target pos`, for example if the same `target pos` is part of a reusable style:
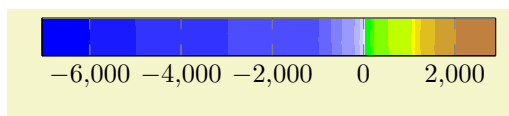
```
\pgfplotsset{
    of colormap/ocean height/.style={
        target pos={-12000,-10000,-6000,-5000,-3000,
            -1000,-750,-500,-250,-100,-50,0,10,100,
            200,500,1000,1100,1200,1500,2000,4000,
            6000,8000},
    },
}
\pgfplotscolorbardrawstandalone[
  point meta min=-7046,
  point meta max=2895,
  colormap={whiteblue}{color=(blue) color=(white)},
  colormap={gb}{color=(green) color=(yellow)
      color=(brown)},
  colormap={CM}{
      of colormap={
          whiteblue,
          ocean height,
          target pos min*=
           \pgfkeysvalueof{/pgfplots/point meta min},
          target pos max=0,
          sample for=const,
      },
      of colormap={
          gb,
          ocean height,
          target pos min=0.1,
          target pos max*=
           \pgfkeysvalueof{/pgfplots/point meta max},
          sample for=const,
      }
  },
  colorbar horizontal,
  colormap access=const]
```

The example defines a style named '`ocean height`' with a suitable list of positions somewhere in the document. Then, it defines a colormap '`CM`' which makes use of these keys – but only in the range $[-7046, 2895]$, and with a special combination of two other `colormap`s. The first `of colormap` specification selects only those target positions which fall in the range $[-7046, 0]$ and ensures that -7046 actually becomes an element of `target pos`. The second `of colormap` specification selects all in the range $[0.1, 2895]$ and ensures that 2895 becomes an element of `target pos`. Note that the 0.1 merely serves as indicator to *not* select 0 again. Thus, the selection is essentially equivalent to

```
...
target pos={-7046,-6000,-5000,-3000,-1000,-750,-500,-250,-100,-50,0}
...
target pos={10,100,200,500,1000,1100,1200,1500,2000,2895}
```

with the exception that the predefined style defined a list of suitable positions.

PGFPLOTS uses these keys in order to implement `contour filled`.

7. `const color of colormap`(⟨*position*⟩)=(⟨*value*⟩ `of` ⟨*colormap name*⟩).

   This key is almost the same as `color of colormap` mentioned above, but it uses the same functionality as `colormap access`=`piecewise constant` while it determines colors from the *source* color map (including `colormap access/extra interval width`). Note that the resulting colormap can still be used with any value of `colormap access`, including both `colormap access`=`const` and `colormap access`=`map`.

   Note that `const color of colormap` is also available as key for drawing operations.

   All special remarks of `samples of colormap` (like curly braces, option list support, positions) apply here as well.

8. `const colors of colormap`(⟨*position*⟩)=(⟨*list*⟩ `of` ⟨*colormap name*⟩)

   A convenience key which is equivalent to a sequence of `const color of colormap`(⟨*position*⟩), one for each element in ⟨*list*⟩. The ⟨*list*⟩ is evaluated using `\foreach`.

   Note that `const colors of colormap` is also available during `cycle list` definitions.

   All special remarks of `samples of colormap` (like curly braces, option list support, positions) apply here as well.

/pgfplots/`colormap access/extra interval width`={⟨*fraction*⟩}   (initially `h`)

Attention: this key is supposed to be a technical part of the implementation. You may want to skip its documentation as it typically works out of the box. You only need to respect `sample for`.

This key applies *only* to `colormap access`=`piecewise constant`: it ensures that each color in the `colormap` receives its own *interval*. This ensures that each color is actually visible in the output. Thus, each provided color resembles an *interval*. This is different from `colormap access`=`map` where each provided color resembles an *interval boundary*.

Normally, PGFPLOTS, activates this feature if and only if it has automatically computed positions. Consequently, the following example implicitly uses `extra interval width=h` (the default):
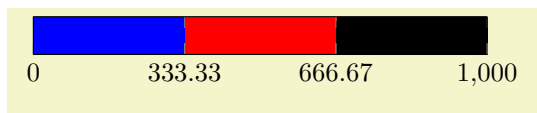
```
\pgfplotscolorbardrawstandalone[
    colormap={example}{%
        color=(blue)
        color=(red)
        color=(black)
    },
    colorbar horizontal,
    colorbar style={xtick=data},
    colormap access=const]
```

As soon as you provide positions manually, PGFPLOTS defaults to `extra interval width=0` in order to respect the input settings:
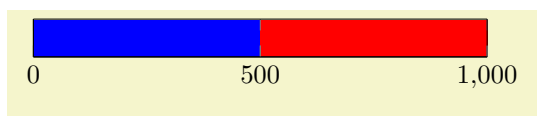
```
\pgfplotscolorbardrawstandalone[
    colormap={example}{%
        color(0)=(blue)
        color(500)=(red)
        color(1000)=(black)
    },
    colorbar horizontal,
    colorbar style={xtick=data},
    colormap access=const]
```

Note that the positions make up the input nodes for the `colormap` with the consequence that the last color is *unused*; it merely serves as interval boundary. In this context, "provide manually" means positions in round braces or a non-empty value of `target pos`.

In order to override the input positions and get an extra interval, you have to set the option:
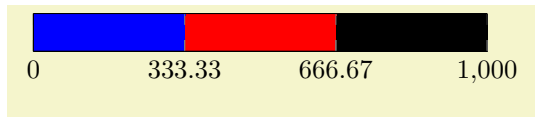
```
\pgfplotscolorbardrawstandalone[
    colormap={example}{%
        color(0)=(blue)
        color(500)=(red)
        color(1000)=(black)
    },
    colorbar horizontal,
    colorbar style={xtick=data},
    colormap access/extra interval width=h,
    colormap access=const]
```

Note how the extra interval of `colormap access`=const modifies the positions of the colormap defini-
tion: they are all shifted to the left and the chosen input positions are scaled accordingly. This becomes
more apparent in the following example. First, we generate a colormap with the default settings which
disables the extra interval, but omits the last (brightest) color:
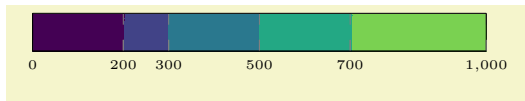
```
\pgfplotscolorbardrawstandalone[
    colormap={nonuniform}{
        of colormap={
            viridis,
            target pos={0,200,300,500,700,1000}
        }
    },
    colorbar horizontal,
    colormap access=const,
    colorbar style={xtick=data,font=\tiny,
        /pgf/number format/precision=0},
    colormap access=const]
```

Next, we explicitly enable the extra interval and see that the input positions are scaled to the left. Note
that they keep their relative distances, but the last color of the colormap is finally visible:
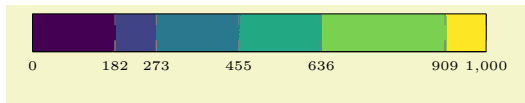
```
\pgfplotscolorbardrawstandalone[
    colormap={nonuniform}{
        of colormap={
            viridis,
            target pos={0,200,300,500,700,1000}
        }
    },
    colorbar horizontal,
    colormap access=const,
    colormap access/extra interval width=h,
    colorbar style={xtick=data,font=\tiny,
        /pgf/number format/precision=0},
    colormap access=const]
```

The last example relies on `of colormap` and a *sampling* procedure. In this context, PGFPLOTS offers
`sample for`=const which results in the expected look:
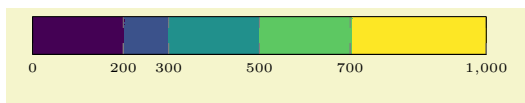
```
\pgfplotscolorbardrawstandalone[
    colormap={nonuniform}{
        of colormap={
            viridis,
            target pos={0,200,300,500,700,1000},
            sample for=const,
        }
    },
    colorbar horizontal,
    colormap access=const,
    colorbar style={xtick=data,font=\tiny,
        /pgf/number format/precision=0},
    colormap access=const]
```

Please refer to the documentation of `sample for`.

The default width of this interval is the mesh width of the color map (the value `h`), i.e. it will always
be as large as the other intervals. If the color map has non-uniform distances, the smallest encountered
mesh width is used for the extra interval. This can be seen if we omit the key and add some artifical
color at the right end manually – we only need to ensure that the rightmost interval has the correct
length. In our example above, the smallest mesh width is 100, so we can generate an equivalent result
by means of
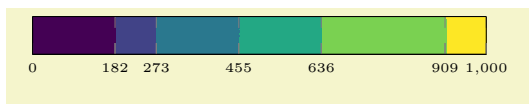
```
\pgfplotscolorbardrawstandalone[
    colormap={nonuniform}{
        of colormap={
            viridis,
            target pos={0,200,300,500,700,1000}
        }
        color(1100)=(red)
    },
    colorbar horizontal,
    colormap access=const,
    colorbar style={xtick=data,font=\tiny,
        /pgf/number format/precision=0},
    colormap access=const]
```

As already mentioned, `colormap access`=const ignores the rightmost color ("red"). Note that this approach is almost the same as the internal implementation of `sample for`=const.

The value of `colormap access/extra interval width`=⟨*fraction*⟩ can also be used to customize the width of the artifical interval: it is a fraction of the total width and accepted values are $0 \leq$⟨*fraction*⟩$\leq$ 0.9 where 0 disables the extra interval and 0.9 corresponds to 90% of the resulting width. Any non-0 value for ⟨*fraction*⟩ creates an extra interval and its width is ⟨*fraction*⟩ percent of the entire color map. The special magic value `colormap access/extra interval width`=h will use the colormap's mesh width. If the colormap has non-uniform distances, it will use the smallest encountered mesh width. This is the default.

Note that ⟨*fraction*⟩ is a property of the `colormap`. The key defines it for the *current* color map only. Defining a new `colormap` uses the default width for the new `colormap` (but keeps the configured value for the old `colormap`).

Attention: at the time of this writing, uniform color maps only support the default interval width 'h' and ⟨*fraction*⟩= 0, further customization is only possible for non-uniform color maps. If you ever need to work around this limitation, you should file a feature requests and move one of your color position until the colormap becomes a non-uniform colormap.

Choosing a Colormap Entry as Normal Color

/pgfplots/**color of colormap**=⟨*value*⟩
/pgfplots/**color of colormap**=⟨*value*⟩ of ⟨*colormap name*⟩

[See also Section 4.7.6 on page 198 for how to employ this within `colormap` definitions]

Defines the Ti*k*Z `color` to be the ⟨*value*⟩ of ⟨*colormap name*⟩. If ⟨*colormap name*⟩ is omitted, the value of `colormap name` is evaluated (i.e. the current colormap is used).

The argument ⟨*value*⟩ is expected to be a number in the range $[0, 1000]$ where 0 resembles the lower end of the color map and 1000 the upper end.

Current colormap (hot):
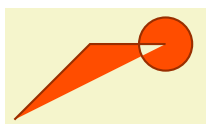
```
\tikz\fill[color of colormap={800}, thick,
    draw=.!60!black]
    (0,0) -- (1,1) -- (2,1) circle (10pt);
```

The key computes the requested color and calls `color`=.. Keep in mind that the magic color name '.' always reflects the "current color", i.e. the result of `color`=⟨*some color*⟩. Also keep in mind that `color` is a Ti*k*Z command which merely defines the color, you also have to provide one of '`draw`' or '`fill`' such that it has an effect. Since '.' is a normal color, we can write `draw`=.!60!black to combine it with another color.
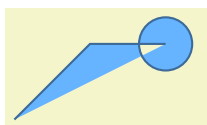
viridis:
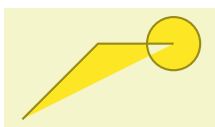
```
\pgfplotsset{colormap name=viridis}
\tikz\fill[color of colormap={1000},thick,
    draw=.!60!black]
    (0,0) -- (1,1) -- (2,1) circle (10pt);
```

```
\tikz\fill[color of colormap={300 of viridis},thick,
    draw=.!60!black]
    (0,0) -- (1,1) -- (2,1) circle (10pt);
```

The argument ⟨*colormap name*⟩ is either a valid argument of `colormap name` *or* a style name like `colormap/cool`:

cool:

```
\tikz\fill[color of colormap={300 of colormap/cool},
    thick,draw=.!60!black]
    (0,0) -- (1,1) -- (2,1) circle (10pt);
```

This last syntax allows to evaluate colormaps lazily. However, if you have many references to the same colormap, it makes sense to write `\pgfplotsset{colormap/cool}` first followed by many references to `color of colormap={... of cool}` in order to avoid unnecessary lazy evaluations.

It is possible to write lots of invocations without an explicit ⟨*colormap name*⟩, i.e. lots of invocations of sorts `color of colormap=`⟨*value*⟩. They will all use the `colormap name` which is active at that time.

Note that there are actually keys with two key prefixes: `/pgfplots/color of colormap` and an alias `/tikz/color of colormap`. This allows to use the keys both for plain TikZ graphics and for PGFPLOTS.

See also `colormap access=map`.

`/pgfplots/index of colormap=`⟨*index*⟩
`/pgfplots/index of colormap=`⟨*index*⟩ of ⟨*colormap name*⟩

[See also Section 4.7.6 on page 198 for how to employ this within `colormap` definitions]

A variant of `color of colormap` which accesses the ⟨*colormap name*⟩ by index. Consequently, the argument ⟨*index*⟩ is an integer number in the range $0, \ldots, N-1$ where N is the number of colors which define the ⟨*colormap name*⟩. A ⟨*index*⟩ outside of this range is automatically clipped to the upper bound.
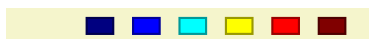
```
\pgfplotsset{colormap/jet}

\foreach \i
  in {0,...,\pgfplotscolormaplastindexof{jet}}
{
  \tikz\fill[index of colormap={\i of jet},
    thick,
    draw=.!60!black] (0,0) rectangle (10pt,6pt);
}
```

`\pgfplotscolormapsizeof{`⟨*colormap name*⟩`}`

Expands to the number of colors which make up ⟨*colormap name*⟩.

If the argument ⟨*colormap name*⟩ is an unknown colormap, it expands to 0.

`\pgfplotscolormaplastindexof{`⟨*colormap name*⟩`}`

Expands to the last index of ⟨*colormap name*⟩, i.e. it is a convenience method to access $N-1$.

If the argument ⟨*colormap name*⟩ is an unknown colormap, it expands to -1.

See also `colormap access=direct`.

`/pgfplots/const color of colormap=`⟨*value*⟩

/pgfplots/**const color of colormap**=⟨*value*⟩ of ⟨*colormap name*⟩

[See also Section 4.7.6 on page 198 for how to employ this within **colormap** definitions]

Defines the Ti*k*Z **color** to be the ⟨*value*⟩ of ⟨*colormap name*⟩. If ⟨*colormap name*⟩ is omitted, the value of **colormap name** is evaluated (i.e. the current colormap is used).

This key is almost the same as **color of colormap**, except that it uses **colormap access**=piecewise constant in order to determine the interpolated value.

4.7.7   Cycle Lists – Options Controlling Line Styles

/pgfplots/**cycle list**={⟨*list*⟩}
/pgfplots/**cycle list name**={⟨*name*⟩}

Allows to specify a list of plot specifications which will be used for each **\addplot** command without explicit plot specification. Thus, the currently active **cycle list** will be used if you write either **\addplot**+[⟨*keys*⟩] ...; or if you *don't* use square brackets as in **\addplot**[⟨*explicit plot specification*⟩] ...;.

The list element with index i will be chosen where i is the index of the current **\addplot** command (see also the **cycle list shift** key which allows to use $i + n$ instead). This indexing does also include plot commands which don't use the **cycle list**.

There are several possibilities to change the currently active **cycle list**:

Predefined Lists

Use one of the predefined lists[38],

- **color** (from top to bottom)
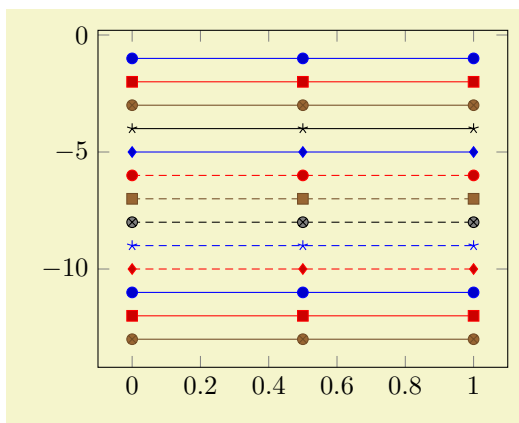
```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
\begin{axis}[
    stack plots=y,stack dir=minus,
    cycle list name=color]
\addplot coordinates {(0,1) (0.5,1) (1,1)};
\addplot coordinates {(0,1) (0.5,1) (1,1)};
\addplot coordinates {(0,1) (0.5,1) (1,1)};
\addplot coordinates {(0,1) (0.5,1) (1,1)};
\addplot coordinates {(0,1) (0.5,1) (1,1)};
\addplot coordinates {(0,1) (0.5,1) (1,1)};
\addplot coordinates {(0,1) (0.5,1) (1,1)};
\addplot coordinates {(0,1) (0.5,1) (1,1)};
\addplot coordinates {(0,1) (0.5,1) (1,1)};
\addplot coordinates {(0,1) (0.5,1) (1,1)};
\addplot coordinates {(0,1) (0.5,1) (1,1)};
\addplot coordinates {(0,1) (0.5,1) (1,1)};
\addplot coordinates {(0,1) (0.5,1) (1,1)};
\end{axis}
\end{tikzpicture}
```

- **exotic** (from top to bottom)

---

[38]In an early version, these lists were called \coloredplotspeclist and \blackwhiteplotspeclist which appeared to be unnecessarily long, so they have been renamed. The old names are still accepted, however.
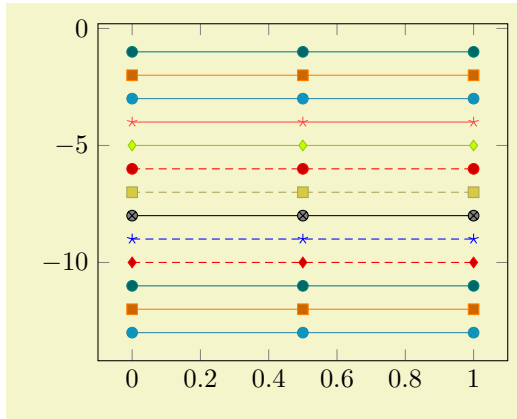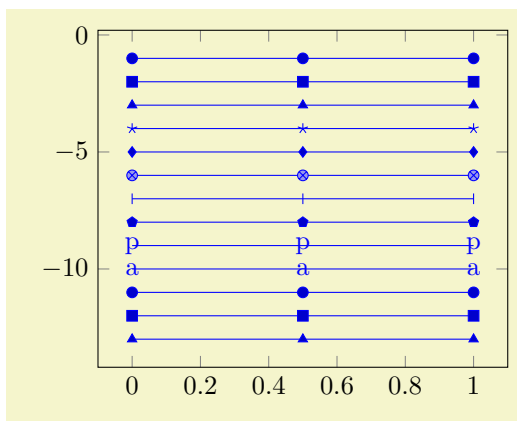
```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
\begin{axis}[
    stack plots=y,stack dir=minus,
    cycle list name=exotic]
\addplot coordinates {(0,1) (0.5,1) (1,1)};
\addplot coordinates {(0,1) (0.5,1) (1,1)};
\addplot coordinates {(0,1) (0.5,1) (1,1)};
\addplot coordinates {(0,1) (0.5,1) (1,1)};
\addplot coordinates {(0,1) (0.5,1) (1,1)};
\addplot coordinates {(0,1) (0.5,1) (1,1)};
\addplot coordinates {(0,1) (0.5,1) (1,1)};
\addplot coordinates {(0,1) (0.5,1) (1,1)};
\addplot coordinates {(0,1) (0.5,1) (1,1)};
\addplot coordinates {(0,1) (0.5,1) (1,1)};
\addplot coordinates {(0,1) (0.5,1) (1,1)};
\addplot coordinates {(0,1) (0.5,1) (1,1)};
\addplot coordinates {(0,1) (0.5,1) (1,1)};
\end{axis}
\end{tikzpicture}
```

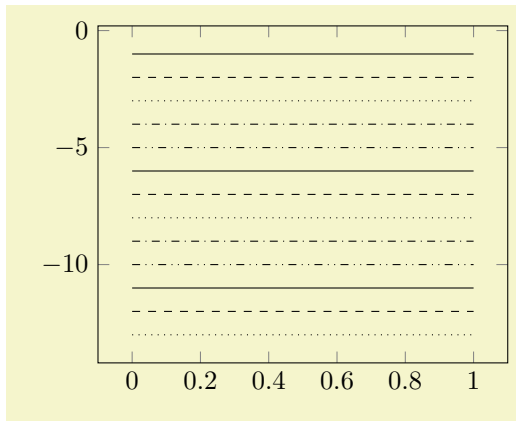- **black white** (from top to bottom)
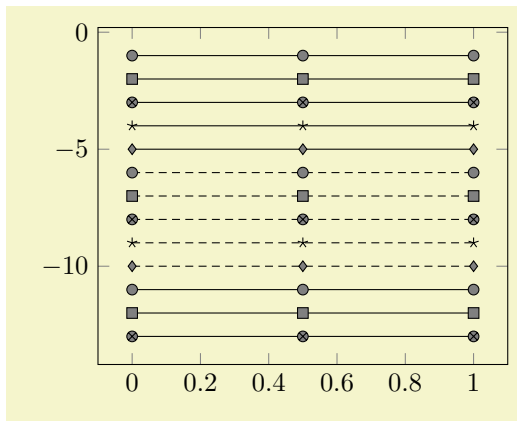
```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
\begin{axis}[
    stack plots=y,stack dir=minus,
    cycle list name=black white]
\addplot coordinates {(0,1) (0.5,1) (1,1)};
\addplot coordinates {(0,1) (0.5,1) (1,1)};
\addplot coordinates {(0,1) (0.5,1) (1,1)};
\addplot coordinates {(0,1) (0.5,1) (1,1)};
\addplot coordinates {(0,1) (0.5,1) (1,1)};
\addplot coordinates {(0,1) (0.5,1) (1,1)};
\addplot coordinates {(0,1) (0.5,1) (1,1)};
\addplot coordinates {(0,1) (0.5,1) (1,1)};
\addplot coordinates {(0,1) (0.5,1) (1,1)};
\addplot coordinates {(0,1) (0.5,1) (1,1)};
\addplot coordinates {(0,1) (0.5,1) (1,1)};
\addplot coordinates {(0,1) (0.5,1) (1,1)};
\end{axis}
\end{tikzpicture}
```

- **mark list** (from top to bottom)

```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
\begin{axis}[
    stack plots=y,stack dir=minus,
    cycle list name=mark list]
\addplot+[blue] coordinates {(0,1) (0.5,1) (1,1)};
\addplot+[blue] coordinates {(0,1) (0.5,1) (1,1)};
\addplot+[blue] coordinates {(0,1) (0.5,1) (1,1)};
\addplot+[blue] coordinates {(0,1) (0.5,1) (1,1)};
\addplot+[blue] coordinates {(0,1) (0.5,1) (1,1)};
\addplot+[blue] coordinates {(0,1) (0.5,1) (1,1)};
\addplot+[blue] coordinates {(0,1) (0.5,1) (1,1)};
\addplot+[blue] coordinates {(0,1) (0.5,1) (1,1)};
\addplot+[blue] coordinates {(0,1) (0.5,1) (1,1)};
\addplot+[blue] coordinates {(0,1) (0.5,1) (1,1)};
\addplot+[blue] coordinates {(0,1) (0.5,1) (1,1)};
\addplot+[blue] coordinates {(0,1) (0.5,1) (1,1)};
\end{axis}
\end{tikzpicture}
```

The mark list always employs the current color, but it doesn't define one (the \addplot+ statement explicitly sets the current color to blue).

The mark list is especially useful in conjunction with cycle multi list which allows to combine it with other lists (for example linestyles or a list of colors).

- `mark list*` A list containing only markers. In contrast to `mark list`, all these markers are filled. They are defined as (from top to bottom)

```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
\begin{axis}[
    stack plots=y,stack dir=minus,
    cycle list name=mark list*]
\addplot+[blue] coordinates {(0,1) (0.5,1) (1,1)};
\addplot+[blue] coordinates {(0,1) (0.5,1) (1,1)};
\addplot+[blue] coordinates {(0,1) (0.5,1) (1,1)};
\addplot+[blue] coordinates {(0,1) (0.5,1) (1,1)};
\addplot+[blue] coordinates {(0,1) (0.5,1) (1,1)};
\addplot+[blue] coordinates {(0,1) (0.5,1) (1,1)};
\addplot+[blue] coordinates {(0,1) (0.5,1) (1,1)};
\addplot+[blue] coordinates {(0,1) (0.5,1) (1,1)};
\addplot+[blue] coordinates {(0,1) (0.5,1) (1,1)};
\addplot+[blue] coordinates {(0,1) (0.5,1) (1,1)};
\addplot+[blue] coordinates {(0,1) (0.5,1) (1,1)};
\addplot+[blue] coordinates {(0,1) (0.5,1) (1,1)};
\addplot+[blue] coordinates {(0,1) (0.5,1) (1,1)};
\end{axis}
\end{tikzpicture}
```

Similar to `mark list`, the `mark list*` always employs the current color, but it doesn't define one (see above for the `\addplot+`).

- `color list` (from top to bottom)

```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
\begin{axis}[
    stack plots=y,stack dir=minus,
    cycle list name=color list]
\addplot coordinates {(0,1) (0.5,1) (1,1)};
\addplot coordinates {(0,1) (0.5,1) (1,1)};
\addplot coordinates {(0,1) (0.5,1) (1,1)};
\addplot coordinates {(0,1) (0.5,1) (1,1)};
\addplot coordinates {(0,1) (0.5,1) (1,1)};
\addplot coordinates {(0,1) (0.5,1) (1,1)};
\addplot coordinates {(0,1) (0.5,1) (1,1)};
\addplot coordinates {(0,1) (0.5,1) (1,1)};
\addplot coordinates {(0,1) (0.5,1) (1,1)};
\addplot coordinates {(0,1) (0.5,1) (1,1)};
\addplot coordinates {(0,1) (0.5,1) (1,1)};
\addplot coordinates {(0,1) (0.5,1) (1,1)};
\addplot coordinates {(0,1) (0.5,1) (1,1)};
\end{axis}
\end{tikzpicture}
```

The `cycle list name=color` choice also employs markers whereas `color list` uses *only* colors.

- `linestyles` (from top to bottom)

```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
\begin{axis}[
    stack plots=y,stack dir=minus,
    cycle list name=linestyles]
\addplot coordinates {(0,1) (0.5,1) (1,1)};
\addplot coordinates {(0,1) (0.5,1) (1,1)};
\addplot coordinates {(0,1) (0.5,1) (1,1)};
\addplot coordinates {(0,1) (0.5,1) (1,1)};
\addplot coordinates {(0,1) (0.5,1) (1,1)};
\addplot coordinates {(0,1) (0.5,1) (1,1)};
\addplot coordinates {(0,1) (0.5,1) (1,1)};
\addplot coordinates {(0,1) (0.5,1) (1,1)};
\addplot coordinates {(0,1) (0.5,1) (1,1)};
\addplot coordinates {(0,1) (0.5,1) (1,1)};
\addplot coordinates {(0,1) (0.5,1) (1,1)};
\addplot coordinates {(0,1) (0.5,1) (1,1)};
\addplot coordinates {(0,1) (0.5,1) (1,1)};
\end{axis}
\end{tikzpicture}
```

- `linestyles*` contains more dotted line styles than `linestyles` (from top to bottom)

```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
\begin{axis}[
    stack plots=y,stack dir=minus,
    cycle list name=linestyles*]
\addplot coordinates {(0,1) (0.5,1) (1,1)};
\addplot coordinates {(0,1) (0.5,1) (1,1)};
\addplot coordinates {(0,1) (0.5,1) (1,1)};
\addplot coordinates {(0,1) (0.5,1) (1,1)};
\addplot coordinates {(0,1) (0.5,1) (1,1)};
\addplot coordinates {(0,1) (0.5,1) (1,1)};
\addplot coordinates {(0,1) (0.5,1) (1,1)};
\addplot coordinates {(0,1) (0.5,1) (1,1)};
\addplot coordinates {(0,1) (0.5,1) (1,1)};
\addplot coordinates {(0,1) (0.5,1) (1,1)};
\addplot coordinates {(0,1) (0.5,1) (1,1)};
\addplot coordinates {(0,1) (0.5,1) (1,1)};
\addplot coordinates {(0,1) (0.5,1) (1,1)};
\end{axis}
\end{tikzpicture}
```

- `auto` The `cycle list name`=`auto` always denotes the most recently used cycle list activated by `cycle list` or `cycle list name`.

The definitions of all predefined cycle lists follow (see the end of this paragraph for a syntax description).

```
\pgfplotscreateplotcyclelist{color}{%
    blue,every mark/.append style={fill=blue!80!black},mark=*\\%
    red,every mark/.append style={fill=red!80!black},mark=square*\\%
    brown!60!black,every mark/.append style={fill=brown!80!black},mark=otimes*\\%
    black,mark=star\\%
    blue,every mark/.append style={fill=blue!80!black},mark=diamond*\\%
    red,densely dashed,every mark/.append style={solid,fill=red!80!black},mark=*\\%
    brown!60!black,densely dashed,every mark/.append style={
        solid,fill=brown!80!black},mark=square*\\%
    black,densely dashed,every mark/.append style={solid,fill=gray},mark=otimes*\\%
    blue,densely dashed,mark=star,every mark/.append style=solid\\%
    red,densely dashed,every mark/.append style={solid,fill=red!80!black},mark=diamond*\\%
}
```

```
\pgfplotscreateplotcyclelist{black white}{%
    every mark/.append style={fill=gray},mark=*\\%
    every mark/.append style={fill=gray},mark=square*\\%
    every mark/.append style={fill=gray},mark=otimes*\\%
    mark=star\\%
    every mark/.append style={fill=gray},mark=diamond*\\%
    densely dashed,every mark/.append style={solid,fill=gray},mark=*\\%
    densely dashed,every mark/.append style={solid,fill=gray},mark=square*\\%
    densely dashed,every mark/.append style={solid,fill=gray},mark=otimes*\\%
    densely dashed,every mark/.append style={solid},mark=star\\%
    densely dashed,every mark/.append style={solid,fill=gray},mark=diamond*\\%
}
```

```
\pgfplotscreateplotcyclelist{exotic}{%
    teal,every mark/.append style={fill=teal!80!black},mark=*\\%
    orange,every mark/.append style={fill=orange!80!black},mark=square*\\%
    cyan!60!black,every mark/.append style={fill=cyan!80!black},mark=otimes*\\%
    red!70!white,mark=star\\%
    lime!80!black,every mark/.append style={fill=lime},mark=diamond*\\%
    red,densely dashed,every mark/.append style={solid,fill=red!80!black},mark=*\\%
    yellow!60!black,densely dashed,
        every mark/.append style={solid,fill=yellow!80!black},mark=square*\\%
    black,every mark/.append style={solid,fill=gray},mark=otimes*\\%
    blue,densely dashed,mark=star,every mark/.append style=solid\\%
    red,densely dashed,every mark/.append style={solid,fill=red!80!black},mark=diamond*\\%
}
```

```
% note that "." is the currently defined Tikz color.
\pgfplotscreateplotcyclelist{mark list}{%
    every mark/.append style={solid,fill=\pgfplotsmarklistfill},mark=*\\%
    every mark/.append style={solid,fill=\pgfplotsmarklistfill},mark=square*\\%
    every mark/.append style={solid,fill=\pgfplotsmarklistfill},mark=triangle*\\%
    every mark/.append style={solid},mark=star\\%
    every mark/.append style={solid,fill=\pgfplotsmarklistfill},mark=diamond*\\%
    every mark/.append style={solid,fill=\pgfplotsmarklistfill!40},mark=otimes*\\%
    every mark/.append style={solid},mark=|\\%
    every mark/.append style={solid,fill=\pgfplotsmarklistfill},mark=pentagon*\\%
    every mark/.append style={solid},mark=text,text mark=p\\%
    every mark/.append style={solid},mark=text,text mark=a\\%
}
```

In this context, a common fill color expression can be customized using mark list fill:

/pgfplots/mark list fill={⟨*color*⟩}   (initially .!80!black)

Allows to customize the fill color for the mark list and mark list*.

For example, if you have black as color, the alternative choice mark list fill=.!50!white will produce much better results.

\pgfplotsmarklistfill

Expands to \pgfkeysvalueof{/pgfplots/mark list fill}.

```
% note that "." is the currently defined Tikz color.
\pgfplotscreateplotcyclelist{mark list*}{%
    every mark/.append style={solid,fill=\pgfplotsmarklistfill},mark=*\\%
    every mark/.append style={solid,fill=\pgfplotsmarklistfill},mark=square*\\%
    every mark/.append style={solid,fill=\pgfplotsmarklistfill},mark=triangle*\\%
    every mark/.append style={solid,fill=\pgfplotsmarklistfill},mark=halfsquare*\\%
    every mark/.append style={solid,fill=\pgfplotsmarklistfill},mark=pentagon*\\%
    every mark/.append style={solid,fill=\pgfplotsmarklistfill},mark=halfcircle*\\%
    every mark/.append style={solid,fill=\pgfplotsmarklistfill,rotate=180},mark=halfdiamond*\\%
    every mark/.append style={solid,fill=\pgfplotsmarklistfill!40},mark=otimes*\\%
    every mark/.append style={solid,fill=\pgfplotsmarklistfill},mark=diamond*\\%
    every mark/.append style={solid,fill=\pgfplotsmarklistfill},mark=halfsquare right*\\%
    every mark/.append style={solid,fill=\pgfplotsmarklistfill},mark=halfsquare left*\\%
}
```

```
\pgfplotscreateplotcyclelist{color list}{%
    red,blue,black,yellow,brown,teal,orange,violet,cyan,green!70!black,magenta,gray}
```

```
\pgfplotscreateplotcyclelist{linestyles}{solid,dashed,dotted}
\pgfplotscreateplotcyclelist{linestyles*}{solid,dashed,dotted,dashdotted,dashdotdotted}
```

Defining Own Cycle Lists

The second choice for cycle lists is to provide each entry directly as argument to cycle list,
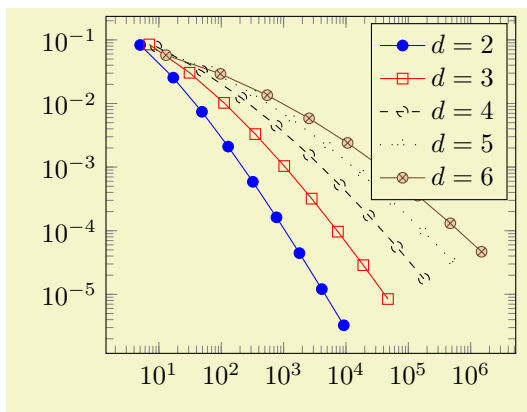

```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
\begin{loglogaxis}[cycle list={%
    {blue,mark=*},
    {red,mark=square},
    {dashed,mark=o},
    {loosely dotted,mark=+},
    {brown!60!black,
        mark options={fill=brown!40},
        mark=otimes*}}
]
\plotcoords
\legend{$d=2$,$d=3$,$d=4$,$d=5$,$d=6$}
\end{loglogaxis}
\end{tikzpicture}
```

(This example list requires `\usetikzlibrary{plotmarks}`).

The input format is described below in more detail.

Defining and Labeling Own Cycle Lists

The last method for cycle lists is to combine the define *named* cycle lists in the preamble and use them with '`cycle list name`':

`\pgfplotscreateplotcyclelist`{⟨*name*⟩}{⟨*list*⟩}

```
\pgfplotscreateplotcyclelist{mylist}{%
    {blue,mark=*},
    {red,mark=square},
    {dashed,mark=o},
    {loosely dotted,mark=+},
    {brown!60!black,mark options={fill=brown!40},mark=otimes*}}
...
\begin{axis}[cycle list name=mylist]
    ...
\end{axis}
```

Defining Cycle Lists: Input Format

A `cycle list` is defined by key-value pairs of sorts `cycle list`={⟨*list*⟩} or by the equivalent macro outlined above, `\pgfplotscreateplotcyclelist`{⟨*name*⟩}{⟨*list*⟩}.

In this context, the argument ⟨*list*⟩ is usually a comma separated list of lists of style keys like colors, line styles, marker types and marker styles. This "comma list of comma lists" structure requires to encapsulate the inner list using curly braces:

```
\pgfplotscreateplotcyclelist{mylist}{%
    {blue,mark=*},
    {red,mark=square},
    {dashed,mark=o},
    {loosely dotted,mark=+},
    {brown!60!black,mark options={fill=brown!40},mark=otimes*}}
```

Alternatively, one can terminate the inner lists (i.e. those for one single plot) with '\\':

```
\begin{axis}[cycle list={%
    blue,mark=*\\%
    red,mark=square\\%
    dashed,mark=o\\%
    loosely dotted,mark=+\\%
    brown!60!black,mark options={fill=brown!40},mark=otimes*\\%
}
]
...
\end{axis}
```

In this case, the *last* entry also needs a terminating '\\', but one can omit braces around the single entries.

Manipulating Associations of Cycle Lists to Plots

/pgfplots/cycle list shift={⟨*integer*⟩}   (initially `empty`)

   Allows to *shift* the index into the `cycle list`. If ⟨*integer*⟩ is n, the list element $i + n$ will be taken instead of the ith one. Remember that i is the index of the current `\addplot` command (starting with 0).

   Since a `cycle list` is queried *immediately* when `\addplot` (or `\addplot+`) is called, you can adjust the `cycle list shift` for selected plots:

```
\pgfplotsset{cycle list shift=3}
\addplot ....

\pgfplotsset{cycle list shift=-1}
\addplot ....
```

Special case: If the result is negative, $i + n < 0$, the list index $-(i + n)$ will be taken. For example, `cycle list shift`=-10 and $i < 10$ will result in list index $10 - i$. Note that you can use `reverse legend` to reverse legends, so this feature is probably never needed.

Defining Cycle Lists based on Color Maps

In addition to defining `cycle list`s from scratch, PGFPLOTS supports dedicated input definitions of `cycle list`=⟨*list*⟩ which allow to acquire values from an existing `colormap`. In this case, ⟨*list*⟩ contains keys enclosed in square brackets:

The first syntax, `of colormap`, allows to convert the colors of a `colormap` to a `cycle list`. It can be specified without argument by means of `cycle list`={[of colormap]} in order to take the value of the most recently assigned `colormap name` (i.e. the current `colormap`). It can also be specified as `cycle list`={[of colormap=name]} in which case it will use the specified `colormap name`=name. In both cases, the definition merely converts the colors as they are found in the colormap into the cycle list, i.e. there is no interpolation involved. Applying this to the default `colormap name`=hot which has 4 colors results in the following example:
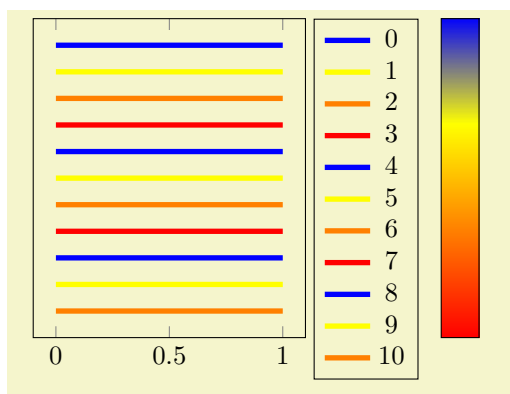

```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
\begin{axis}[
    colormap name=hot,colorbar,
    cycle list={[of colormap]},
    %
    cycle from colormap manual style,
    ]
\addplot coordinates {(0,1) (0.5,1) (1,1)};
\addplot coordinates {(0,1) (0.5,1) (1,1)};
\addplot coordinates {(0,1) (0.5,1) (1,1)};
\addplot coordinates {(0,1) (0.5,1) (1,1)};
\addplot coordinates {(0,1) (0.5,1) (1,1)};
\addplot coordinates {(0,1) (0.5,1) (1,1)};
\addplot coordinates {(0,1) (0.5,1) (1,1)};
\addplot coordinates {(0,1) (0.5,1) (1,1)};
\addplot coordinates {(0,1) (0.5,1) (1,1)};
\addplot coordinates {(0,1) (0.5,1) (1,1)};
\addplot coordinates {(0,1) (0.5,1) (1,1)};
\end{axis}
\end{tikzpicture}
```

Note that since `hot` has 4 colors, the `cycle list` also contains 4 entries which are repeated every 4 plots.

The second possibility is similar to `color of colormap`: it expects `colors of colormap`={⟨*list*⟩} or `colors of colormap`={⟨*list*⟩} of ⟨*colormap name*⟩. This choice *interpolates* colors and expects a ⟨*list*⟩ of values in the range $[0, 1000]$ where 0 is the lowest element in the `colormap` and 1000 is its highest element:
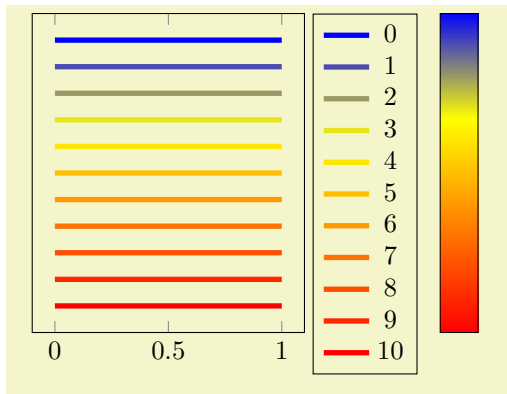
```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
\begin{axis}[
    colormap name=hot,colorbar,
    cycle list={
        [colors of colormap={0,100,...,1000}]},
    %
    cycle from colormap manual style,
    ]
\addplot coordinates {(0,1) (0.5,1) (1,1)};
\addplot coordinates {(0,1) (0.5,1) (1,1)};
\addplot coordinates {(0,1) (0.5,1) (1,1)};
\addplot coordinates {(0,1) (0.5,1) (1,1)};
\addplot coordinates {(0,1) (0.5,1) (1,1)};
\addplot coordinates {(0,1) (0.5,1) (1,1)};
\addplot coordinates {(0,1) (0.5,1) (1,1)};
\addplot coordinates {(0,1) (0.5,1) (1,1)};
\addplot coordinates {(0,1) (0.5,1) (1,1)};
\addplot coordinates {(0,1) (0.5,1) (1,1)};
\addplot coordinates {(0,1) (0.5,1) (1,1)};
\end{axis}
\end{tikzpicture}
```

In this case, we specified 11 colors and have 11 plots. Clearly, interpolated colors are of limited use and are only applicable for special use-cases. Use only `cycle list`s of this sort if the `colormap` allows a suitable distinction of adjacent plot lines! Note that `colors of colormap` is quite similar to the related way to build colormaps based on existing colormaps as outlined in Section 4.7.6 on page 198.

A related choice is `indices of colormap`={⟨*list*⟩}. As above, it accepts an optional 'of' clause of the form `indices of colormap`={⟨*list*⟩} of ⟨*colormap name*⟩. The main argument is a list of indices $0 \le N_i < N$ where N is the number colors in the colormap definition (compare the documentation of `index of colormap`). Indices which are out of range are clipped to the nearest index. For example, `viridis` comes with 18 elements and we can write
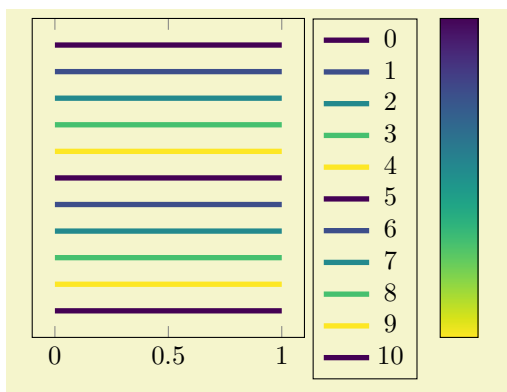

```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
\begin{axis}[
    colormap name=viridis,colorbar,
    cycle list={
      [indices of colormap={0,4,8,12,17} of viridis]},
    %
    cycle from colormap manual style,
    ]
\addplot coordinates {(0,1) (0.5,1) (1,1)};
\addplot coordinates {(0,1) (0.5,1) (1,1)};
\addplot coordinates {(0,1) (0.5,1) (1,1)};
\addplot coordinates {(0,1) (0.5,1) (1,1)};
\addplot coordinates {(0,1) (0.5,1) (1,1)};
\addplot coordinates {(0,1) (0.5,1) (1,1)};
\addplot coordinates {(0,1) (0.5,1) (1,1)};
\addplot coordinates {(0,1) (0.5,1) (1,1)};
\addplot coordinates {(0,1) (0.5,1) (1,1)};
\addplot coordinates {(0,1) (0.5,1) (1,1)};
\addplot coordinates {(0,1) (0.5,1) (1,1)};
\end{axis}
\end{tikzpicture}
```

Note that ' of viridis' is actually redundant as `viridis` was already selected in this case. In general, the syntax allows to select any (defined) colormap. Note that `indices of colormap` is quite similar to the related way to build colormaps based on existing colormaps as outlined in Section 4.7.6 on page 198.

A further related choice is `const colors of colormap`={⟨*list*⟩}. It is about the same as `colors of colormap`, except that it uses `const color of colormap` as color specification, i.e. the strategy `colormap access`=piecewise constant.

Note that all these special lists are valid arguments for `\pgfplotscreateplotcyclelist` and can also appear as sub-lists in `cycle multi list` and its variants.

Since creating a `cycle list` from a `colormap` necessarily results in plots without markers and line style variations, it makes sense to combine the result with `cycle multiindex* list`, i.e. to join two existing lists. The following example joins a pure color list with markers:
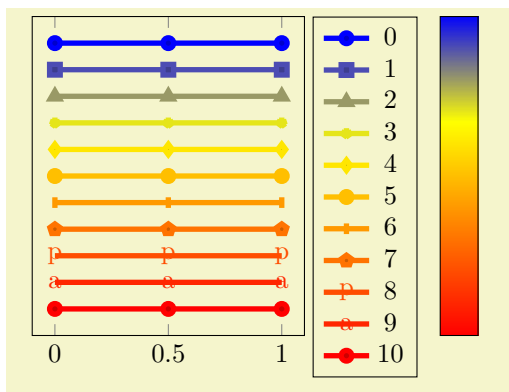
```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
\begin{axis}[
    colormap name=hot,colorbar,
    cycle multiindex* list={
        [colors of colormap={0,100,...,1000}]\nextlist
        mark list\nextlist
    },
    %
    cycle from colormap manual style,
    ]
\addplot coordinates {(0,1) (0.5,1) (1,1)};
\addplot coordinates {(0,1) (0.5,1) (1,1)};
\addplot coordinates {(0,1) (0.5,1) (1,1)};
\addplot coordinates {(0,1) (0.5,1) (1,1)};
\addplot coordinates {(0,1) (0.5,1) (1,1)};
\addplot coordinates {(0,1) (0.5,1) (1,1)};
\addplot coordinates {(0,1) (0.5,1) (1,1)};
\addplot coordinates {(0,1) (0.5,1) (1,1)};
\addplot coordinates {(0,1) (0.5,1) (1,1)};
\addplot coordinates {(0,1) (0.5,1) (1,1)};
\addplot coordinates {(0,1) (0.5,1) (1,1)};
\end{axis}
\end{tikzpicture}
```

Please refer to the next subsection for details about `cycle multiindex* list`.

Note that the preceding examples all use the following style.

/pgfplots/cycle from colormap manual style   (style, no value)

A style defined in this manual. It has the value

```
\pgfplotsset{
    cycle from colormap manual style/.style={
        x=3cm,y=10pt,ytick=\empty,
        colorbar style={x=,y=,ytick=\empty},
        point meta min=0,point meta max=1,
        stack plots=y,
        y dir=reverse,colorbar style={y dir=reverse},
        every axis plot/.style={line width=2pt},
        legend entries={0,...,20},
        legend pos=outer north east,
    }
}
```

Remark: It is possible to call `\pgfplotsset{cycle list={⟨a list⟩}}` or `cycle list name` *between* plots. Such a setting remains effective until the end of the current TEX group (that means curly braces). Every `\addplot` command queries the `cycle list` using the plot index; it doesn't hurt if `cycle list`s have changed in the meantime.

/pgfplots/cycle list/.define={⟨name⟩}list

A command which merely calls `\pgfplotscreateplotcyclelist{⟨name⟩}{⟨list⟩}` without actually selecting it as the current list.

Note that PGFPLOTS uses this to implement its `cycle list` key as follows:

```
\pgfplotsset{
    cycle list/.style={%
        cycle list/.define={@internal@}{#1},%
        cycle list name={@internal@}%
    },
}
```

Building Block to Combine Different Cycle Lists

The following keys allow to combined different `cycle list`s in order to build more complex ones.

/pgfplots/cycle multi list=⟨list 1⟩\nextlist⟨list 2⟩\nextlist···

This is one of two ways to employ more than one `cycle list` in order to determine the plot style (see also `cycle multiindex list` for the other one). This is probably best explained using an example:
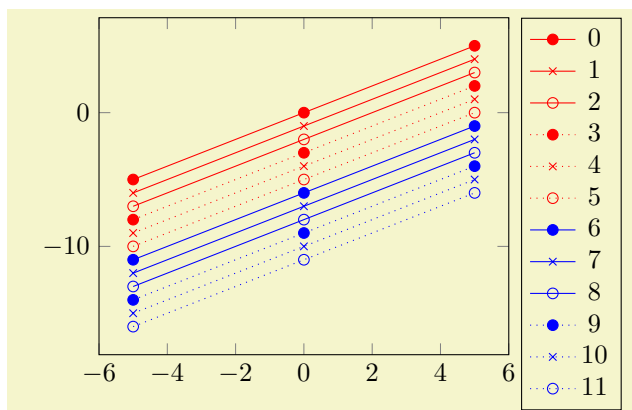

```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
\begin{axis}[
    cycle multi list={
      red,blue\nextlist
      solid,{dotted,mark options={solid}}\nextlist
      mark=*,mark=x,mark=o
    },
    samples=3,
    legend entries={0,...,20},
    legend pos=outer north east
]
    \addplot {x};
    \addplot {x-1};
    \addplot {x-2};
    \addplot {x-3};
    \addplot {x-4};
    \addplot {x-5};
    \addplot {x-6};
    \addplot {x-7};
    \addplot {x-8};
    \addplot {x-9};
    \addplot {x-10};
    \addplot {x-11};
\end{axis}
\end{tikzpicture}
```

The provided `cycle multi list` consists of three lists. The style for a single plot is made up using elements of each of the three lists: the first plot has style `red,solid,mark=*`, the second has `red,solid,mark=x`, the third has `red,solid,mark=o`. The fourth plot restarts the third list and uses the next one of list 2: it has `red,dotted,mark options={solid},mark=*` and so on.

The last list will always be advanced for a new plot. The list before the last (in our case the second list) will be advanced after the last one has been reset. In other words: `cycle multi list` allows a composition of different `cycle list` in a lexicographical way[39].

The argument for `cycle multi list` is a sequence of arguments as they would have been provided for `cycle list`, separated by `\nextlist`. In addition to providing a new cycle list, the ⟨*list i*⟩ elements can also denote `cycle list name` values (including the special `auto` cycle list which is the most recently assigned `cycle list` or `cycle list name`). The final `\nextlist` is optional.

The list in our example above could have been written as

```
\begin{axis}[
    cycle multi list={
        red\\blue\\\nextlist
        solid\\dotted,mark options={solid}\\\nextlist
        mark=*\\mark=x\\mark=o\\
    }]
```

---

[39]For those who prefer formulas: The plot with index $0 \leq i < N$ will use cycle list offsets $i_0, i_1, \ldots, i_k$, $0 \leq i_m < N_m$ where k is the number of arguments provided to `cycle multi list` and N_m is the number of elements in the mth cycle list. The offsets i_m are computed in a loop { int tmp=i; for(int m=k-1; m>=0; m=m-1) { i_m = tmp%N_m; tmp = tmp/N_m; }}.

as well (note the terminating \\ commands!).


```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
\begin{axis}[
    title={Cycle color between successive plots, then marks},
    cycle multi list={
        mark list\nextlist
        blue,red%
    },
    samples=3,
    legend entries={0,...,20},
    legend pos=outer north east
]
    \addplot {x};
    \addplot {x-1};
    \addplot {x-2};
    \addplot {x-3};
    \addplot {x-4};
    \addplot {x-5};
    \addplot {x-6};
    \addplot {x-7};
    \addplot {x-8};
    \addplot {x-9};
    \addplot {x-10};
    \addplot {x-11};
\end{axis}
\end{tikzpicture}
```
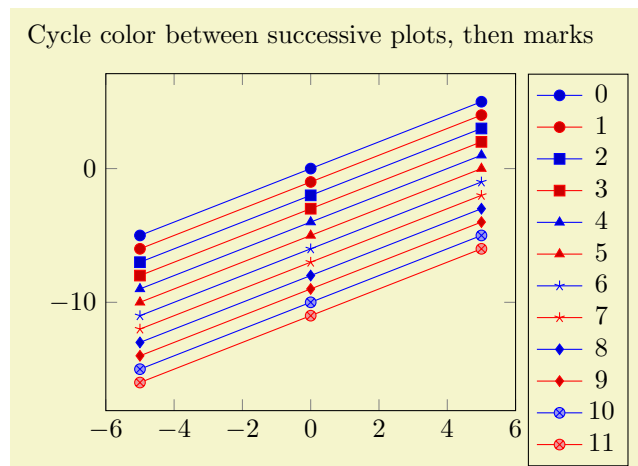
Using Sub–Lists   The $\langle list\ i \rangle$ entry can also contain just the first n elements of an already known cycle list name using the syntax [$\langle number \rangle$ of]$\langle cycle\ list\ name \rangle$. For example [2 of]mark list will use the first 2 elements of `mark list`:
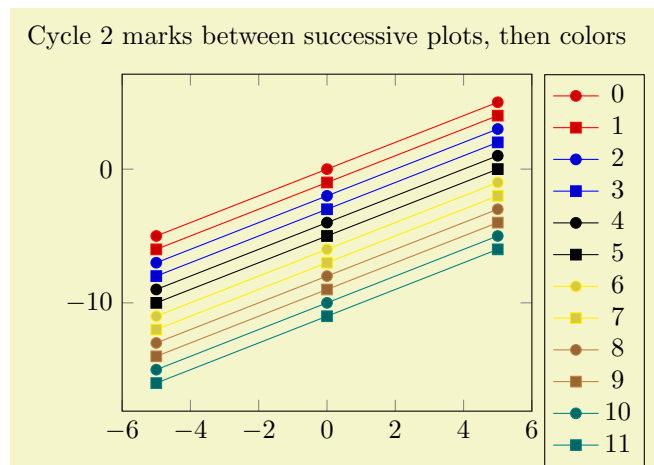
```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
\begin{axis}[
    title={Cycle 2 marks between successive plots, then colors},
    cycle multi list={%
        color list\nextlist
        [2 of]mark list
    },
    samples=3,
    legend entries={0,...,20},
    legend pos=outer north east
]
    \addplot {x};
    \addplot {x-1};
    \addplot {x-2};
    \addplot {x-3};
    \addplot {x-4};
    \addplot {x-5};
    \addplot {x-6};
    \addplot {x-7};
    \addplot {x-8};
    \addplot {x-9};
    \addplot {x-10};
    \addplot {x-11};
\end{axis}
\end{tikzpicture}
```

/pgfplots/cycle multiindex list=⟨*list 1*⟩\nextlist⟨*list 2*⟩\nextlist···

This is one of two ways to employ more than one `cycle list` in order to determine the plot style (see also `cycle multi list` for the other one). The difference between the two choices is how the list index is mapped into the sub lists. Let us start with our example:
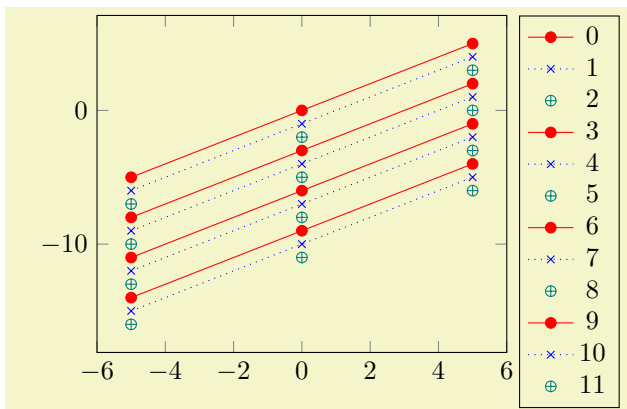
```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
\begin{axis}[
    cycle multiindex list={
      red,blue,teal\nextlist
      solid\\dotted,mark options={solid}\\only marks\\\nextlist
      mark=*,mark=x,mark=oplus\nextlist
    },
    samples=3,
    legend entries={0,...,20},
    legend pos=outer north east
]
    \addplot {x};
    \addplot {x-1};
    \addplot {x-2};
    \addplot {x-3};
    \addplot {x-4};
    \addplot {x-5};
    \addplot {x-6};
    \addplot {x-7};
    \addplot {x-8};
    \addplot {x-9};
    \addplot {x-10};
    \addplot {x-11};
\end{axis}
\end{tikzpicture}
```

The provided `cycle multiindex list` consists of three lists. The style for a single plot is made up using elements of each of the three lists: the first plot has style `red,solid,mark=*`, the second has `blue,dotted,mark options={solid},mark=x`, the third has `teal,only marks,oplus`. The fourth plot restarts all lists and uses the same as the first plot, i.e. `red,solid,mark=*`.

Note that the second list uses the list-separator '\\' which requires a final terminator as defined for `cycle list`.

Thus, this style uses *the same* index into every list (a "multi index"). Consequently, it has considerably less different choices than `cycle multi list` (which results in all possible variations), but its combination method addresses different use-cases.

The argument for `cycle multiindex list` has the very same format as the one for `cycle multi list`, including the special `[2 of]mark list` syntax and providing other cycle lists by name:
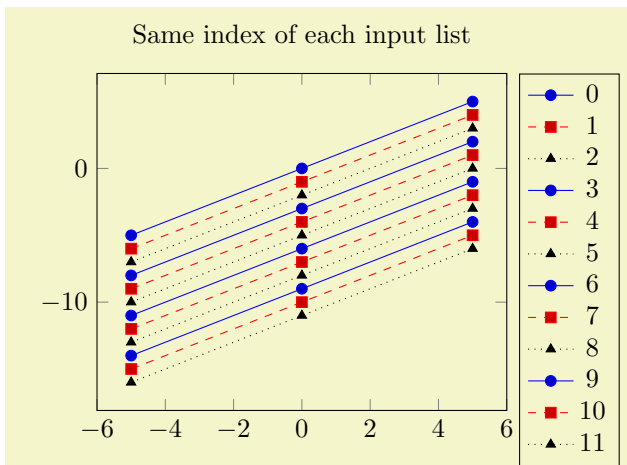
```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
\begin{axis}[
    title={Same index of each input list},
    cycle multiindex list={
        [3 of]mark list\nextlist
        blue,red\nextlist
        linestyles\nextlist
    },
    samples=3,
    legend entries={0,...,20},
    legend pos=outer north east
]
    \addplot {x};
    \addplot {x-1};
    \addplot {x-2};
    \addplot {x-3};
    \addplot {x-4};
    \addplot {x-5};
    \addplot {x-6};
    \addplot {x-7};
    \addplot {x-8};
    \addplot {x-9};
    \addplot {x-10};
    \addplot {x-11};
\end{axis}
\end{tikzpicture}
```

Note that `cycle multiindex list` accepts lists of different sizes. The size of a `cycle multiindex list` is the size of the *largest* input list, all smaller input lists are padded with empty option lists. That is why the previous example uses the color `black` for every third plot: there is no color in the second list, and omitting the color results in `black`. As soon as the last item of the largest sub-list has been used, the list is restarted.

/pgfplots/`cycle multiindex* list`=⟨*list 1*⟩\nextlist⟨*list 2*⟩\nextlist···

A variant of `cycle multiindex list` which behaves in the same way – except for sub-lists of different sizes.

As documented above, the unstarred version `cycle multiindex list` pads missing entries with *empty* options lists until all list elements have the same size.

The starred key `cycle multiindex* list` restarts sub-lists independently whenever they reach their end:
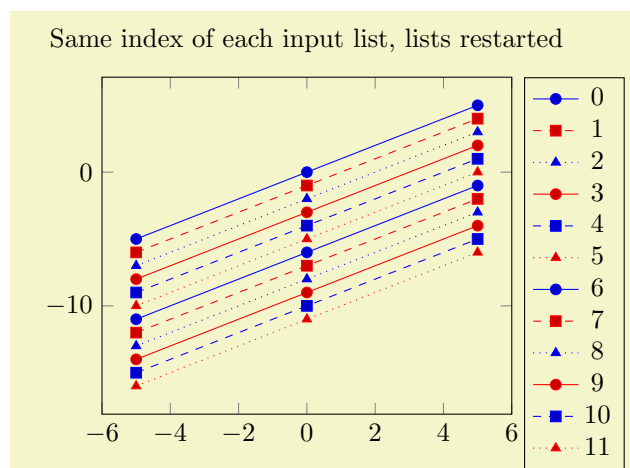
```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
\begin{axis}[
    title={Same index of each input list, lists restarted},
    cycle multiindex* list={
        [3 of]mark list\nextlist
        blue,red\nextlist
        linestyles\nextlist
    },
    samples=3,
    legend entries={0,...,20},
    legend pos=outer north east
]
    \addplot {x};
    \addplot {x-1};
    \addplot {x-2};
    \addplot {x-3};
    \addplot {x-4};
    \addplot {x-5};
    \addplot {x-6};
    \addplot {x-7};
    \addplot {x-8};
    \addplot {x-9};
    \addplot {x-10};
    \addplot {x-11};
\end{axis}
\end{tikzpicture}
```

This is the very same example as documented for the unstarred variant `cycle multiindex list`. However, the second sub-list has fewer elements – and while the unstarred variant resulted in `black`, the starred variant restarts the second sub-list as soon as its two existing colors are consumed.

This style allows to concatenate lists in complex ways:
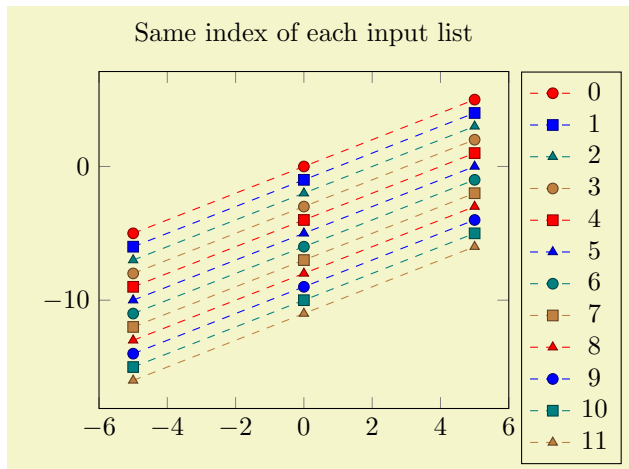
```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
\begin{axis}[
    title={Same index of each input list},
    cycle multiindex* list={
        red,blue,teal,brown\nextlist
        mark=*,mark=square*,mark=triangle*\nextlist
        dashed,every mark/.append style={
            solid,draw=.!50!black,fill=.,}\\
        \nextlist
    },
    samples=3,
    legend entries={0,...,20},
    legend pos=outer north east
]
    \addplot {x};
    \addplot {x-1};
    \addplot {x-2};
    \addplot {x-3};
    \addplot {x-4};
    \addplot {x-5};
    \addplot {x-6};
    \addplot {x-7};
    \addplot {x-8};
    \addplot {x-9};
    \addplot {x-10};
    \addplot {x-11};
\end{axis}
\end{tikzpicture}
```

We see that the four different colors appear periodically as expected. We also see the three different markers with their own period (which restarts every fourth plot as expected). But the third sub-list contains just one element as we can see by its separator character '\\' which appears just once at the end of the list! Consequently, this list is restarted for *every* plot such that every plot receives its arguments.

4.7.8 Axis Background

/pgfplots/axis background   (initially empty)

This is a style to configure the appearance of the axis as such. It can be defined and/or changed using the axis background/.style={⟨options⟩} method. A background path will be generated with ⟨options⟩, which may contain fill colors or shadings.
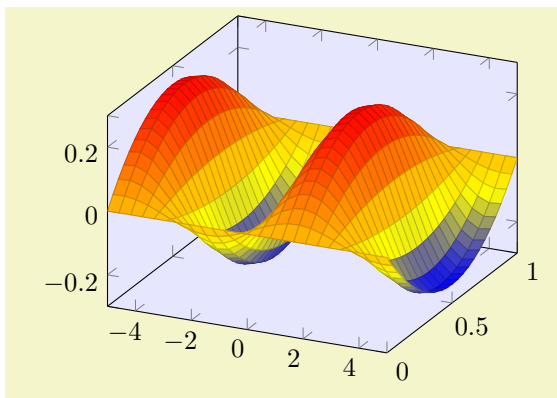

```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
    \begin{axis}[
        axis background/.style={fill=blue!10}]

    \addplot3[surf,y domain=0:1]
        {sin(deg(x)) * y*(1-y)};

    \end{axis}
\end{tikzpicture}
```

Please note that legends are filled with white in the default configuration.
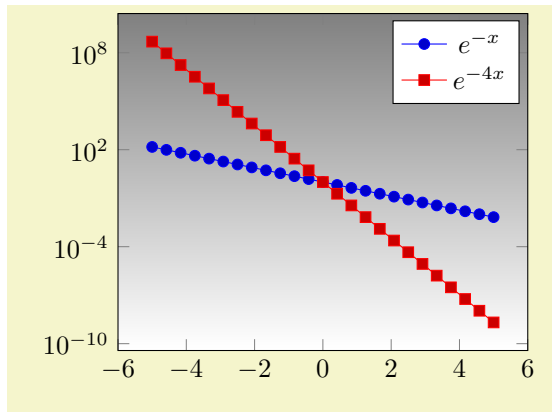
```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
    \begin{semilogyaxis}[
        axis background/.style={
            shade,top color=gray,bottom color=white},
        legend style={fill=white}]

    \addplot {exp(-x)};
    \addplot {exp(-4*x)};
    \legend{$e^{-x}$,$e^{-4x}$}
    \end{semilogyaxis}
\end{tikzpicture}
```

Details about `fill` and `shade` can be found in the Ti*k*Z manual, [7].

4.8 Providing Color Data - Point Meta

PGFPLOTS provides features which modify plots depending on a special coordinate, the "point meta data". For example, scatter plots may vary marker colors, size or appearance depending on this special data. Surface and mesh plots are another example: here, the color of a surface patch (or mesh part) depends on "point meta". The "meta data" of a node is not the position (which is given as (x, y) or (x, y, z)). It is "some information" about that node; you could say: it is a specific property of the node. This is commonly called "meta data".

4.8.1 Point Meta Overview

In PGFPLOTS, every node has its coordinate *and* its meta data. Thus, two–dimensional plots have three values: x, y, and the `point meta` data. Three–dimensional plots have four values for each coordinate: x, y, z, and the `point meta`.

In many cases, `point meta` is interpreted to be color data. To be more precise: it is interpreted to be *scalar* color data which is mapped into the `colormap` (more about this approach in the next paragraphs). However, `point meta` can be anything. Often, it is a single number as in the case of color data. That number is mapped linearly to the interval $[0, 1000]$ such that 0 corresponds to the smallest encountered value and 1000 corresponds to the largest encountered scalar value. The mapped value is available as `\pgfplotspointmetatransformed`. This special value allows to define some property of the plot: it can be the color (together with `colormap`). It can also be the `line width` in a `mesh` plot (more precisely: the `line width` could be defined to depend on the transformed meta data). An example for this approach is on page 93 where a `quiver` plot's arrow line with depends on `\pgfplotspointmetatransformed`. The value can also be used to define `mark size` as in the example for `scatter/@pre marker code` on page 117. However, `point meta` data does not necessarily need to be a number. It can be a text label (any text that you like). This is used by `nodes near coords`, for example. It could also contain a tuple like RGB color information (compare `mesh/color input`=explicit). Thus, `point meta` is really some abstract information about individual coordinates.

Note that there is only *one* `point meta` per point. See the key `visualization depends on` if you need more than one meta data value per coordinate.

The common idea is to tell PGFPLOTS how to get the meta data. It is not necessary to provide data explicitly – in many cases, the data which is used to color `surf`ace patches or `mark`er colors is the plot's y or z coordinate. The method used to tell PGFPLOTS where to find "point meta data" is the `point meta` key.

The most common use-case of `point meta` is color information: if the point meta data is in the interval $[m_{\min}, m_{\max}]$, the point meta coordinate for the smallest encountered value $m = m_{\min}$ will get the lowest color provided by the `colormap` while the largest encountered value $m = m_{\max}$ will get the highest color provided by the `colormap`. As already mentioned, this is accomplished using `\pgfplotspointmetatransformed` $\in [0, 1000]$ (per convention). Any coordinate between the smallest and largest values will be mapped linearly: for example, the mean $m = 1/2(m_{\max} + m_{\min})$ will get the middle color of the color map (it will have `\pgfplotspointmetatransformed` $= 500$). This is why "point meta" is sometimes called "color data" in this manual.
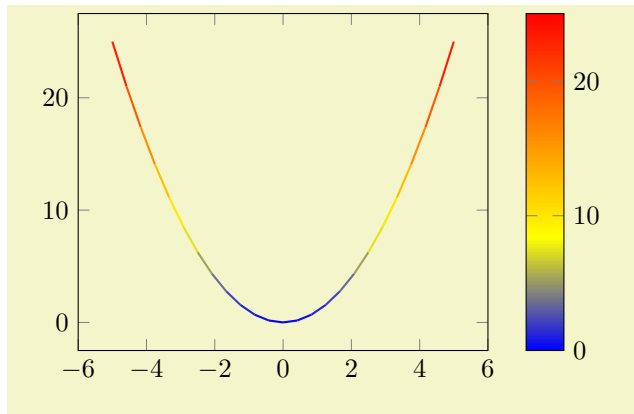
```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
    \begin{axis}[colorbar]
        \addplot[mesh,point meta=y,thick] {x^2};
    \end{axis}
\end{tikzpicture}
```

4.8.2   User Input Format for Point Meta

/pgfplots/point meta=none|⟨*expression*⟩|x|y|z|f(x)|explicit|explicit symbolic   (initially none)

The point meta key tells PGFPLOTS where to get the special point meta data. Please note that point meta and scatter src is actually the same – scatter src is an alias for point meta. Thus, the summary provided for scatter src on page 109 covers the same topics. However, the main reference for point meta is here.

none The initial choice none disables point meta data, resulting in no computational work. Any other choice will activate the computation of upper and lower ranges for point meta data, i.e. the computation of $[m_{\min}, m_{\max}]$.

x The choice x uses the already available x coordinates as point meta data. This does always refer to the *final* x coordinates after any user transformations, logarithms, stacked plot computations etc. have been applied. Consider using rawx if you need the unprocessed coordinate value here.

y

z The choices y and z are similar: they use the y or z coordinates respectively as point meta data. Consequently, these three choices do *not* need any extra data. As for x, there are math constants rawy and rawz which yield the unprocessed y and z value, respectively.

f(x) This will use the last available coordinate, in other words: it is the same as y for two dimensional plots and z for three dimensional ones.

explicit This choice tells PGFPLOTS to expect *numerical* point meta data which is provided explicitly in the coordinate input streams. This data will be transformed linearly into the current color map as it has been motivated above.

How point meta data is provided for plot coordinates, plot table and the other input methods is described in all detail in Section 4.3.1 – but we provide small examples here to summarize the possibilities:

```
% for 'coordinates':
% provide color data explicitly using [<data>]
% behind coordinates:
\addplot+[point meta=explicit]
    coordinates {
        (0,0) [1.0e10]
        (1,2) [1.1e10]
        (2,3) [1.2e10]
        (3,4) [1.3e10]
        % ...
    };
```

```
% for 'table':
% Assumes a datafile.dat like
% xcolname  ycolname     colordata
% 0         0            0.001
% 1         2            0.3
% 2         2.1          0.4
% 3         3            0.5
% ...
% the file may have more columns.
\addplot+[point meta=explicit]
    table[x=xcolname,y=ycolname,meta=colordata]
        {datafile.dat};
% or, equivalently (perhaps a little bit slower):
\addplot+[point meta=\thisrow{colordata}]
    table[x=xcolname,y=ycolname]
        {datafile.dat};
```

```
% for 'file':
% Assumes a datafile.dat like
% 0         0            0.001
% 1         2            0.3
% 2         2.1          0.4
% 3         3            0.5
% ...
% the first three columns will be used here as x,y and meta,
% resp.
\addplot+[point meta=explicit]
    file {datafile.dat};
```

```
% 'table' using expressions which may depend on all
% columns:
% Assumes a datafile.dat like
% xcolname  ycolname     anything     othercol
% 0         0            4            15
% 1         2            5            20
% 2         2.1          8            30
% 3         3            42           40
% ...
% the file may have more columns.
\addplot+[point meta={0.5*(\thisrow{anything} + sqrt(\thisrow{othercol}))}]
    table[x=xcolname,y=ycolname]
        {datafile.dat};
```

Thus, there are several methods to provide point meta (color data). The key for the choice explicit is that some data is provided explicitly – although point meta does not know how. The data is expected to be of numerical type and is mapped linearly into the range $[0, 1000]$ (maybe for use in the current color map).

explicit symbolic The choice explicit symbolic is very similar to explicit in that it expects extra data by the coordinate input routines. However, explicit symbolic does not necessarily expect numerical data: you can provide any sort of symbols. One might provide a set of styles, one for each class in a scatter plot. This is implemented using scatter/classes, see page 112. Input data is provided in the same fashion as mentioned above for the choice explicit.

This choice is usedful for nodes near coords with textual labels (see page 114) and for surface plots with explicit color (see mesh/color input=explicit for details).

$\langle expression \rangle$ This choice allows to compute point meta data using a mathematical expression. The $\langle expression \rangle$ may depend on x, y, z which yield the current x, y or z coordinate, respectively. The coordinates are completely processed (transformations, logs) as mentioned above for the choice x. Furthermore, the $\langle expression \rangle$ may depend on commands which are valid during \addplot like \plotnum or \coordindex (see Section 4.25 for details). If coordinates are provided using \addplot table, the macro \thisrow{$\langle colname \rangle$} is particularly useful as it allows to access the value of the provided $\langle colname \rangle$ of the "current" row. Computations are performed using the floating point unit of PGF, and all supported arithmetical operations can be used.

In essence, the $\langle expression \rangle$ may depend on everything which is known to all \addplot commands: the x, y and (if any) z coordinates. In addition, it may depend upon rawx, rawy or rawz. These three expressions yield the unprocessed x, y or z value as it has been found in the input stream

(no logs, no user transformations)[40]. If used together with `plot table`, you may also access other table columns (for example with `\thisrow{⟨colname⟩}`).

TeX code=⟨*code*⟩ A rather low level choice which allows to provide TeX ⟨*code*⟩ to compute a numerical value. The ⟨*code*⟩ should define the macro `\pgfplotspointmeta`. It is evaluated in a locally scoped environment (it's local variables are freed afterwards). It may depend on the same values as described for ⟨*expression*⟩ above, especially on `\thisrow{⟨colname⟩}` for table input.

Note that the math parser will be configured to use the `fpu` at this time, so `\pgfmathparse` yields floats.

Note that you need an extra pair of braces to provide this key, i.e.

`point meta={TeX code={⟨code⟩}}`.

TeX code symbolic=⟨*code*⟩ Just as `TeX code`, you can provide ⟨*code*⟩ which defines the macro `\pgfplotspointmeta`, but the result is not interpreted as a number. It is like the `explicit symbolic` choice.

Note that you need an extra pair of braces to provide this key, i.e.

`point meta={TeX code symbolic={⟨code⟩}}`.

symbolic=⟨*symbol*⟩ A choice which accepts some arbitrary ⟨*symbol*⟩ which is used for every coordinate. As `explicit symbolic` and `TeX code symbolic`, this choice yields symbolic representations, i.e. it is kept as–is without mapping the result.

The difference to `explicit symbolic` is that ⟨*symbol*⟩ is a common symbol for all points whereas `explicit symbolic` expects the input data stream (like a table) to provide individual symbols.

The different to `TeX code symbolic` is marginal: `symbolic` is actually the same as

`point meta/TeX code symbolic={\def\pgfplotspointmeta{⟨symbol⟩}}`.

A use-case for `symbolic` is `mesh/color input`=explicit mathparse, see the documentation therein.

Note that you need an extra pair of braces to provide this key, i.e.

`point meta={symbolic={⟨symbol⟩}}`.

As already mentioned, a main application of point meta data is to determine (marker/face/edge) colors using a linear map into the range $[0, 1000]$ (maybe for use in the current color map). This map works as follows: it is a function

$$\phi\colon [m_{\min}, m_{\max}] \to [0, 1000]$$

with

$$\phi(m) = \frac{m - m_{\min}}{1000}$$

such that $\phi(m_{\min}) = 0$ and $\phi(m_{\max}) = 1000$. The value 1000 is – per convention – the upper limit of all color maps. Now, if a coordinate (or edge/face) has the point meta data m, its color will be determined using $\phi(m)$: it is the color at $\phi(m)$‰ of the current color map.

This transformation depends on the interval $[m_{\min}, m_{\max}]$ which, in turn, can be modified using the keys `point meta rel`, `point meta min` and `point meta max` described below.

The untransformed point meta data is available in the macro `\pgfplotspointmeta` (only in the correct context, for example the scatter plot styles or the `scatter/@pre marker code` interface). This macro contains a low level floating point number (unless it is non-parsed string data). The transformed data will be available in the macro `\pgfplotspointmetatransformed` and is in fixed point representation. It is expected to be in the range $[0, 1000]$.

/pgfplots/set point meta if empty=`{⟨point meta source⟩}`

Sets `point meta`=⟨*point meta source*⟩, but only if `point meta`=none currently. This is used for `scatter`, `mesh` and `surf` with `set point meta if empty`=f(x).

---

[40]In rare circumstances, it might be interesting to apply a math expression to another source of point meta (one of the other choices. To this end, the ⟨*expression*⟩ is checked after the other possible choices have already been evaluated. In other words, the statement `point meta=explicit, point meta=meta*meta+3` will evaluate the expression with `meta` set to whatever data has been provided explicitly.

4.8.3   Mapping Point Meta and Color Maps

As already explained in the documentation for point meta, one application for point meta data is to determine colors using the current color map and a linear map from point meta data into the current color map. This subsection shows keys to control this mapping.

The plot handlers surf, mesh, patch, scatter, contour prepared, and some related ones all make use of mapped colors. To this end, the value provided by point meta is processed as follows:

- First, all encountered values are collected (during \addplot) and the largest and smallest value, $m_{\max}$ and $m_{\min}$, are computed. The value is stored in \pgfplotspointmeta.

- Second, every encountered value m is mapped to $[0, 1000]$ using a linear map: $m_{\min} \to 0$; $m_{\max} \to 1000$, and all values in-between are mapped linearly. This value is stored (and available) in the TEX macro \pgfplotspointmetatransformed (but not before \end{axis}).

- Finally, the mapped value \pgfplotspointmetatransformed is mapped into the current colormap. The resulting color is called mapped color.

The plot handlers, in turn, use mapped color in order to render their colors (often combined with color mixins like mapped color!80!black).

/pgfplots/point meta rel=axis wide|per plot   (initially axis wide)

The key point meta rel configures whether the interval of all point meta coordinates, $[m_{\min}, m_{\max}]$ is computed as maximum over all plots in the complete axis (the choice axis wide) or only for one particular plot (the choice per plot).
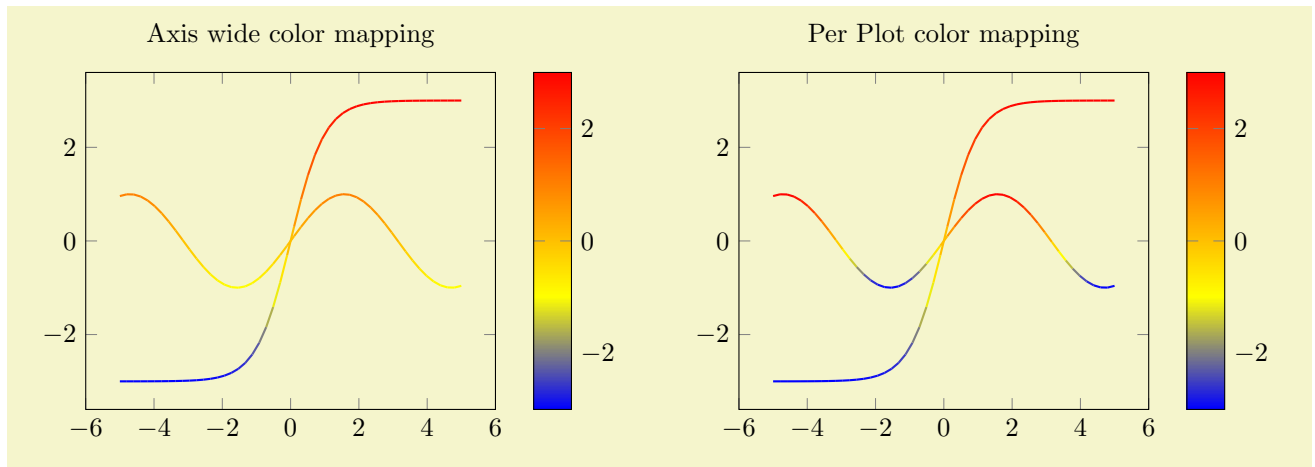

```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
   \begin{axis}[
      title=Axis wide color mapping,
      colorbar,
      samples=50,point meta rel=axis wide,
      point meta=y]

      \addplot[mesh,thick] {sin(deg(x))};
      \addplot[mesh,thick] {3*tanh(x)};
   \end{axis}
\end{tikzpicture}
~
\begin{tikzpicture}
   \begin{axis}[
      title=Per Plot color mapping,
      colorbar,
      samples=50,
      point meta rel=per plot,
      point meta=y]

      \addplot[mesh,thick] {sin(deg(x))};
      \addplot[mesh,thick] {3*tanh(x)};
   \end{axis}
\end{tikzpicture}
```

Note that a `colorbar` will still use the `axis wide` point meta limits. Consider the `colorbar source` key if you want the color data limits of a *particular* plot for your color bar. The `point meta rel` key configures how point meta maps to colors in the `colormap`.

`/pgfplots/point meta min={`⟨*number*⟩`}`
`/pgfplots/point meta max={`⟨*number*⟩`}`

These keys allow to define the range required for the linear map of point meta data into the range $[0, 1000]$ (for example, for current maps) explicitly. This is necessary if the same mapping shall be used for more than one axis.

Remarks about special cases:

- It is possible to provide limits partially; in this case, only the missing limit will be computed.
- If point meta data falls outside of these limits, the linear transformation is still well defined which is acceptable (unless the interval is of zero length). However, color data can't be outside of these limits, so color bars perform a truncation.
- This key can be provided for single plots as well as for the complete axis (or for both).
- If meta limits are provided for a single plot, these limits may also contribute to the axis wide meta interval.

`/pgfplots/colormap access=map|direct|const|`
  `piecewise constant|piecewise const|piecewise linear`   (initially `map`)

This key configures how point meta data is used to determine colors from a color map.

Mapping Point Meta using Piecewise Constant Interpolation

The initial configuration `map` performs the linear mapping operation explained above in all detail.

Using Colormaps as Indexed Color Space (Palette)

The choice `direct` does not perform any transformation; it interpretes the value of `point meta` as integer indices into the current color map. If a number is no integer, it will be truncated by throwing away any fraction parts of the number. Consequently, it is quite similar to `index of colormap`.

Suppose we have the color definitions ■ RdPu-K, ■ RdPu-I, ■ RdPu-G, ■ RdPu-E, and □ RdPu-B (which are actually taken from `\usetikzlibrary{colorbrewer}`).

We will use these colors in order to define a `colormap`:
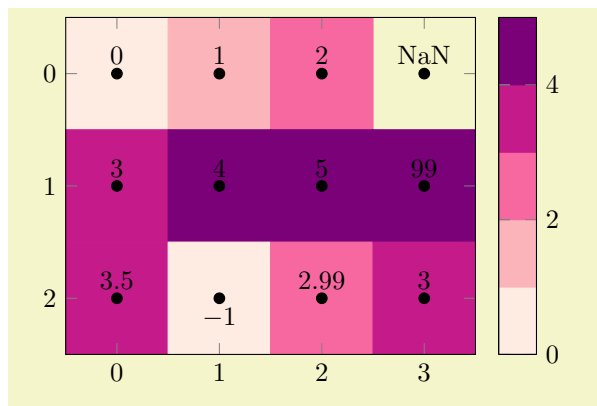

```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
% requires \usetikzlibrary{colorbrewer}
\begin{tikzpicture}
\begin{axis}[
    colormap={brewer}{
        color=(RdPu-B) color=(RdPu-E)
        color=(RdPu-G) color=(RdPu-I)
        color=(RdPu-K)},
    enlargelimits=false,
    colorbar as palette,
]
\addplot[matrix plot,
    nodes near coords,mark=*,
    point meta=explicit,
    colormap access=direct,
]
coordinates {
(0,0) [0] (1,0) [1] (2,0) [2] (3,0) [NaN]

(0,1) [3] (1,1) [4] (2,1) [5] (3,1) [99]

(0,2) [3.5] (1,2) [-1] (2,2) [2.99] (3,2) [3]
};
\end{axis}
\end{tikzpicture}
```

The example has a 3×4 matrix, each with explicitly provided values of point meta. The first point has a point meta value of 0 and uses the first color of the colormap (RdPu-B, ▭). The second point has value 1 and uses the second color, RdPu-E ▭, and so on. Note that NaN is interpreted as 'hole' in the matrix and is left empty (you see the background color here). Note furthermore that coordinate (1,2) [-1] is mapped to the first color since values outside of the allowed range are automatically clipped to the next correct color. The same holds for the point with [99]: it is mapped to the last available color ▪. Finally, the point with [2.99] is mapped to index 2 (▭) since colormap access=direct truncates to the next integer index.

/pgfplots/colorbar as palette   (no value)

The example above makes use of colorbar as palette, a dedicated style useful for such palette-type applications.

It is defined as

```
\pgfplotsset{
    colorbar as palette/.style={
        colorbar sampled={
            surf,
            colormap access=direct,
            shader=flat corner,
            samples=\pgfplotscolormapsizeof
            {\pgfkeysvalueof{/pgfplots/colormap name}}+1,
        },
        colorbar style={
            point meta min=0,
            point meta max=\pgfplotscolormapsizeof
            {\pgfkeysvalueof{/pgfplots/colormap name}},
        }}}
```

The idea is to show only the colors of the "palette", i.e. without interpolating values of the colormap. Furthermore, it is supposed to show all available colors.

See also the closely related (but more general) colorbar as legend.

Note that colormap access=direct changes the way how point meta is translated to colors. However, it does *not affect* shader. In other words, it is perfectly sane to use shader=interp or shader=flat mean. This, however, will interpolate the colors resulting from colormap access=direct! Our example above uses shader=flat corner which results in no color interpolation at all.

The choice colormap access=direct is actually like a color palette for images with indexed colorspaces: suppose we use the famous "Lena" image [5], downsample it to 128×128, and export it to coordinates of the form

```
1 1 194
1 2 194
1 3 170
1 4 193
1 5 188
1 6 188
...
```

with an indexed colorspace. Furthermore, we import its color palette as PGFPLOTS colormap. To this end, a small Matlab script serves as utility to convert a tiff image to coordinates:[41]

```
[Z,cm] = imread('4.2.04_128.tiff');
[X,Y]=meshgrid(1:size(Z,1), 1:size(Z,2));
data = [ X(:) Y(:) Z(:) ];
fid = fopen('lena.dat', 'w');
fprintf(fid, "%d %d %d\n", data');
fclose(fid);

fid = fopen('lena_cm.tex', 'w');
fprintf(fid, "\\pgfplotsset{colormap={lena palette}{\n");
fprintf(fid, "rgb=(%f,%f,%f)\n", cm');
fprintf(fid, "}}\n");
fclose(fid);
```

---

[41]Also see Section 7.2.1, "Importing Mesh Data From Matlab To PGFPlots" on page 532

This allows us to import the graphics into PGFPLOTS as `matrix plot`:
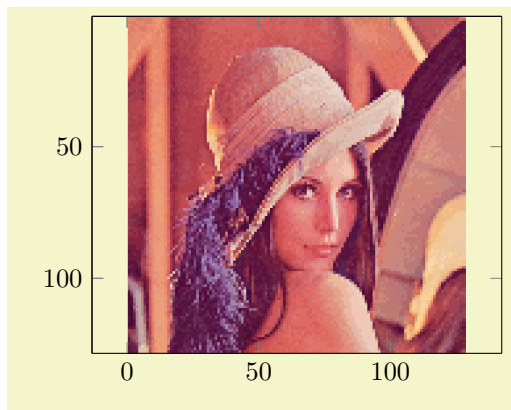

```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
    % load and activate the CM:
    \input lena_cm.tex
    \begin{axis}[view={0}{90},axis equal]
    \addplot3[matrix plot,
        colormap access=direct,
        mesh/rows=128,
        mesh/ordering=colwise,
    ]
        table {lena.dat};
    \end{axis}
\end{tikzpicture}
```

The files `lena_cm.tex` and `lena.dat` are shipped with PGFPLOTS and can be downloaded from CTAN. The keys to decode the table data into a `mesh` are specific to the Matlab export format of our script.

Note that rendering images from coordinates is considerably less efficient than `\includegraphics` in terms of

- computational time required by PGFPLOTS,
- space consumption in the resulting `pdf` document,
- and time to render the resulting `pdf` in the viewer(s).

Depending on the use-case, `\addplot graphics` may help to reduce typesetting times.

Some more details:

- If there are m colors in the color map and the color data falls outside of $[0, m-1]$, it will be pruned to either the first or the last color.
- If color data is a real number, it will be truncated to the next smaller integer.
- If `colormap access`=direct is combined with a `shader`≠flat corner, color interpolation takes place. However, the color interpolation is not carried out in terms of the scalar `point meta` (as would have been done for `colormap access`=map). Instead, it is carried out on the *resulting* colors in their own colorspace.
- Note that `patch refines` or `patch to triangles` is unsupported in this context (at the time of this writing, it will interpolate the color indices, resulting in badly defined behavior).

See also the related keys `color of colormap` and `index of colormap`.

The choice `colormap access`=piecewise linear is an alias for `colormap access`=map. It is related to `color of colormap`.

Mapping Point Meta using Piecewise Constant Interpolation

Beware: Viewer Limitations The following paragraph makes uses of PDF features which are unsupported by some free viewers (including `pdf.js` and `evince`). Please resort to a suitable viewer if you see unexpected results.

The choice `colormap access`=piecewise constant is very similar to `colormap access`=map: it accepts the same `point meta` values as input, maps them linearly into $[0, 1000]$ and uses the first color of the `colormap` if the value of `point meta` is `point meta min` and the last color of the `colormap` if the value of `point meta` is `point meta max`. However, values of `point meta` which fall *between* two `colormap` entries are interpolated using *piecewise constant* interpolation, i.e. just like `const plot`: the interpolated color resembles the value of the *first* color of the interval. As a consequence, the result contains at most as many colors as the `colormap` provides:
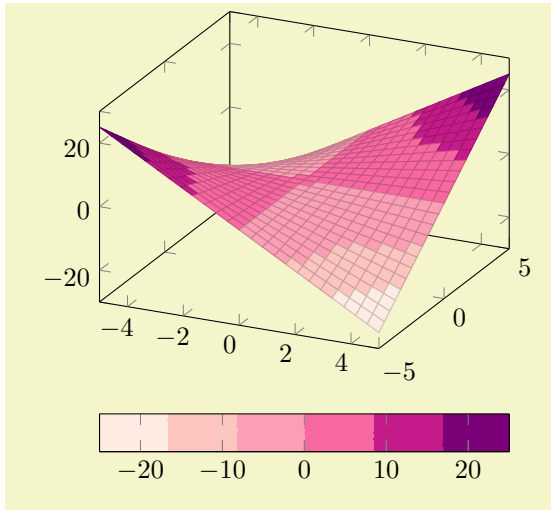
```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
% requires \usepgfplotslibrary{colorbrewer}
\begin{tikzpicture}
\begin{axis}[
    colormap access=piecewise constant,
    colormap/RdPu-6,
    %
    colorbar horizontal,
]
\addplot3[
    surf,
] {x*y};
\end{axis}
\end{tikzpicture}
```

The choice `colormap access`=piecewise constant is compatible with all available `shader`s, but its best results are possible using `shader=interp` as this will avoid rectangular artifacts at mesh boundaries.
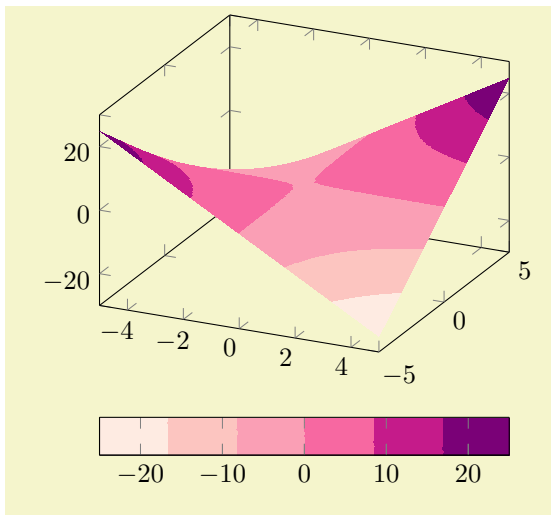

```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
% requires \usepgfplotslibrary{colorbrewer}
\begin{tikzpicture}
\begin{axis}[
    colormap access=piecewise constant,
    colormap/RdPu-6,
    %
    colorbar horizontal,
]
\addplot3[
    surf,
    shader=interp,
] {x*y};
\end{axis}
\end{tikzpicture}
```

The choice `colormap access`=piecewise constant requires `colormap`s with a suitable number of colors. This is quite different to `colormap access`=map (or `piecewise linear`) where the actual number of colors in the `colormap` cannot be seen in the resulting plot. In order to get the desired effects, one may need the same `colormap` with a different number of samples. To this end, one can make use of the special `colormap` syntax which is based on `samples of colormap` and its variants:
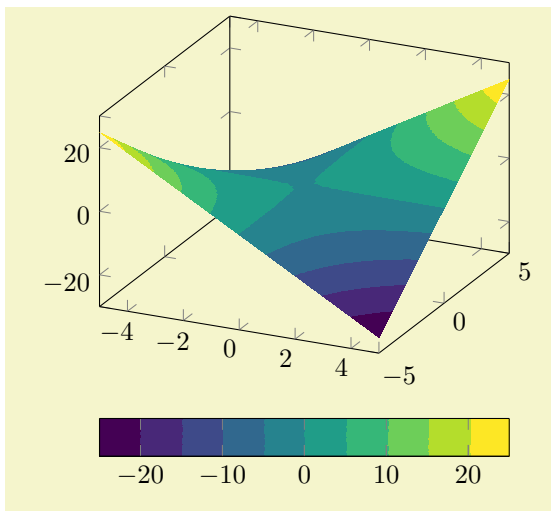

```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
\begin{axis}[
    colormap access=piecewise constant,
    colormap={my sampled version of viridis}{
        samples of colormap=(10 of viridis)},
    %
    colorbar horizontal,
]
\addplot3[
    surf,
    shader=interp,
] {x*y};
\end{axis}
\end{tikzpicture}
```

The example takes the existing `colormap name`=viridis and chooses 10 samples of it. The result is called `my sampled version of viridis` and is used as "current colormap". Details about this process can be read in Section 4.7.6 on page 198.

See also the plot handler `contour filled` which is based on such a visualization scheme.

The strategy which determines colors in this context is also available as `const color of colormap`.

The choices `piecewise const` and `const` are aliases for `piecewise constant`.

4.9 Axis Descriptions

Axis descriptions are labels for x and y axis, titles, legends and the like. Axis descriptions are drawn after the plot is finished and they are not subjected to clipping.

4.9.1 Placement of Axis Descriptions

This section describes how to *modify* the placement of titles, labels, legends and other axis descriptions. It may be skipped at first reading.

There are different methods to place axis descriptions. One of them is to provide coordinates relative to the axis' rectangle such that (0,0) is the lower left corner and (1,1) is the upper right corner – this is very useful for figure titles or legends. Coordinates of this type, i.e. without unit like (0,0) or (1.03,1), are called `axis description cs` (the `cs` stands for "coordinate system"). One other method is of primary interest for axis labels – they should be placed near the tick labels, but it a way that they don't overlap or obscure tick labels. Furthermore, axis labels shall be placed such that they are automatically moved if the axis is rotated (or tick labels are moved to the right side of the figure). There is a special coordinate system to realize these two demands, the `ticklabel cs`.

In the following, the two coordinate systems `axis description cs` and `ticklabel cs` are described in more detail. It should be noted that `axis description cs` is used automatically, so it might never be necessary to use it explicitly.

Coordinate system `axis description cs`

A coordinate system which is used to place axis descriptions. Whenever the option '`at`={($\langle x \rangle$,$\langle y \rangle$)}' occurs in `label style`, `legend style` or any other axis description, ($\langle x \rangle$,$\langle y \rangle$) is interpreted to be a coordinate in `axis description cs`.

The point $(0, 0)$ is always the lower left corner of the tightest bounding box around the axes (without any descriptions or ticks) while the point $(1, 1)$ is the upper right corner of this bounding box.

In most cases, it is *not* necessary to explicitly write `axis description cs` as it is the default coordinate system for any axis description. An example for how coordinates are placed is shown below.
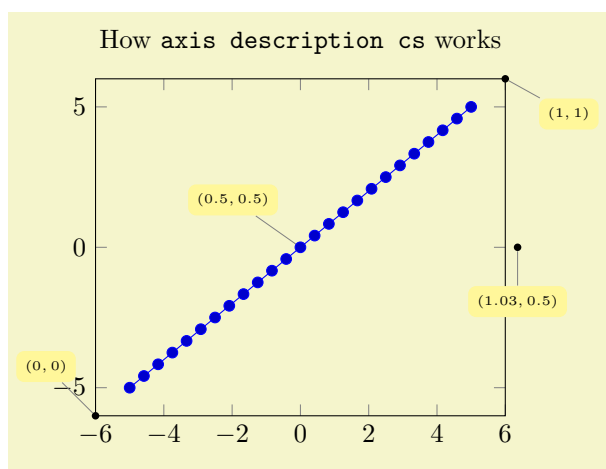
```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
% [See the TikZ manual if you'd like to learn about nodes and pins]
\begin{tikzpicture}
    \tikzset{
        every pin/.style={fill=yellow!50!white,rectangle,rounded corners=3pt,font=\tiny},
        small dot/.style={fill=black,circle,scale=0.3}
    }
    \begin{axis}[
        clip=false,
        title=How \texttt{axis description cs} works
    ]
    \addplot {x};

    \node[small dot,pin=120:{$(0,0)$}]      at (axis description cs:0,0) {};
    \node[small dot,pin=-30:{$(1,1)$}]      at (axis description cs:1,1) {};
    \node[small dot,pin=-90:{$(1.03,0.5)$}] at (axis description cs:1.03,0.5) {};
    \node[small dot,pin=125:{$(0.5,0.5)$}]  at (axis description cs:0.5,0.5) {};
    \end{axis}
\end{tikzpicture}
```

Axis descriptions are TikZ nodes, that means all placement and detail options of [7] apply. The point on the node's boundary which is actually shifted to the `at` coordinate needs to be provided with an anchor (cf [7, Nodes and Edges]):
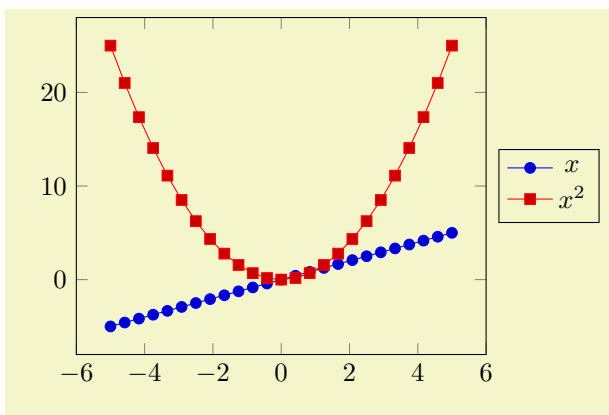

```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
    \begin{axis}[
        legend entries={$x$,$x^2$},
        legend style={
            at={(1.03,0.5)},
            anchor=west
        }
    ]
    \addplot {x};
    \addplot {x^2};
    \end{axis}
\end{tikzpicture}
```

Standard anchors of nodes are `north`, `east`, `south`, `west` and mixed components like `north east`. Please refer to [7] for a complete documentation of anchors.

Remarks:

- Each of the anchors described in Section 4.19 can be described by `axis description cs` as well.
- The `axis description cs` is independent of axis reversals or skewed axes. Only for the default configuration of boxed axes is it the same as `rel axis cs`, i.e. `(0,0)` is the same as the smallest axis coordinate and `(1,1)` is the largest one in case of standard boxed axes[42].
- Even for three dimensional axes, the `axis description cs` is still two-dimensional: it always refers to coordinates relative to the tightest bounding box around the axis (without any descriptions or ticks).

---

[42]This was different in versions before 1.3: earlier versions did not have the distinction between `axis description cs` and `rel axis cs`.
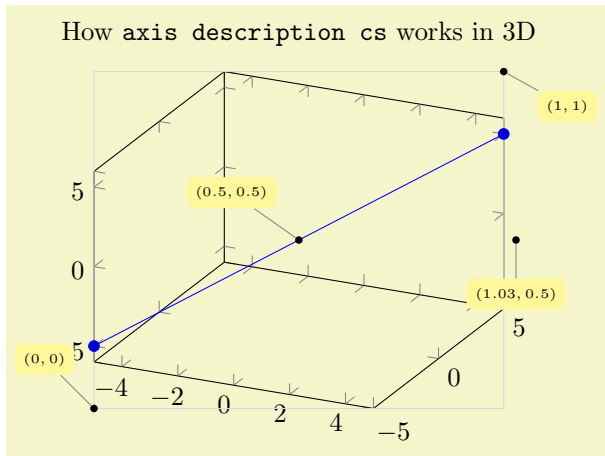
```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
% the same as above for 3D ...
% [See the TikZ manual if you'd like to learn about nodes and pins]
\begin{tikzpicture}
    \tikzset{
        every pin/.style={fill=yellow!50!white,rectangle,rounded corners=3pt,font=\tiny},
        small dot/.style={fill=black,circle,scale=0.3}
    }
    \begin{axis}[
        clip=false,
        title=How \texttt{axis description cs} works in 3D
    ]
    \addplot3 coordinates {(-5,-5,-5) (5,5,5)};

    \draw[black!15] (axis description cs:0,0) rectangle (axis description cs:1,1);

    \node[small dot,pin=120:{$(0,0)$}]     at (axis description cs:0,0) {};
    \node[small dot,pin=-30:{$(1,1)$}]     at (axis description cs:1,1) {};
    \node[small dot,pin=-90:{$(1.03,0.5)$}] at (axis description cs:1.03,0.5) {};
    \node[small dot,pin=125:{$(0.5,0.5)$}]  at (axis description cs:0.5,0.5) {};
    \end{axis}
\end{tikzpicture}
```

- Since the view does not influence these positions, `axis description cs` might not be a good choice for axis labels in 3D. The `ticklabel cs` is used in this case.

Coordinate system `xticklabel cs`
Coordinate system `yticklabel cs`
Coordinate system `zticklabel cs`
Coordinate system `ticklabel cs`
Coordinate system `xticklabel* cs`
Coordinate system `yticklabel* cs`
Coordinate system `zticklabel* cs`
Coordinate system `ticklabel* cs`

A set of special coordinate systems intended to place axis descriptions (or any other drawing operation) besides tick labels, in a way such that neither tick labels nor the axis as such are obscured.

See also `xlabel near ticks` as one main application of `ticklabel cs`.

The `xticklabel cs` (and its variants) always refer to one, uniquely identified axis: the one which is (or would be) annotated with tick labels.

The `ticklabel cs` (without explicit x, y or z) can only be used in contexts where the axis character is known from context (for example, inside of `xlabel style` – there, the `ticklabel cs` is equivalent to `xticklabel cs`).

The starred variants `xticklabel* cs` and its friends do not take the size of any tick labels into account.

Each of these coordinate systems allows to specify points on a straight line which is placed parallel to an axis containing tick labels, moved away just far enough to avoid overlaps with the tick labels:
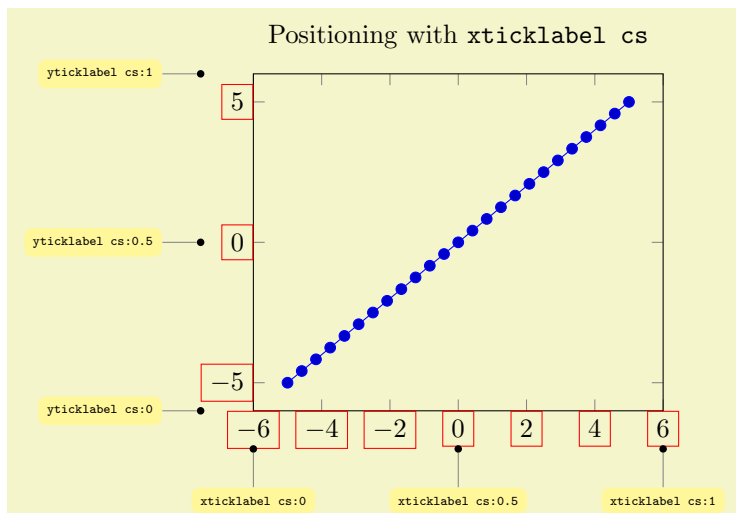
```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\tikzset{
    every pin/.style={fill=yellow!50!white,rectangle,rounded corners=3pt,font=\tiny},
    small dot/.style={fill=black,circle,scale=0.3}
}
\begin{tikzpicture}
\begin{axis}[
    clip=false,
    ticklabel style={draw=red},
    title=Positioning with \texttt{xticklabel cs}]
    \addplot {x};
    \node[small dot,pin=-90:{\texttt{xticklabel cs:0}}]     at (xticklabel cs:0) {};
    \node[small dot,pin=-90:{\texttt{xticklabel cs:0.5}}]   at (xticklabel cs:0.5) {};
    \node[small dot,pin=-90:{\texttt{xticklabel cs:1}}]     at (xticklabel cs:1) {};


    \node[small dot,pin=180:{\texttt{yticklabel cs:0}}]     at (yticklabel cs:0) {};
    \node[small dot,pin=180:{\texttt{yticklabel cs:0.5}}]   at (yticklabel cs:0.5) {};
    \node[small dot,pin=180:{\texttt{yticklabel cs:1}}]     at (yticklabel cs:1) {};
\end{axis}
\end{tikzpicture}
```

The basic idea is to place coordinates on a straight line which is parallel to the axis containing tick labels – but shifted such that the line does not cut through tick labels.

Note that an axis description which has been placed with `xticklabel cs` or its friends is also useful for skewed axes or the `axis x line` variants – it is often the same value for all these variants. In particular, it is useful for three–dimensional axes, see below.

Typically, `xticklabel cs` places nodes exactly at the position where the largest associated tick label is finished. While this is very useful, it might be undesired – for example if one wants to move into the opposite direction (here, the special anchor `near ticklabel opposite` might be of interest). To this end, there are the starred variants, i.e. `xticklabel* cs` and its friends:
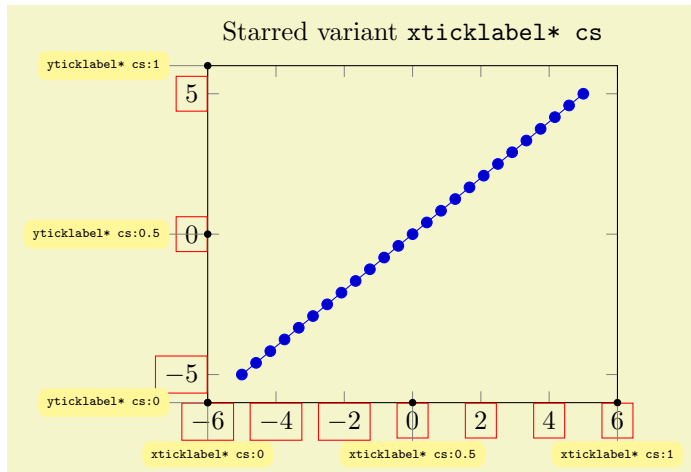
```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\tikzset{
    every pin/.style={fill=yellow!50!white,rectangle,rounded corners=3pt,font=\tiny},
    small dot/.style={fill=black,circle,scale=0.3}
}
\begin{tikzpicture}
\begin{axis}[
    clip=false,
    ticklabel style={draw=red},
    title=Starred variant \texttt{xticklabel* cs}]
    \addplot {x};
    \node[small dot,pin=-90:{\texttt{xticklabel* cs:0}}]      at (xticklabel* cs:0) {};
    \node[small dot,pin=-90:{\texttt{xticklabel* cs:0.5}}]    at (xticklabel* cs:0.5) {};
    \node[small dot,pin=-90:{\texttt{xticklabel* cs:1}}]      at (xticklabel* cs:1) {};


    \node[small dot,pin=180:{\texttt{yticklabel* cs:0}}]      at (yticklabel* cs:0) {};
    \node[small dot,pin=180:{\texttt{yticklabel* cs:0.5}}]    at (yticklabel* cs:0.5) {};
    \node[small dot,pin=180:{\texttt{yticklabel* cs:1}}]      at (yticklabel* cs:1) {};
\end{axis}
\end{tikzpicture}
```

The preceding example places all the additional anchors precisely onto the axis on which tick labels are drawn. The starred version `xticklabel* cs` ignores the size of tick labels.

Of course, it is relatively simple to get the same coordinates as in the two dimensional example above with `axis description cs`, except that `ticklabel cs` always respects the tick label sizes appropriately. However, `ticklabel cs` becomes far superior when it comes to three dimensional positioning:
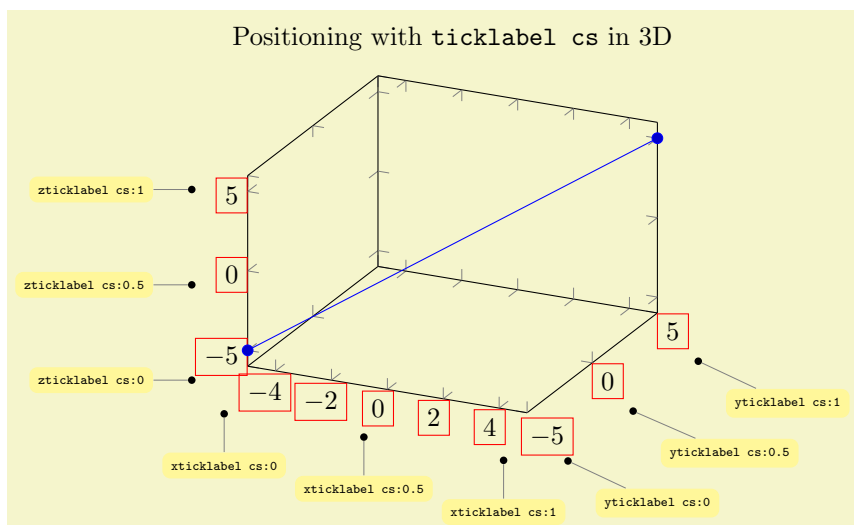
```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
% the same as above for 3D ...
\begin{tikzpicture}
    \tikzset{
        every pin/.style={fill=yellow!50!white,rectangle,rounded corners=3pt,font=\tiny},
        small dot/.style={fill=black,circle,scale=0.3}
    }
    \begin{axis}[
        ticklabel style={draw=red},
        clip=false,
        title=Positioning with \texttt{ticklabel cs} in 3D
    ]
    \addplot3 coordinates {(-5,-5,-5) (5,5,5)};

    \node[small dot,pin=-90:{\texttt{xticklabel cs:0}}]    at (xticklabel cs:0) {};
    \node[small dot,pin=-90:{\texttt{xticklabel cs:0.5}}]  at (xticklabel cs:0.5) {};
    \node[small dot,pin=-90:{\texttt{xticklabel cs:1}}]    at (xticklabel cs:1) {};

    \node[small dot,pin=-45:{\texttt{yticklabel cs:0}}]    at (yticklabel cs:0) {};
    \node[small dot,pin=-45:{\texttt{yticklabel cs:0.5}}]  at (yticklabel cs:0.5) {};
    \node[small dot,pin=-45:{\texttt{yticklabel cs:1}}]    at (yticklabel cs:1) {};

    \node[small dot,pin=180:{\texttt{zticklabel cs:0}}]    at (zticklabel cs:0) {};
    \node[small dot,pin=180:{\texttt{zticklabel cs:0.5}}]  at (zticklabel cs:0.5) {};
    \node[small dot,pin=180:{\texttt{zticklabel cs:1}}]    at (zticklabel cs:1) {};
    \end{axis}
\end{tikzpicture}
```

The coordinate `ticklabel cs:0` is associated with the lower axis limit while `ticklabel cs:1` is near the upper axis limit. The value `0.5` is in the middle of the axis, any other values (including negative values or values beyond 1) are linearly interpolated inbetween.

All coordinate systems like `ticklabel cs` also accepts a second (optional) argument: a shift "away" from the tick labels. The shift points to a vector which is orthogonal[43] the associated axis, away from the tick labels. A shift of `0pt` is directly at the edge of the tick labels in direction of the normal vector, positive values move the position away and negative closer to the tick labels.

---
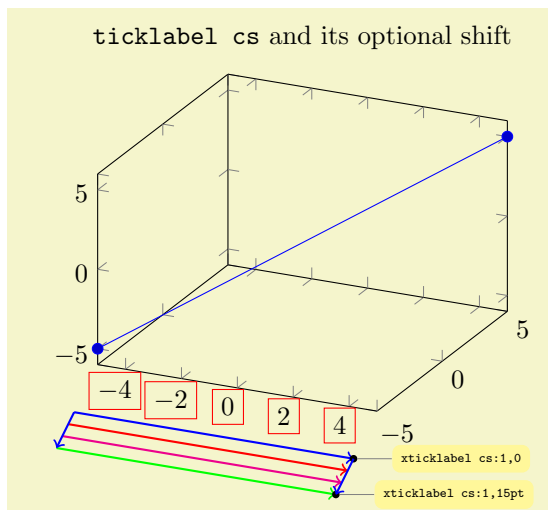
[43]Actually, the outer normal has the impression of being "orthogonal" to its axis, which appears to be sufficient.

```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\tikzset{
    every pin/.style={fill=yellow!50!white,rectangle,rounded corners=3pt,font=\tiny},
    small dot/.style={fill=black,circle,scale=0.3}
}
\begin{tikzpicture}
    \begin{axis}[
        xticklabel style={draw=red},
        clip=false,
        title=\texttt{ticklabel cs} and its optional shift
    ]
    \addplot3 coordinates {(-5,-5,-5) (5,5,5)};

    \draw[blue,thick,->]     (xticklabel cs:0,0)      -- (xticklabel cs:1,0);
    \draw[red,thick,->]      (xticklabel cs:0,5pt)    -- (xticklabel cs:1,5pt);
    \draw[magenta,thick,->]  (xticklabel cs:0,10pt)   -- (xticklabel cs:1,10pt);
    \draw[green,thick,->]    (xticklabel cs:0,15pt)   -- (xticklabel cs:1,15pt);
    \node[small dot,pin=0:{\texttt{xticklabel cs:1,0}}]     at (xticklabel cs:1,0) {};
    \node[small dot,pin=0:{\texttt{xticklabel cs:1,15pt}}]  at (xticklabel cs:1,15pt) {};

    \draw[blue,thick,->]     (xticklabel cs:0,0)      -- (xticklabel cs:0,15pt);
    \draw[blue,thick,->]     (xticklabel cs:1,0)      -- (xticklabel cs:1,15pt);
    \end{axis}
\end{tikzpicture}
```

Whenever the `ticklabel cs` is used, the anchor should be set to `anchor`=near ticklabel (see below).

Whenever the starred version `ticklabel* cs` is used, both anchors `anchor`=near ticklabel and `anchor`=near ticklabel opposite are useful choices.

There is one specialty: if you reverse an axis (with `x dir`=reverse), points provided by `ticklabel cs` will be *unaffected* by the axis reversal. This is intented to provide consistent placement even for reversed axes. Use `allow reversal of rel axis cs`=false to disable this feature.

The purpose of `ticklabel cs` is to place nodes "next to tick labels". The position of tick labels as such is determined in a similar way to `ticklabel* cs` with a customized shift along the outer normal vector. The shift is typically

`\pgfkeysvalueof{/pgfplots/major tick length}` (or half of it for centered axes).

Besides the mentioned positioning methods, there is also the predefined node `current axis`. The anchors of `current axis` can also be used to place descriptions: At the time when axis descriptions are drawn, all anchors which refer to the axis origin (that means the "real" point $(0,0)$) or any of the axis corners can be referenced using `current axis.`⟨*anchor name*⟩. Please see Section 4.19, Alignment, for further details.

4.9.2 Alignment of Axis Descriptions

This section describes how to modify the default alignment of axis descriptions. It can be skipped at first reading.

The two topics positioning and alignment always work together: *positioning* means to select an appropriate coordinate and *alignment* means to select an anchor inside of the description which will actually be moved to the desired position.

TikZ uses many anchors to provide alignment; most of them are named like `north`, `north east` etc. These names hold for any axis description as well (as axis descriptions are TikZ nodes). Readers can learn details about this topic in the TikZ manual [7] or some more advice in Section 4.19.

When it comes to axis descriptions, PGFPLOTS offers some specialized anchors and alignment methods which are described below.

Anchor `near xticklabel`
Anchor `near yticklabel`
Anchor `near zticklabel`
Anchor `near ticklabel`

These anchors can be used to align at the part of a node (for example, an axis description) which is *nearest* to the tick labels of a particular axis (or nearest to the position where tick labels would have been drawn if there were any).

These anchors are used for axis labels, especially for three dimensional axes. Furthermore, they are used for every tick label.

Maybe it is best to demonstrate it by example:
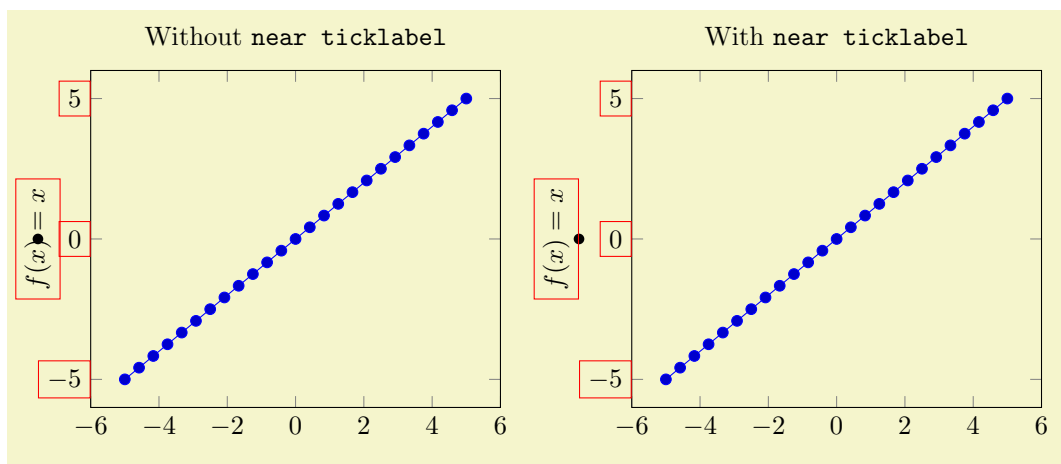

```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
    \begin{axis}[
        title=Without \texttt{near ticklabel},
        ylabel={$f(x)=x$},
        every axis y label/.style=
            {at={(ticklabel cs:0.5)},rotate=90,anchor=center},
        clip=false,% to display the \path below
        ylabel style={draw=red},
        yticklabel style={draw=red}
    ]

        \addplot {x};

        % visualize the position:
        \fill (yticklabel cs:0.5) circle(2pt);
    \end{axis}
\end{tikzpicture}%
~
\begin{tikzpicture}
    \begin{axis}[
        title=With \texttt{near ticklabel},
        ylabel={$f(x)=x$},
        every axis y label/.style=
            {at={(ticklabel cs:0.5)},rotate=90,anchor=near ticklabel},
        clip=false,
        ylabel style={draw=red},
        yticklabel style={draw=red}
    ]

        \addplot {x};
        \fill (yticklabel cs:0.5) circle(2pt);
    \end{axis}
\end{tikzpicture}
```

The motivation is to place nodes such that they are anchored next to the tick label, regardless of the node's rotation or the position of ticks. The special anchor near ticklabel is only available for axis labels (as they have a uniquely identified axis, either x, y or z).

In more detail, the anchor is placed such that first, the node's center is on a line starting in the node's at position going in direction of the inwards normal vector of the axis line which contains the tick labels and second, the node does not intrude the axis (but see also the key near ticklabel align and the details in the lengthy elaboration in the documentation for near xticklabel opposite below). This normal vector is the same which is used for the shift argument in ticklabel cs: it is orthogonal to the tick label axis. Furthermore, near ticklabel inverts the transformation matrix before it computes this intersection point.

The near ticklabel anchor and its friends will be added temporarily to any shape used inside of an axis. This includes axis descriptions, but it is not limited to them: it applies to every Ti*k*Z \node[anchor=near xticklabel] ... setting.

Note that it is not necessary at all to *have* tick labels in an axis. The anchor will be placed such that it is near the axis on which tick labels *would* be drawn. In fact, every tick label uses `anchor`=near ticklabel as initial configuration.

Anchor `near xticklabel opposite`
Anchor `near yticklabel opposite`
Anchor `near zticklabel opposite`
Anchor `near ticklabel opposite`

These anchors are similar to `near xticklabel` and its variants, except that they align at the *opposite* direction.

Mathematically speaking, the only difference to `near xticklabel` and its variants is the sign in front of the normal vector.

But it is probably best explained by means of an example.
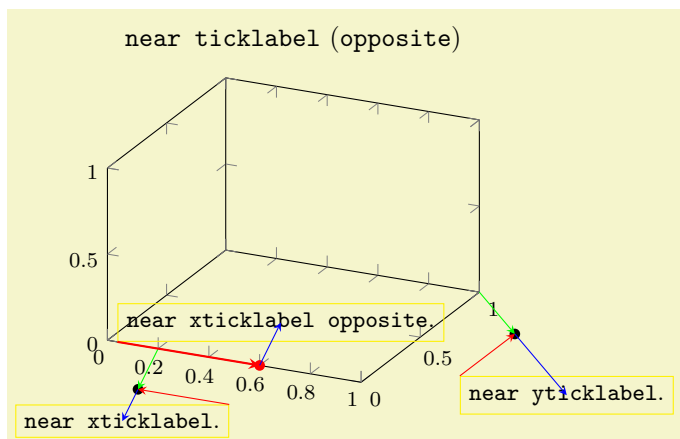

```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
    \begin{axis}[
        clip=false,
        small,
        title=\texttt{near ticklabel} (\texttt{opposite}),
        min=0, max=1
    ]
        \node[draw=yellow,anchor=near xticklabel,font=\small]
            (namex) at (xticklabel cs:0.2) {\texttt{near xticklabel}.};
        \fill (xticklabel cs:0.2) circle(2pt);
        \draw[green,-stealth] (xticklabel* cs:0.2) -- (xticklabel cs:0.2);
        \draw[blue,-stealth] (xticklabel cs:0.2) -- (namex.center);
        \draw[red,-stealth]  (namex.north east) -- (xticklabel cs:0.2);

        \node[draw=yellow,anchor=near xticklabel opposite,font=\small]
            (namexx) at (xticklabel* cs:0.6) {\texttt{near xticklabel opposite}.};
        \fill[red] (xticklabel* cs:0.6) circle(2pt);
        \draw[blue,-stealth] (xticklabel* cs:0.6) -- (namexx.center);
        \draw[red,thick,-stealth]  (namexx.south west) -- (xticklabel* cs:0.6);


        \node[draw=yellow,anchor=near yticklabel,font=\small]
            (name) at (yticklabel cs:1) {\texttt{near yticklabel}.};
        \fill (yticklabel cs:1) circle(2pt);
        \draw[green,-stealth] (yticklabel* cs:1) -- (yticklabel cs:1);
        \draw[blue,-stealth] (yticklabel cs:1) -- (name.center);
        \draw[red,-stealth]  (name.north west) -- (yticklabel cs:1);
    \end{axis}
\end{tikzpicture}
```

The figure is a boxed three–dimensional axis with standard ranges. It has three manually placed nodes. The nodes are placed `at (xticklabel cs:0.2)`, `at (xticklabel* cs:0.6)`, and `at (yticklabel cs:1)`, respectively. The '`at`' locations are visually emphasized using filled circles.

Despite the different locations, we clearly see the effect of `near xticklabel opposite`: it causes the node to be aligned into the box rather than outside of the box. Note that this is the *only* essential difference between the two nodes '`near xticklabel opposite`' and '`near xticklabel`'.

The figure also shows the difference between `xticklabel cs` and `xticklabel* cs` when we compare the 'at' locations. Take, for example, the two nodes on the x axis. The position `at (xticklabel cs:0.2)` is shifted by the green arrow. The length of this arrow is precisely the length of the largest x tick label. The position `at (xticklabel* cs:0.6)` is exactly on the axis; it ignores the size of any tick labels. Note that the direction of the green arrow is the "outer normal vector in x direction" (in our case, it is the vector sum of the z and y unit vectors with appropriate signs).

The difference between `near xticklabel opposite` and `near xticklabel` is that the direction of the green arrow (the "outer normal") is flipped.

The nodes also highlight how the anchoring works. This technique is almost the same for both `anchor`=near xticklabel and `anchor`=near xticklabel opposite. Let us discuss the technique for the node with text 'near yticklabel'. The black circle is placed `at (yticklabel cs:1)`. This position has been computed by starting at 100% of the y axis[44] and moving along the green vector whose magnitude is the size of the bounding box of the largest y tick label. As soon as the 'at' location is fixed, the algorithm for `near yticklabel` starts. First, it computes the anchor inside of the node for which we do not penetrate the y axis. To this end, it checks the direction of the green vector. It came up with `north west`. Then, it considers the red line which starts at (`name.north west`) and has the same direction as the y axis. Note that the red line and the y axis are parallel. It also considers the blue line. This line points into the direction of the green line and is fixed by the current node's `center`. The precise intersection point of the red line and the blue line are the result of `anchor`=near yticklabel. The same applies for the other two nodes as well: the red line is always parallel to the axis under consideration and is anchored at the "snap–to–nearest–anchor" of the node. The blue line is always parallel to the outer normal vector of the axis under consideration, and is anchored at the current node's `center`.

/pgfplots/near ticklabel align=inside|center|outside   (initially `center`)

Allows to change the alignment algorithm of `anchor`=near ticklabel.

In the default configuration, `anchor`=near ticklabel and its variants take the node's `center` in order to derive the final anchor. This corresponds to the target of the blue line in the illustration for near xticklabel opposite, see above.

This key changes the node's anchor which is used here. The choice `center` can move half of the node's bounding box beyond the associated axis. The choice `inside` moves the complete node's bounding box in a way such that it is not beyond the associated axis. The choice `outside` moves the entire node's bounding box in a way that it is beyond the associated axis:

---
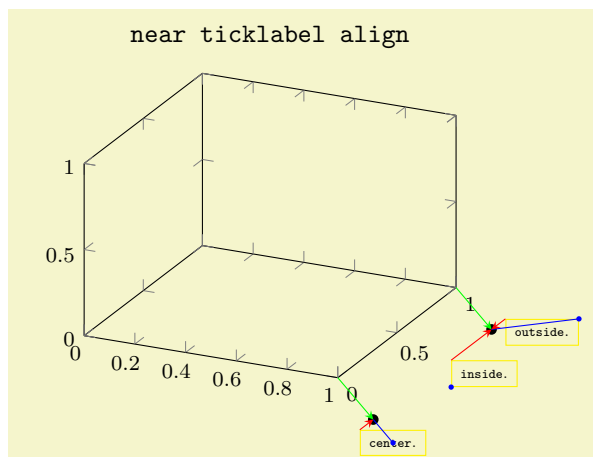
[44]In our example, percentages and absolute values are accidentally the same.

```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
    \begin{axis}[
        clip=false,
        small,
        title=\texttt{near ticklabel align},
        min=0, max=1,
        /tikz/node style/.style={
            draw=yellow,
            anchor=near yticklabel,
            font=\tiny,
        },
    ]
        \node[node style,
            /pgfplots/near ticklabel align=center]
            (C) at (yticklabel cs:0) {\texttt{center}.};

        \node[node style,
            /pgfplots/near ticklabel align=inside]
            (I) at (yticklabel cs:1) {\texttt{inside}.};

        \node[node style,
            /pgfplots/near ticklabel align=outside]
            (O) at (yticklabel cs:1) {\texttt{outside}.};

        \fill (yticklabel cs:0) circle(2pt);
        \fill (yticklabel cs:1) circle(2pt);

        \fill[blue] (C.center) circle(1pt);
        \fill[blue] (I.south west) circle(1pt);
        \fill[blue] (O.north east) circle(1pt);

        \draw[green,-stealth] (yticklabel* cs:0) -- (yticklabel cs:0);
        \draw[blue] (yticklabel cs:0) -- (C.center);
        \draw[red,-stealth]  (C.north west) -- (yticklabel cs:0);

        \draw[green,-stealth] (yticklabel* cs:1) -- (yticklabel cs:1);
        \draw[blue] (yticklabel cs:1) -- (O.north east);
        \draw[red,-stealth]  (O.north west) -- (yticklabel cs:1);
        \draw[red,-stealth]  (I.north west) -- (yticklabel cs:1);
    \end{axis}
\end{tikzpicture}
```

The example is similar to the one above: it generates an empty axis with a default range. Then, it creates three nodes: one for choice `center`, one for choice `inside`, and one for choice `outside`. The node for `center` is placed `at (yticklabel cs:0)` (lower black circle). We see that its bounding box extends the size of the y axis. This is because its anchor `C.center` is used for the alignment. Both the node for `inside` and the node for `outside` are placed `at (yticklabel cs:1)` (upper black circle). Their only difference is the choice for `near ticklabel align`. The node for `inside` does not extend the size of the y axis; it is placed within its boundaries – because its internal anchor (`I.north east`) (blue) has automatically been used in order to align the node. The node for `outside` is completely outside of the extends for the y axis because its (blue) anchor (`O.south west`) has been chosen.

Note that the red lines are always the same. They are the "snap–to–nearest" anchor such that the node is outside of the axis. Only the location of the blue anchors is affected by this key.

Note that `near ticklabel align` always results in the same alignment, independent of the actual *position* of the node. This is because an `anchor` is independent of the `at` location of a node. In this context, the names "inside" and "outside" might be a bad choice: they stress the intended meaning if the node is chosen at the upper end of the axis. However, if you say `at (yticklabel cs:0)`, `near ticklabel align`=`inside`, it will actually end up *outside* of the axis. This is because the "inside" anchor has been computed without considering where the node is.

/pgfplots/**near ticklabel at**={⟨*coordinate*⟩}   (initially `empty`)

Occasionally, `anchor`=`near ticklabel` results in a *different* anchor depending on where the node is placed. This can happen for a `polaraxis`.

If this key is needed, PGFPLOTS will spit out the warning "The anchor 'near ticklabel' cannot be computed correctly because the position is missing. Please add 'near ticklabel at=coordinate' with a suitable coordinate".

PGFPLOTS uses context information to determine the correct information, so this may be unnecessary. If you encounter this warning, you should add `near ticklabel at`=⟨*value*⟩ with a suitable value.

/tikz/**sloped like x axis**	(no value)
/tikz/**sloped like y axis**	(no value)
/tikz/**sloped like z axis**	(no value)
/tikz/**sloped like x axis**={⟨*options*⟩}	
/tikz/**sloped like y axis**={⟨*options*⟩}	
/tikz/**sloped like z axis**={⟨*options*⟩}	

A key which replaces the rotational / scaling parts of the transformation matrix such that the node is sloped like the provided axis. For two dimensional plots, `sloped like y axis` is effectively the same as `rotate=90`. For a three dimensional axis, this will lead to a larger difference:
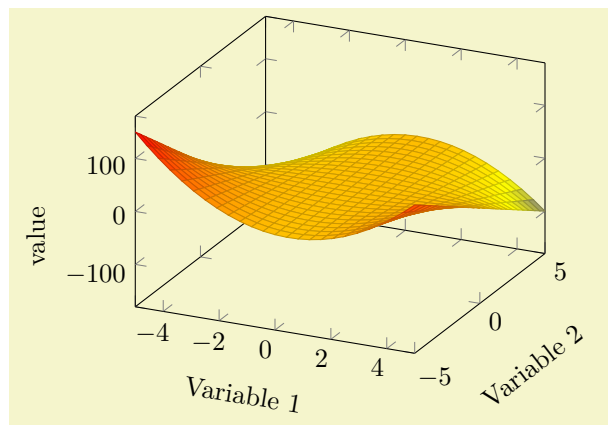

```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
    \begin{axis}[
        xlabel=Variable 1,
        ylabel=Variable 2,
        zlabel=value,
        xlabel style={sloped like x axis},
        ylabel style={sloped}
    ]

    \addplot3[surf] {y*x*(1-x)};
    \end{axis}
\end{tikzpicture}
```

Inside of axis labels, `sloped` is an alias for `sloped like ⟨char⟩ axis` with the correct ⟨*char*⟩ chosen automatically.

Please note that rotated text might not look very good (neither on screen nor printed).

It is possible to customize `sloped like x axis` by means of the following keys, which need to be provided as ⟨*options*⟩ (simply ignore the lengthy gray key prefixes):

/pgfplots/sloped/**allow upside down**=true|false   (initially `false`)

> Use `sloped like x axis`=allow upside down to enable upside down labels.

/pgfplots/sloped/**execute for upside down**=code   (initially `empty`)

> Use `sloped like x axis`={execute for upside down=\tikzset{`anchor`=north}} or something like that to handle upside down text nodes in a customized way (this is used by the `smithchart` library).

/pgfplots/sloped/**reset nontranslations**=true|false   (initially `true`)

> Use `sloped like x axis`={reset nontranslations=false} to *append* the transformations to the actual transformation matrix (instead of replacing it).

/pgfplots/sloped/**at position**={⟨*position*⟩}   (initially `empty`)

> This key can either be empty or a position. It is merely of interest for axes in which the transformation depends on the axis position as for `polaraxis`.

4.9.3   Labels

/pgfplots/**xlabel**={⟨*text*⟩}
/pgfplots/**ylabel**={⟨*text*⟩}
/pgfplots/**zlabel**={⟨*text*⟩}

These options set axis labels to ⟨*text*⟩ which is any TEX text.

To include special characters, you can use curly braces: "`xlabel`={, = characters}". This is necessary if characters like '=' or ',' need to be included literally.

Use `xlabel`/.add={⟨*prefix*⟩}{⟨*suffix*⟩} to modify an already assigned label.

Labels are TikZ-nodes which are placed with

```
% for x:
\node
    [style=every axis label,
    style=every axis x label]

% for y:
\node
    [style=every axis label,
    style=every axis y label]
```

so their position and appearance can be customized.

For example, a multiline `xlabel` can be configured using

```
\begin{axis}[xlabel style={align=right,text width=3cm},xlabel=A quite long label with a line break]
...
\end{axis}
```

See [7] to learn more about `align` and `text width`.

Upgrade notice: Since version 1.3, label placement *can* respect the size of adjacent tick labels. Use `\pgfplotsset{compat=1.3}` (or newer) in the preamble to activate this feature. See `xlabel near ticks` for details.

/pgfplots/**xlabel shift**={⟨*dimension*⟩}   (initially `0pt`)
/pgfplots/**ylabel shift**={⟨*dimension*⟩}   (initially `0pt`)
/pgfplots/**zlabel shift**={⟨*dimension*⟩}   (initially `0pt`)
/pgfplots/**label shift**={⟨*dimension*⟩}

> Shifts labels in direction of the outer normal vector of the axis by an amount of ⟨*dimension*⟩. The `label shift` sets all three label shifts to the same value.
>
> **Attention:** This does only work if `\pgfplotsset{compat=1.3}` (or newer) has been called (more precisely: if `xlabel near ticks` is active for the respective axis).

/pgfplots/**xlabel near ticks**   (no value)
/pgfplots/**ylabel near ticks**   (no value)
/pgfplots/**zlabel near ticks**   (no value)
/pgfplots/**compat**=1.3

> These keys place axis labels (like `xlabel`) near the tick labels. If tick labels are small, labels will move closer to the axis. If tick labels are large, axis labels will move away from the axis. This is the default for every three dimensional plot, but it *won't* be used initially for two–dimensional plots for backwards compatibility. Take a look at the definition of `near ticklabel` on page 241 for an example.
>
> The definition of these styles is

```
\pgfplotsset{
    /pgfplots/xlabel near ticks/.style={
        /pgfplots/every axis x label/.style={
            at={(ticklabel cs:0.5)},anchor=near ticklabel
        }
    },
    /pgfplots/ylabel near ticks/.style={
        /pgfplots/every axis y label/.style={
            at={(ticklabel cs:0.5)},rotate=90,anchor=near ticklabel
        }
    }
}
```

> It is encouraged to write

```
\pgfplotsset{compat=1.3} % or newer
```

in your preamble to install the styles document-wide – it leads to the best output (it avoids unnecessary space). It is not activated initially for backwards compatibility with older versions which used fixed distances from the tick labels.

/pgfplots/**xlabel absolute**	(no value)
/pgfplots/**ylabel absolute**	(no value)
/pgfplots/**zlabel absolute**	(no value)

/pgfplots/**compat**=pre 1.3

Installs placement styles for axis labels such that **xlabel** yields a description of absolute, fixed distance to the axis. This is the initial configuration (for backwards compatibility with versions before 1.3). Use **compat**=1.3 to get the most recent, more flexible configuration. Take a look at the definition of **near ticklabel** on page 241 for an example.

These styles are defined by

```
\pgfplotsset{
    /pgfplots/xlabel absolute/.style={%
        /pgfplots/every axis x label/.style={at={(0.5,0)},below,yshift=-15pt},%
        /pgfplots/every x tick scale label/.style={
            at={(1,0)},yshift=-2em,left,inner sep=0pt
        },
    },
    /pgfplots/ylabel absolute/.style={%
        /pgfplots/every axis y label/.style={at={(0,0.5)},xshift=-35pt,rotate=90},
        /pgfplots/every y tick scale label/.style={
            at={(0,1)},above right,inner sep=0pt,yshift=0.3em
        },
    }
}
```

There is no predefined absolute placement style for three dimensional axes.

Whenever possible, consider using /**.append style** instead of overwriting the default styles to ensure compatibility with future versions.

```
\pgfplotsset{every axis label/.append style={...}}
\pgfplotsset{every axis x label/.append style={...}}
\pgfplotsset{every axis y label/.append style={...}}
```

/pgfplots/**title**={⟨*text*⟩}

Adds a caption to the plot. This will place a TikZ-node with

```
\node[every axis title] {text};
```

to the current axis.
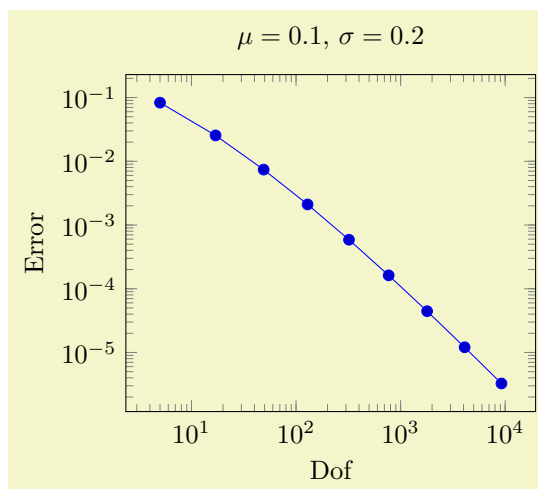

```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
\begin{loglogaxis}[
    xlabel=Dof,ylabel=Error,
    title={$\mu=0.1$, $\sigma=0.2$}]

    \addplot coordinates {
        (5,     8.312e-02)
        (17,    2.547e-02)
        (49,    7.407e-03)
        (129,   2.102e-03)
        (321,   5.874e-04)
        (769,   1.623e-04)
        (1793, 4.442e-05)
        (4097, 1.207e-05)
        (9217, 3.261e-06)
    };
\end{loglogaxis}
\end{tikzpicture}%
```

The title's appearance and/or placement can be reconfigured with

```
\pgfplotsset{title style={at={(0.75,1)}}}
% or, equivalently,
\pgfplotsset{every axis title/.append style={at={(0.75,1)}}}
```

This will place the title at 75% of the x-axis. The coordinate $(0,0)$ is the lower left corner and $(1,1)$ the upper right one (see `axis description cs` for details).

Use `title/.add={⟨prefix⟩}{⟨suffix⟩}` to modify an already assigned title.

/pgfplots/extra description/.code={⟨...⟩}

Allows to insert ⟨*commands*⟩ after axis labels, titles and legends have been typeset.

As all other axis descriptions, the code can use $(0,0)$ to access the lower left corner and $(1,1)$ to access the upper right one. It won't be clipped.
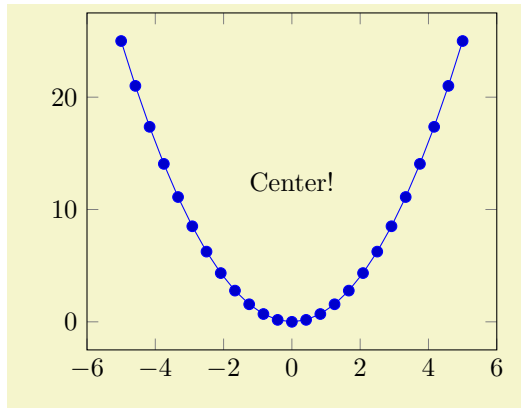
```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\pgfplotsset{every axis/.append style={
    extra description/.code={
        \node at (0.5,0.5) {Center!};
    }}}
\begin{tikzpicture}
    \begin{axis}
    \addplot {x^2};
    \end{axis}
\end{tikzpicture}
```

4.9.4 Legends

Legends can be generated in two ways: the first is to use `\addlegendentry` or `\legend` inside of an axis. The other method is to use the key `legend entries`.

\addlegendentry[⟨options⟩]{⟨name⟩}

Adds a single legend entry to the legend list. This will also enable legend drawing.
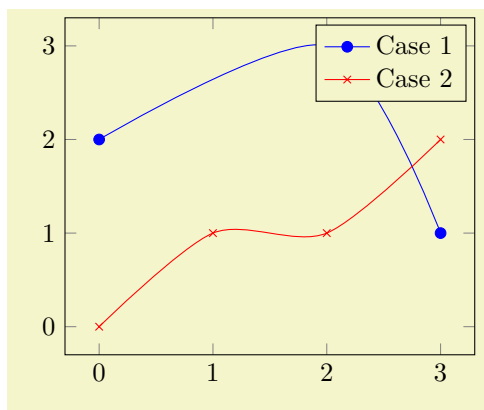
```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
\begin{axis}
\addplot[smooth,mark=*,blue] coordinates {
    (0,2)
    (2,3)
    (3,1)
};
\addlegendentry{Case 1}

\addplot[smooth,color=red,mark=x]
    coordinates {
        (0,0)
        (1,1)
        (2,1)
        (3,2)
    };
\addlegendentry{Case 2}
\end{axis}
\end{tikzpicture}
```

It does not matter where `\addlegendentry` commands are placed, only the sequence matters. You will need one `\addlegendentry` for every `\addplot` command (unless you prefer an empty legend).

The optional ⟨*options*⟩ affect how the text is drawn; they apply only for this particular description text. For example, `\addlegendentry[red]{Text}` would yield a red legend text. Behind the scenes, the text is placed with `\node[⟨options⟩] {⟨name⟩};`, so ⟨*options*⟩ can be any Ti*k*Z option which affects nodes.

Using `\addlegendentry` disables the key `legend entries`.

\addlegendentryexpanded[⟨*options*⟩]{⟨*TEX text*⟩}

A variant of **\addlegendentry** which provides a method to deal with macros inside of ⟨*TEX text*⟩.

Suppose ⟨*TEX text*⟩ contains some sort of parameter which varies *for every plot.* Moreover, you like to use a loop to generate the plots. Then, it is simpler to use **\addlegendentryexpanded**:
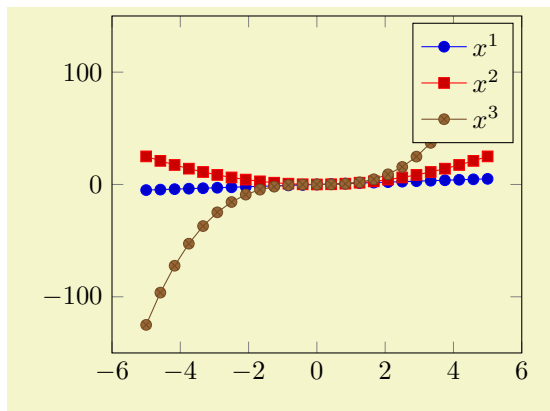

```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
\begin{axis}
    \foreach \p in {1,2,3} {
        \addplot {x^\p};
        \addlegendentryexpanded{$x^\p$}
    }
\end{axis}
\end{tikzpicture}
```

Note that this example wouldn't have worked with **\addlegendentry**{$x^\p$} because the macro \p is no longer defined when PGFPLOTS attempts to draw the legend.

The invocation **\addlegendentryexpanded**{$x^\p$} is equivalent to calling **\addlegendentry**{x^2} if \p expands to 2.

The argument ⟨*TEX text*⟩ is expanded until nothing but un-expandable material remains (i.e. it uses the TEX primitive \edef). Occasionally, ⟨*TEX text*⟩ contains parts which should be expanded (like \p) and other parts which should be left unexpanded (for example **\pgfmathprintnumber**{\p}). Then, use

\noexpand**\pgfmathprintnumber**{\p}

or, equivalently

\protect**\pgfmathprintnumber**{\p}

to avoid expansion of the macro which follows the \protect immediately.

\legend{⟨*list*⟩}

You can use **\legend**{⟨*list*⟩} to assign a complete legend.

```
\legend{$d=2$,$d=3$,$d=4$,$d=5$,$d=6$}
```

The argument of **\legend** is a list of entries, one for each plot.

Two different delimiters are supported:

1. There are comma–separated lists like

```
\legend{$d=2$,$d=3$,$d=4$,$d=5$,$d=6$}
```

These lists are processed using the PGF **\foreach** command and are quite powerful.

The **\foreach** command supports a dots–notation to denote ranges like **\legend**{1,2,...,5} or even **\legend**{x^1,$x^...$,x^d}.

Attention with periods: to avoid confusion with the dots ... notation, you may need to encapsulate a legend entry containing periods by curly braces: **\legend**{{ML spcm.},{CW spcm.},{ML AC}} (or use the \\ delimiter, see below).

2. It is also possible to delimit the list by '\\'. In this case, the *last element must be terminated* by \\ as well:

```
\legend{$a=1, b=2$\\,$a=2, b=3$\\$a=3, b=5$\\}
```

This syntax simplifies the use of ',' inside of legend entries, but it does not support the dots–notation.

The short marker/line combination shown in legends is acquired from the ⟨*style options*⟩ argument of `\addplot`.

Using `\legend` overwrites any other existing legend entries.

/pgfplots/legend entries={⟨*comma separated list*⟩}

This key can be used to assign legend entries just like the commands `\addlegendentry` and `\legend`. Again, the positioning is relative to the axis rectangle (unless units like `cm` or `pt` are specified explicitly).
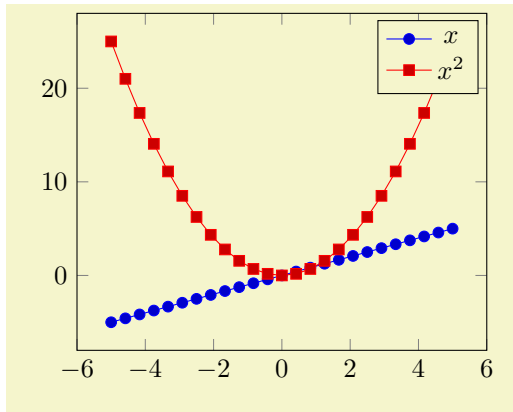

```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
    \begin{axis}[legend entries={$x$,$x^2$}]
    \addplot {x};
    \addplot {x^2};
    \end{axis}
\end{tikzpicture}
```

The commands for legend creation take precedence: the key `legend entries` is only considered if there is no legend command in the current axis.
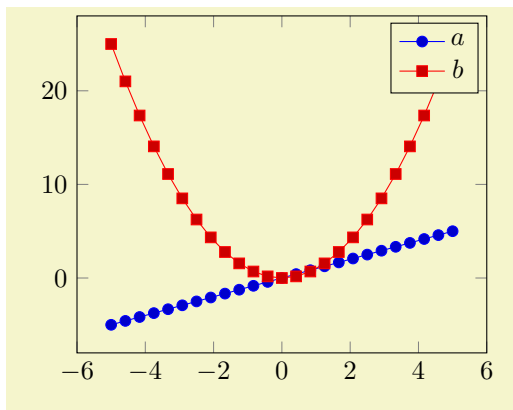

```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
    \begin{axis}[legend entries={$x$,$x^2$}]
    \addplot {x};
    \addplot {x^2};
    \legend{$a$,$b$}% overrides the option
    \end{axis}
\end{tikzpicture}
```

Please be careful with whitespaces in ⟨*comma separated list*⟩: they will contribute to legend entries. Consider using '`%`' at the end of each line in multiline arguments (the end of line character is also a whitespace in TeX).

Just as for `\addlegendentry`, it is possible to provide [⟨*options*⟩] to single descriptions. To do so, place the options in square brackets right before the text:
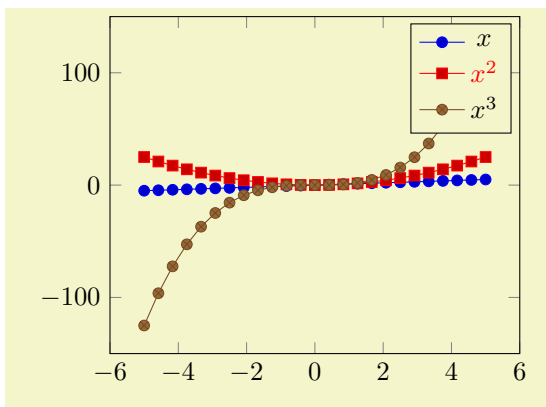

```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
\begin{axis}[legend entries={$x$,[red]$x^2$,$x^3$}]
    \addplot {x};
    \addplot {x^2};
    \addplot {x^3};
\end{axis}
\end{tikzpicture}
```

If the square brackets contain a comma, you can enclose the complete entry in curly braces like
{[red,font=\Huge]Text} (or you can use the '\\' delimiters).

4.9.5   Legend Appearance

/pgfplots/every axis legend   (style, no value)

The style "every axis legend" determines the legend's position and outer appearance:

```
\pgfplotsset{every axis legend/.append style={
        at={(0,0)},
        anchor=south west}}
```

will draw it at the lower left corner of the axis while

```
\pgfplotsset{every axis legend/.append style={
        at={(1,1)},
        anchor=north east}}
```

means the upper right corner. The 'anchor' option determines which point *of the legend* will be placed
at $(0,0)$ or $(1,1)$.

The legend is a TikZ-matrix, so one can use any TikZ option which affects nodes and matrices (see [7,
section 13 and 14]). The matrix is created by something like

```
\matrix[style=every axis legend] {
    draw plot specification 1 & \node{legend 1}\\
    draw plot specification 2 & \node{legend 2}\\
    ...
};
```
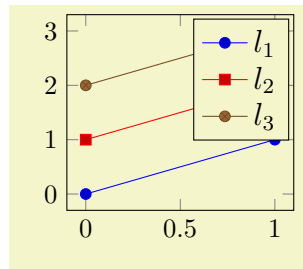


```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
\begin{axis}[
    % this modifies 'every axis legend':
    legend style={font=\large}
]
\addplot coordinates {(0,0) (1,1)};
\addplot coordinates {(0,1) (1,2)};
\addplot coordinates {(0,2) (1,3)};
\legend{$l_1$,$l_2$,$l_3$}
\end{axis}
\end{tikzpicture}
```
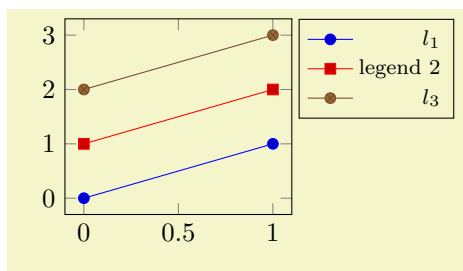


```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
\begin{axis}[
    % align right:
    legend style={
        cells={anchor=east},
        legend pos=outer north east,
    }
]
\addplot coordinates {(0,0) (1,1)};
\addplot coordinates {(0,1) (1,2)};
\addplot coordinates {(0,2) (1,3)};
\legend{$l_1$, legend $2$,$l_3$}
\end{axis}
\end{tikzpicture}
```
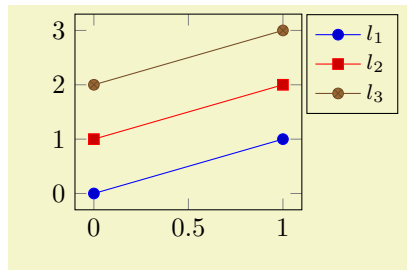
```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
% similar placement as previous example:
\pgfplotsset{every axis legend/.append style={
        at={(1.02,1)},
        anchor=north west}}
\begin{tikzpicture}
\begin{axis}
\addplot coordinates {(0,0) (1,1)};
\addplot coordinates {(0,1) (1,2)};
\addplot coordinates {(0,2) (1,3)};
\legend{$l_1$,$l_2$,$l_3$}
\end{axis}
\end{tikzpicture}
```

Use `legend columns`={⟨*number*⟩} to configure the number of horizontal legend entries.
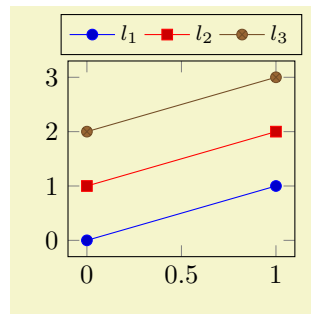

```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
\pgfplotsset{every axis legend/.append style={
        at={(0.5,1.03)},
        anchor=south}}
\begin{axis}[legend columns=4]
\addplot coordinates {(0,0) (1,1)};
\addplot coordinates {(0,1) (1,2)};
\addplot coordinates {(0,2) (1,3)};
\legend{$l_1$,$l_2$,$l_3$}
\end{axis}
\end{tikzpicture}
```

Instead of the `/.append style`, it is possible to use `legend style` as in the following example. It has the same effect.
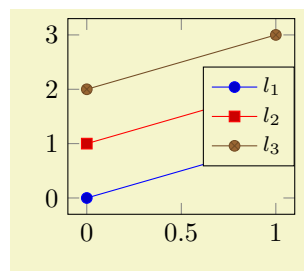

```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
\begin{axis}[
    legend style={
        at={(1,0.5)},
        anchor=east}]
\addplot coordinates {(0,0) (1,1)};
\addplot coordinates {(0,1) (1,2)};
\addplot coordinates {(0,2) (1,3)};
\legend{$l_1$,$l_2$,$l_3$}
\end{axis}
\end{tikzpicture}
```

The default `every axis legend` style is

```
\pgfplotsset{every axis legend/.style={
    cells={anchor=center},% Centered entries
    inner xsep=3pt,inner ysep=2pt,nodes={inner sep=2pt,text depth=0.15em},
    anchor=north east,
    shape=rectangle,
    fill=white,
    draw=black,
    at={(0.98,0.98)}
    }
}
```

Whenever possible, consider using `/.append style` to keep the default styles active. This ensures compatibility with future versions.

```
\pgfplotsset{every axis legend/.append style={...}}
```

Note that in order to disable drawing of the legend box, you can use `draw=none` as style argument:
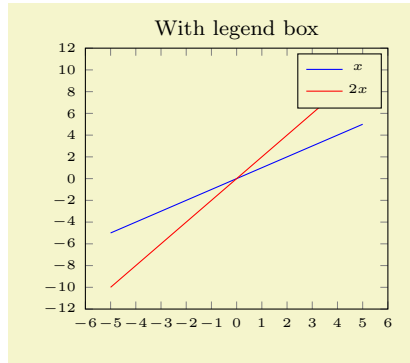
/pgfplots/legend style={⟨*key-value-list*⟩}
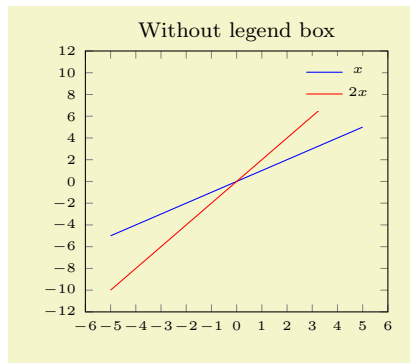
An abbreviation for every axis legend/.append style={⟨*key-value-list*⟩}.

It appends options to the already existing style every axis legend.

/pgfplots/legend pos=south west|south east|north west|north east|outer north east

A style which provides shorthand access to some commonly used legend positions.

Each of these styles appends at={(⟨*x*⟩,⟨*y*⟩)},anchor=⟨*name*⟩ values to every axis legend.
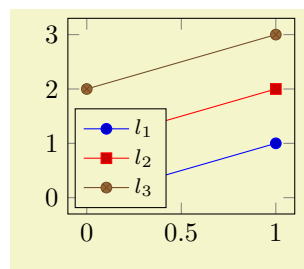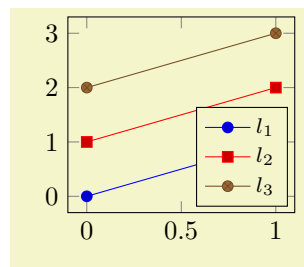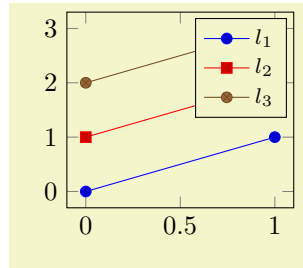
```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
\begin{axis}[legend pos=north east]
\addplot coordinates {(0,0) (1,1)};
\addplot coordinates {(0,1) (1,2)};
\addplot coordinates {(0,2) (1,3)};
\legend{$l_1$,$l_2$,$l_3$}
\end{axis}
\end{tikzpicture}
```
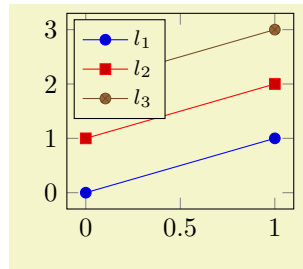


```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
\begin{axis}[legend pos=north west]
\addplot coordinates {(0,0) (1,1)};
\addplot coordinates {(0,1) (1,2)};
\addplot coordinates {(0,2) (1,3)};
\legend{$l_1$,$l_2$,$l_3$}
\end{axis}
\end{tikzpicture}
```
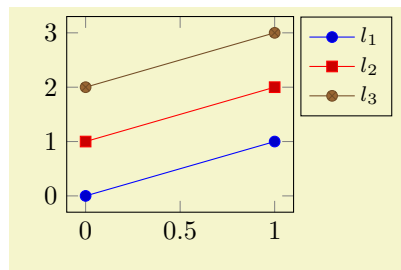


```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
\begin{axis}[legend pos=outer north east]
\addplot coordinates {(0,0) (1,1)};
\addplot coordinates {(0,1) (1,2)};
\addplot coordinates {(0,2) (1,3)};
\legend{$l_1$,$l_2$,$l_3$}
\end{axis}
\end{tikzpicture}
```

/pgfplots/legend cell align=left|right|center   (initially center)

These keys provide horizontal alignment of legend cells.
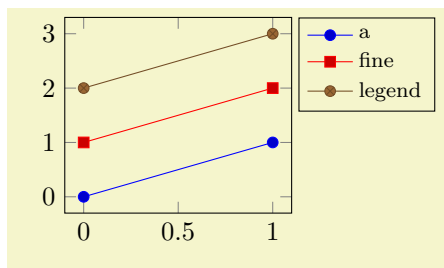

```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
\begin{axis}[legend cell align=left,
    legend pos=outer north east]
\addplot coordinates {(0,0) (1,1)};
\addplot coordinates {(0,1) (1,2)};
\addplot coordinates {(0,2) (1,3)};
\legend{a,fine,legend}
\end{axis}
\end{tikzpicture}
```
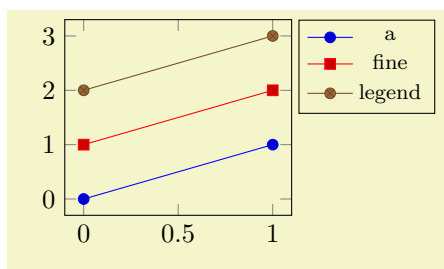


```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
\begin{axis}[legend cell align=center,
    legend pos=outer north east]
\addplot coordinates {(0,0) (1,1)};
\addplot coordinates {(0,1) (1,2)};
\addplot coordinates {(0,2) (1,3)};
\legend{a,fine,legend}
\end{axis}
\end{tikzpicture}
```
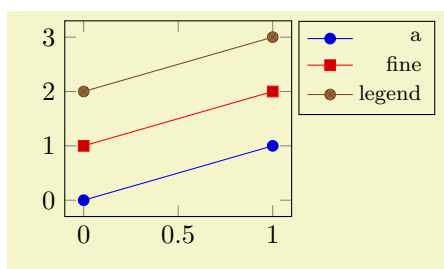


```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
\begin{axis}[legend cell align=right,
    legend pos=outer north east]
\addplot coordinates {(0,0) (1,1)};
\addplot coordinates {(0,1) (1,2)};
\addplot coordinates {(0,2) (1,3)};
\legend{a,fine,legend}
\end{axis}
\end{tikzpicture}
```

They are actually just styles for commonly used alignment choices: the choice `left` is equivalent to `legend style`={cells={anchor=west}}; the second choice `right` is equivalent to `legend style`={cells={anchor=east}}, and `center` to `legend style`={cells={anchor=center}}. Using different values allows more control over cell alignment.

/pgfplots/legend columns={⟨*number*⟩}   (default `1`)

Allows to configure the maximum number of adjacent legend entries. The default value `1` places legend entries vertically below each other.

Use `legend columns`=-1 to draw all entries horizontally.

/pgfplots/legend plot pos=left|right|none   (initially `left`)

Configures where the small line specifications will be drawn: left of the description, right of the description or not at all.

/pgfplots/every legend image post   (style, no value)

A style which can be used to provide drawing options to every small legend image. These options apply after `current plot style` has been set, allowing users different line styles for legends than for plots.

For example, suppose you have a line plot and you plot selected markers on top of it (in the same color). Then, you may want to draw just a *single* legend entry (which should contain both the line *and* the markers). The following example shows a solution:
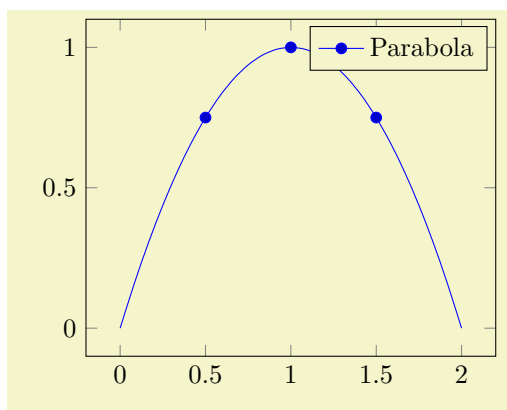

```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
    \begin{axis}[legend image post style={mark=*}]
    \addplot+[only marks,forget plot]
        coordinates {(0.5,0.75) (1,1) (1.5,0.75)};
    \addplot+[mark=none,smooth,domain=0:2]
        {-x*(x-2)};
    \addlegendentry{Parabola}
    \end{axis}
\end{tikzpicture}
```

The example has two `\addplot` commands, one for the line and one for the markers. Due to the `forget plot` option, the marker plot (the first one) doesn't advance the `cycle list`. The axis has only one legend entry, and since `legend image post style`={mark=*} has been used, the legend has a plot mark as well. Due to the `forget plot` option, the marker plot will not get a separate legend label.

/pgfplots/legend image post style={⟨*key-value-list*⟩}

An abbreviation for `every legend image post`/.append style={⟨*key-value-list*⟩}.

It appends options to the already existing style `every legend image post`.

/pgfplots/legend image code/.code={⟨...⟩}

Allows to replace the default images which are drawn inside of legends. When this key is evaluated, the current plot specification has already been activated (using `\begin{scope}[current plot style]`)[45], so any drawing operations use the same styles as the `\addplot` command.

The default is the style `line legend`.

Technical note: At the time when legend images are drawn, the style `every axis legend` is in effect – which have unwanted side-effects due to changed parameters (especially those concerning node placement, alignment, and shifting). It might be necessary to reset these parameters manually (PGFPLOTS also attempts to reset the fill color).

---

[45]This was different in versions before 1.3. The new scope features allow plot styles to change `legend image code`.

/pgfplots/line legend (style, no value)

A style which sets `legend image code` (back) to its initial value.

Its initial value is

```
\pgfplotsset{
    /pgfplots/line legend/.style={
        legend image code/.code={
            \draw[mark repeat=2,mark phase=2,##1]
                plot coordinates {
                    (0cm,0cm)
                    (0.3cm,0cm)
                    (0.6cm,0cm)
                };%
        }
    }
}
```

The style `line legend` can also be used to apply a different legend style to one particular plot (see the documentation on `area legend` for an example).

/pgfplots/empty legend (style, no value)

A style which clears `legend image code`, thereby omitting the legend image.

/pgfplots/area legend (style, no value)

A style which sets `legend image code` to

```
\pgfplotsset{
    legend image code/.code={%
        \draw[#1] (0cm,-0.1cm) rectangle (0.6cm,0.1cm);
    }
}
```
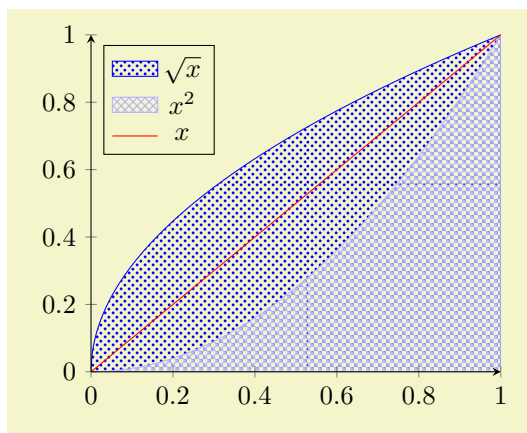


```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
% \usetikzlibrary{patterns}
\begin{tikzpicture}
\begin{axis}[area legend,
    axis x line=bottom,
    axis y line=left,
    domain=0:1,
    legend style={at={(0.03,0.97)},
        anchor=north west},
    axis on top,xmin=0]
\addplot[pattern=crosshatch dots,
    pattern color=blue,draw=blue,
    samples=500]
    {sqrt(x)}    \closedcycle;

\addplot[pattern=crosshatch,
    pattern color=blue!30!white,
    draw=blue!30!white]
    {x^2} \closedcycle;

\addplot[red,line legend] coordinates {(0,0) (1,1)};
\legend{$\sqrt x$,$x^2$,$x$}
\end{axis}
\end{tikzpicture}
```

/pgfplots/xbar legend	(no value)
/pgfplots/ybar legend	(no value)
/pgfplots/zbar legend	(no value)
/pgfplots/xbar interval legend	(no value)
/pgfplots/ybar interval legend	(no value)
/pgfplots/zbar interval legend	(no value)

These style keys redefine `legend image code` such that legends use `xbar`, `ybar` or the `xbar interval` and `ybar interval` handlers.
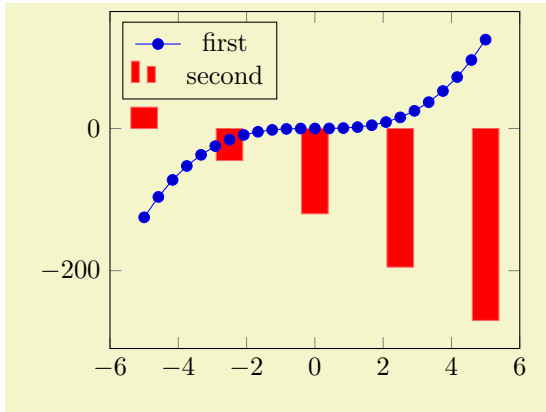
```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
    \begin{axis}[legend pos=north west]
    \addplot {x^3};
    \addplot[ybar,fill=red,draw=red!60,
        ybar legend,mark=none,samples=5]
        {-30*(x +4)};
    \legend{first,second}
    \end{axis}
\end{tikzpicture}
```

The initial values for these styles might be interesting if someone wants to modify them. Here they are:

```
\pgfplotsset{
    /pgfplots/xbar legend/.style={
        /pgfplots/legend image code/.code={%
            \draw[##1,/tikz/.cd,bar width=3pt,yshift=-0.2em,bar shift=0pt]
            plot coordinates {(0cm,0.8em) (2*\pgfplotbarwidth,0.6em)};},
    },
    /pgfplots/ybar legend/.style={
        /pgfplots/legend image code/.code={%
            \draw[##1,/tikz/.cd,bar width=3pt,yshift=-0.2em,bar shift=0pt]
            plot coordinates {(0cm,0.8em) (2*\pgfplotbarwidth,0.6em)};},
    },
    /pgfplots/xbar interval legend/.style={%
        /pgfplots/legend image code/.code={%
            \draw[##1,/tikz/.cd,yshift=-0.2em,bar interval width=0.7,bar interval shift=0.5]
            plot coordinates {(0cm,0.8em) (5pt,0.6em) (10pt,0.6em)};},
    },
    /pgfplots/ybar interval legend/.style={
        /pgfplots/legend image code/.code={%
            \draw[##1,/tikz/.cd,yshift=-0.2em,bar interval width=0.7,bar interval shift=0.5]
            plot coordinates {(0cm,0.8em) (5pt,0.6em) (10pt,0.6em)};},
    },
}
```

/pgfplots/mesh legend   (no value)

Redefines legend image code such that it is compatible with mesh and surf plot handlers (for three dimensional visualization mainly).
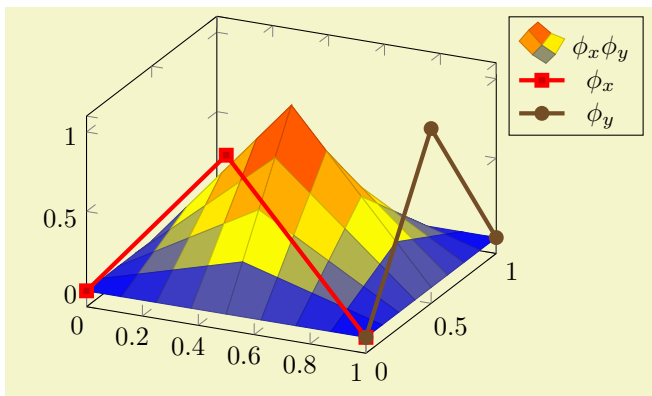
```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
    \begin{axis}[legend pos=outer north east]
    \addplot3[surf,samples=9,domain=0:1]
        {(1-abs(2*(x-0.5))) * (1-abs(2*(y-0.5)))};
    \addlegendentry{$\phi_x \phi_y$}

    \addplot3+[ultra thick] coordinates {(0,0,0) (0.5,0,1) (1,0,0)};
    \addlegendentry{$\phi_x $}

    \addplot3+[ultra thick] coordinates {(1,0,0) (1,0.5,1) (1,1,0)};
    \addlegendentry{$\phi_y $}
    \end{axis}
\end{tikzpicture}
```

/pgfplots/**reverse legend**=true|false   (initially `false`)
/pgfplots/**legend reversed**=true|false   (initially `false`)

    Allows to reverse the order in which the pairs (legend entry, plot style) are drawn.
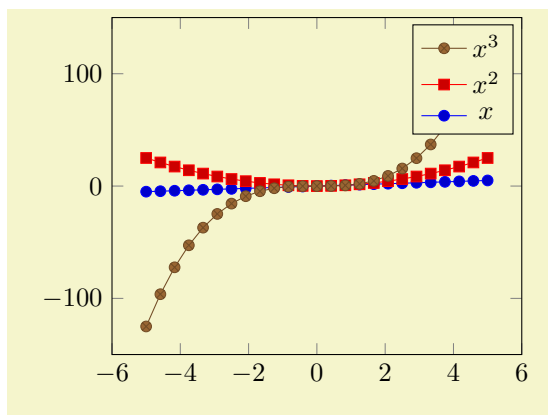

```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
    \begin{axis}[reverse legend]
    \addplot {x};
    \addlegendentry{$x$}
    \addplot {x^2};
    \addlegendentry{$x^2$}
    \addplot {x^3};
    \addlegendentry{$x^3$}
    \end{axis}
\end{tikzpicture}
```

/pgfplots/**transpose legend**=true|false   (initially `false`)
/pgfplots/**legend transposed**=true|false   (initially `false`)

    Allows to transpose the order in which the pairs (legend entry, plot style) are drawn.

    Consider a set of 3 experiments, each consisting of 2 parameters. We might want to draw them together as in the following example:
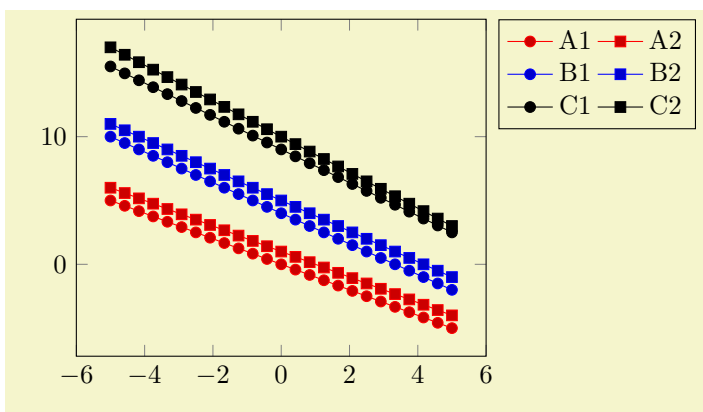
```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
    \begin{axis}[
        legend columns=2,
        legend pos=outer north east,
        cycle multi list={%
            color list\nextlist
            [2 of]mark list
        }]
    \addplot {-x};   \addlegendentry{A1}
    \addplot {-x+1}; \addlegendentry{A2}

    \addplot {-1.2*x + 4};  \addlegendentry{B1}
    \addplot {-1.2*x + 5};  \addlegendentry{B2}

    \addplot {-1.3*x + 9};  \addlegendentry{C1}
    \addplot {-1.4*x + 10}; \addlegendentry{C2}
    \end{axis}
\end{tikzpicture}
```

An alternative might be to draw them horizontally – then, we'd like to use `transpose legend` to get a flat legend:
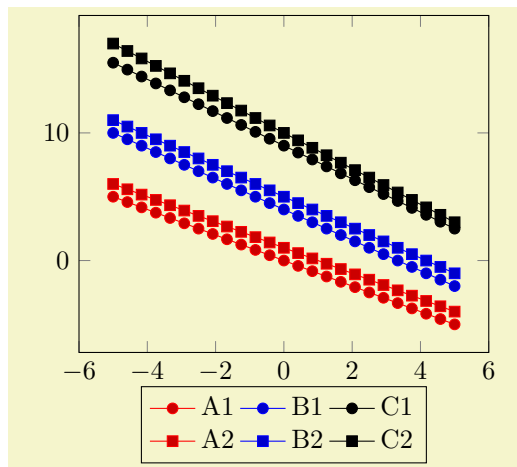

```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
    \begin{axis}[
        transpose legend,
        legend columns=2,
        legend style={at={(0.5,-0.1)},anchor=north},
        cycle multi list={%
            color list\nextlist
            [2 of]mark list
        }]
    \addplot {-x};   \addlegendentry{A1}
    \addplot {-x+1}; \addlegendentry{A2}

    \addplot {-1.2*x + 4};  \addlegendentry{B1}
    \addplot {-1.2*x + 5};  \addlegendentry{B2}

    \addplot {-1.3*x + 9};  \addlegendentry{C1}
    \addplot {-1.4*x + 10}; \addlegendentry{C2}
    \end{axis}
\end{tikzpicture}
```

Thus, `legend columns` defines the *input* columns, before the transposition (in other words, `legend columns` indicates the *rows* of the resulting legend).

Transposing legends has only an effect if `legend columns` > 1. Note that `reverse legend` has higher precedence: it is applied first.

4.9.6   Legends with \label and \ref

PGFPLOTS offers a `\label` and `\ref` feature for LATEX to assemble a legend manually, for example as part of the figure caption. These references work as usual LATEX references: a `\label` remembers where and what needs to be referenced and a `\ref` expands to proper text. In context of plots, a `\label` remembers the plot specification of one plot and a `\ref` expands to the small image which would also be used inside of legends.
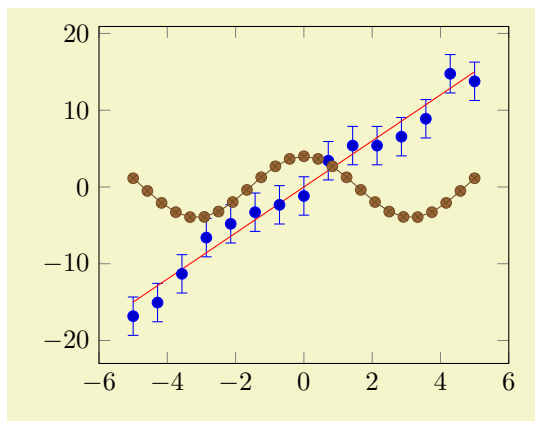
```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}[baseline]
\begin{axis}
    \addplot+[only marks,
            samples=15,
            error bars/y dir=both,
            error bars/y fixed=2.5]
        {3*x+2.5*rand};
    \label{pgfplots:label1}

    \addplot+[mark=none] {3*x};
    \label{pgfplots:label2}

    \addplot {4*cos(deg(x))};
    \label{pgfplots:label3}
\end{axis}
\end{tikzpicture}
```

```
The picture shows the estimations \ref{pgfplots:label1} which are subjected to noise.
It appears the model \ref{pgfplots:label2} fits the data appropriately.
Finally, \ref{pgfplots:label3} is only here to get three examples.
```

The picture shows the estimations • which are subjected to noise. It appears the model —— fits the data appropriately. Finally, —•— is only here to get three examples.

`\label`{⟨*label name*⟩}
`\label`[⟨*reference*⟩]{⟨*label name*⟩}

When used after `\addplot`, this command creates a LaTeX label named ⟨*label name*⟩[46]. If this label is cross-referenced with `\ref`{⟨*label name*⟩} somewhere, the associated plot specification will be inserted.

Label3 = —•—; Label2 = ——

```
Label3 = \ref{pgfplots:label3};
Label2 = \ref{pgfplots:label2}
```

The label is assembled using `legend image code` and the plot style of the last plot. Any PGFPLOTS option is expanded until only TikZ (or PGF) options remain; these options are used to get an independent label.

More precisely, the small image generated by `\ref`{⟨*label name*⟩} is

```
\tikz[/pgfplots/every crossref picture] {...}
```

where the contents is determined by `legend image code` and the plot style.

The second syntax, `\label`[⟨*reference*⟩]{⟨*label name*⟩} allows to label particular pieces of an `\addplot` command. It is (currently) only interesting for `scatter/classes`: there, it allows to reference particular classes of the scatter plot. See page 112 for more details.

Note that `\label` information, even the small TikZ pictures here, can be combined with the `external` library for image externalization, see Section 7.1 for details (in particular, the `external/mode` key). In other words, references remain valid even if the defining axis has been externalized.

`\ref`{⟨*label name*⟩}

Can be used to reference a labeled, single plot. See the example above.

This will also work together with `hyperref` links and `\pageref`[47].

`/pgfplots/`**`refstyle`**`=`{⟨*label name*⟩}

Can be used to set the *styles* of a labeled, single plot. This allows to write

```
\addplot[/pgfplots/refstyle={pgfplots:label2}]
```

somewhere. Please note that it may be easier to define a style with `.style`.

---

[46]This feature is *only* available in LaTeX, sorry.

[47]Older versions of PGFPLOTS required the use of `\protect\ref` when used inside of captions or section headings. This is no longer necessary.

/pgfplots/every crossref picture   (style, no value)

A style which will be used by the cross-referencing feature for plots. The default is

```
\pgfplotsset{every crossref picture/.style={baseline,yshift=0.3em}}
```

/pgfplots/invoke before crossref tikzpicture={⟨*T_EX code*⟩}
/pgfplots/invoke after crossref tikzpicture={⟨*T_EX code*⟩}

Code which is invoked just before or just after every cross reference picture. This applies to legend images generated with `\ref`, `legend to name` and `colorbar to name` images.

The initial configuration checks if the `external` library is in effect. If so, it modifies the generated figure names by means of `\tikzappendtofigurename{_crossref}`.

4.9.7   Legends Outside Of an Axis

Occasionally, one has multiple adjacent plots, each with the same legend – and just *one* legend suffices. But where shall it be placed? And how? One solution is to use the `overlay` key to exclude the legend from bounding box computations, and place it absolutely such that it fits. Another is the `legend to name` feature:

/pgfplots/legend to name={⟨*name*⟩}   (initially `empty`)

Enables a legend export mode: instead of drawing the legend, a self–contained, independent set of drawing commands will be stored using the label ⟨*name*⟩. The definition is done using `\label{`⟨*name*⟩`}`, just like any other LATEX label. The name can be referenced using

`\ref{`⟨*name*⟩`}`.

Thus, typing `\ref{`⟨*name*⟩`}` somewhere outside of the axis, maybe even outside of any picture, will cause the legend to be drawn.
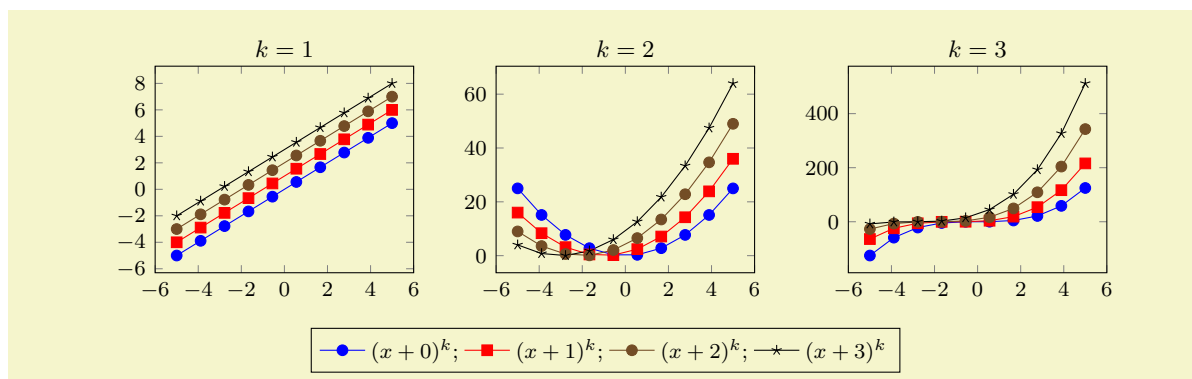
```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\pgfplotsset{footnotesize,samples=10}
\begin{center}% note that \centering uses less vspace...
\begin{tikzpicture}
    \begin{axis}[
        legend columns=-1,
        legend entries={$(x+0)^k$;,$(x+1)^k$;,$(x+2)^k$;,$(x+3)^k$},
        legend to name=named,
        title={$k=1$}]
    \addplot {x};
    \addplot {x+1};
    \addplot {x+2};
    \addplot {x+3};
    \end{axis}
\end{tikzpicture}
%
\begin{tikzpicture}
    \begin{axis}[title={$k=2$}]
    \addplot {x^2};
    \addplot {(x+1)^2};
    \addplot {(x+2)^2};
    \addplot {(x+3)^2};
    \end{axis}
\end{tikzpicture}
%
\begin{tikzpicture}
    \begin{axis}[title={$k=3$}]
    \addplot {x^3};
    \addplot {(x+1)^3};
    \addplot {(x+2)^3};
    \addplot {(x+3)^3};
    \end{axis}
\end{tikzpicture}
\\

\ref{named}
\end{center}
```

Note that only the *first* plot has `legend entries`. Thus, its legend will be created as usual, and stored under the name 'named', but it won't be drawn. The stored legend can then be drawn with `\ref{named}` below the three plots. Since there is no picture in this context, a `\tikz` picture is created and a `\matrix[/pgfplots/every axis legend]` path is drawn inside of it, resulting in the legend as if it had been placed inside of the axis.

The stored legend will contain the currently active values of legend- and plot style related options. This includes `legend image code`, `every axis legend`, and any plot style options (and some more). The algorithm works in the same way as for `\label` and `\ref`, i.e. it keeps any options with `/tikz/` prefix and expands those with `/pgfplots/` prefix.

Note that the legend is drawn with `every axis legend`, even though the placement options might be chosen to fit into an axis. You may want to adjust the style in the same axis in which the stored legend has been defined (the value will be copied and restored as well).

About \ref{⟨*name*⟩} The `\ref{⟨name⟩}` command retrieves a stored legend (one defined by `legend to name`) and draws it.

`\ref{named}:` $\quad$ —•— $(x+0)^k$; —■— $(x+1)^k$; —•— $(x+2)^k$; —⋆— $(x+3)^k$

If you want the legend to be exported *and* drawn inside of the current axis, consider using `extra description/.append code={\ref{⟨name⟩}}`.

Note that `\ref` can be combined with the `external` library for image externalization. In other words, the legend will work even if the defining axis has been externalized, see Section 7.1 for details (in particular the `external/mode` key).

Note furthermore that this `.aux` file related stuff is (currently) only supported, if PGFPLOTS is run by means of LATEX, sorry.

`\pgfplotslegendfromname{⟨name⟩}`

This command poses an equivalent alternative for `\ref{⟨name⟩}`: it has essentially the same effect,

but it does not create links when used with the `hyperref` package[48].

/pgfplots/**every legend to name picture**   (style, no value)

A style which is installed when `\ref` is used outside of a picture: a new picture will be created with `\tikz`[/pgfplots/every legend to name picture].

Thus, you can redefine this style to set alignment options (such as `baseline`). For example, the initialization

```
\pgfplotsset{
    legend style={matrix anchor=west,at={(0pt,0pt)}},
    every legend to name picture/.style={baseline},
}
...
```

will cause the legend to be positioned such that its `west` anchor is at `y=0pt`. The `baseline` option will align this point of the legend with the text baseline (please refer to the documentation for `baseline` in Section 4.19 for details).

4.9.8 Legends with Customized Texts or Multiple Lines

`\addlegendimage`{⟨*options*⟩}

Adds a further legend image for legend creation.

Each `\addplot` command appends its plot style options to a list, and `\addlegendimage` adds ⟨*options*⟩ to the very same list.

Thus, the effect is as if you had provided `\addplot`[⟨*options*⟩], but `\addlegendimage` bypasses all the logic usually associated with a plot. In other words: except for the legend, the state of the axis remains as if the command would not have been issued. Not even the current plot's index is advanced.
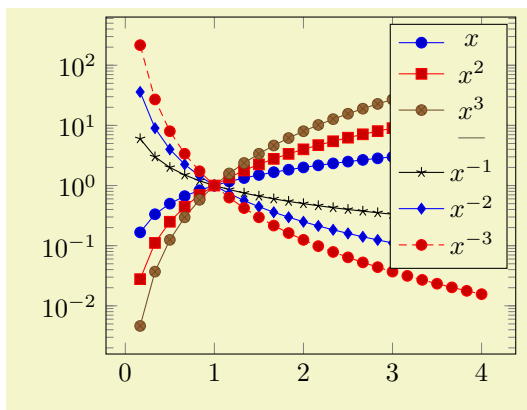

```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
\begin{semilogyaxis}[
    domain=0:4,
]
    \addplot {x};    \addlegendentry{$x$}
    \addplot {x^2}; \addlegendentry{$x^2$}
    \addplot {x^3}; \addlegendentry{$x^3$}
    \addlegendimage{empty legend}
    \addlegendentry{---}
    \addplot {x^(-1)}; \addlegendentry{$x^{-1}$}
    \addplot {x^(-2)}; \addlegendentry{$x^{-2}$}
    \addplot {x^(-3)}; \addlegendentry{$x^{-3}$}
\end{semilogyaxis}
\end{tikzpicture}
```

The example above has six plots, each with its legend entry. Furthermore, it has an `\addlegendimage` command and its separate legend entry. We see that `\addlegendimage` needs its own legend entry, but it is detached from the processing of plots as such. In our case, we chose `empty legend` as style for the separator.

Use `\addlegendimage` to provide custom styles into legends, for example to document custom `\draw` commands inside of an axis.

You can call `\label` after `\addlegendimage` just as for a normal style.

Occasionally, one may want multiple lines for legend entries. That is possible as well using a fixed `text width`:

---

[48]Since this manual uses colored links, the text in `\ref` would usually be blue. Using `\pgfplotslegendfromname` avoids link text colors in the legend (this has been applied to the manual styles here).
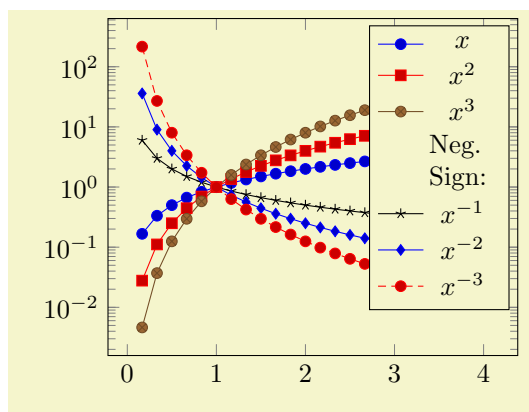
```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
\begin{semilogyaxis}[
    domain=0:4,
]
    \addplot {x};    \addlegendentry{$x$}
    \addplot {x^2}; \addlegendentry{$x^2$}
    \addplot {x^3}; \addlegendentry{$x^3$}
    \addlegendimage{empty legend}
    \addlegendentry[text width=25pt,text depth=]
        {Neg. Sign:}
    \addplot {x^(-1)}; \addlegendentry{$x^{-1}$}
    \addplot {x^(-2)}; \addlegendentry{$x^{-2}$}
    \addplot {x^(-3)}; \addlegendentry{$x^{-3}$}
\end{semilogyaxis}
\end{tikzpicture}
```

The example provides options for the single multiline element. Note that the initial configuration of legend style employs `text depth=0.15em`, which needs to be reset manually to `text depth={}`[49].

There are two approaches with the same effect which are subject of the following example:
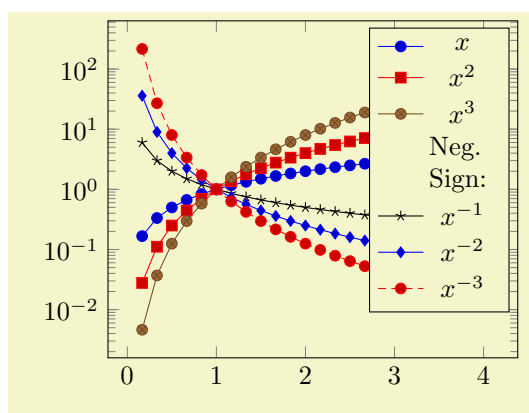
```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
\begin{semilogyaxis}[
    domain=0:4,
    legend entries={%
        $x$,$x^2$,$x^3$,%
        {[text width=25pt,text depth=]Neg. Sign:},%
        $x^{-1}$,$x^{-2}$,$x^{-3}$},
    % same effect:
    % legend style={
    %     nodes={text width=25pt,text depth=}}
]
    \addplot {x};
    \addplot {x^2};
    \addplot {x^3};
    \addlegendimage{empty legend}
    \addplot {x^(-1)};
    \addplot {x^(-2)};
    \addplot {x^(-3)};
\end{semilogyaxis}
\end{tikzpicture}
```

Here, the legend entries are provided using the single key syntax. Note that the special options are provided as part of the legend entry, using square brackets right before the text as such. The comments indicate that you could also add the `text width` stuff to legend style, in which case it would hold for every node.

Note that legend texts are realized using `\node[⟨options⟩] {⟨text⟩};`, so anything which produces a valid TikZ node is permitted (this includes `minipage` or `tabular` environments inside of ⟨text⟩).

4.9.9 Axis Lines

An extension by Pascal Wolkotte

By default the axis lines are drawn as a `box`, but it is possible to change the appearance of the x and y axis lines.

/pgfplots/axis x line=box|top|middle|center|bottom|none	(initially box)
/pgfplots/axis x line*=box|top|middle|center|bottom|none	(initially box)
/pgfplots/axis y line=box|left|middle|center|right|none	(initially box)
/pgfplots/axis y line*=box|left|middle|center|right|none	(initially box)
/pgfplots/axis lines=box|left|middle|center|right|none	
/pgfplots/axis lines*=box|left|middle|center|right|none	

These keys allow to choose the locations of the axis lines. The last one, axis lines sets the same value for every axis.

---

[49]Perhaps I can reset `text depth` automatically in the future.

Ticks and tick labels are placed according to the chosen value as well. The choice `bottom` will draw the x line at $y = y_{\min}$, `middle` will draw the x line at $y = 0$, and `top` will draw it at $y = y_{\max}$. Finally, `box` is a combination of options `top` and `bottom`. The choice `axis x line=none` is an alias for `hide x axis`. The y- and z variants work in a similar way.

The case `center` is a synonym for `middle`, both draw the line through the respective coordinate 0. If this coordinate is not part of the axis limit, the lower axis limit is chosen instead.

The starred versions …`line*` *only* affect the axis lines, without correcting the positions of axis labels, tick lines or other keys which are (possibly) affected by a changed axis line. The non-starred versions are actually styles which set the starred key *and* some other keys which also affect the figure layout:

- In case `axis x line`=box, the style `every boxed x axis` will be installed immediately.

- In case `axis x line`≠box, the style `every non boxed x axis` will be installed immediately. Furthermore, some of these choices will modify axis label positions.

The handling of `axis y line` and `axis z line` is similar. The default styles are defined as

```
\pgfplotsset{
    every non boxed x axis/.style={
        xtick align=center,
        enlarge x limits=false,
        x axis line style={-stealth}
    },
    every boxed x axis/.style={}
}
```

In addition, conditional modifications of axis label styles will be taken. For example, `axis x line`=middle will set

```
\pgfplotsset{every axis x label/.style={at={(current axis.left of origin)},anchor=south west}}
```

if the matching y style has value `axis y line`=right and

```
\pgfplotsset{every axis x label/.style={at={(current axis.right of origin)},anchor=south east}}
```

if `axis y line`≠right.

Feel free to overwrite these styles if the default doesn't fit your needs or taste. Again, these styles will *not* be used for `axis line*`.
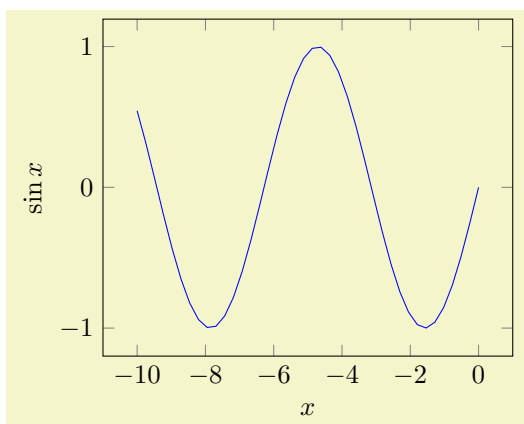
```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
\begin{axis}[
    xlabel=$x$,ylabel=$\sin x$]

    \addplot[blue,mark=none,
        domain=-10:0,samples=40]
        {sin(deg(x))};
\end{axis}
\end{tikzpicture}
```
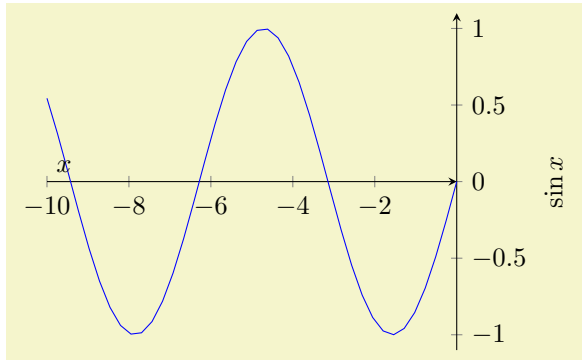
```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
\begin{axis}[
    axis x line=middle,
    axis y line=right,
    ymax=1.1, ymin=-1.1,
    xlabel=$x$,ylabel=$\sin x$
]
    \addplot[blue,mark=none,
        domain=-10:0,samples=40]
        {sin(deg(x))};
\end{axis}
\end{tikzpicture}
```
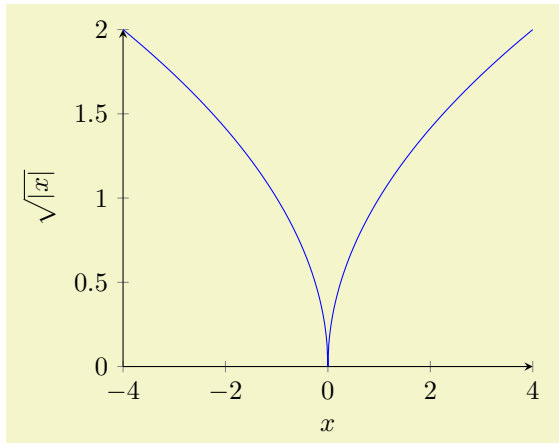


```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
\begin{axis}[
    axis x line=bottom,
    axis y line=left,
    xlabel=$x$,ylabel=$\sqrt{|x|}$
]
\addplot[blue,mark=none,
    domain=-4:4,samples=501]
    {sqrt(abs(x))};
\end{axis}
\end{tikzpicture}
```
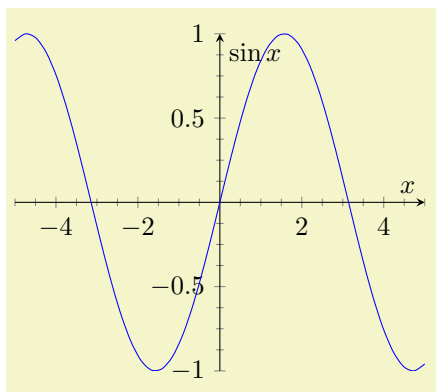


```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
\begin{axis}[
    minor tick num=3,
    axis y line=center,
    axis x line=middle,
    xlabel=$x$,ylabel=$\sin x$
    ]
    \addplot[smooth,blue,mark=none,
        domain=-5:5,samples=40]
        {sin(deg(x))};
\end{axis}
\end{tikzpicture}
```
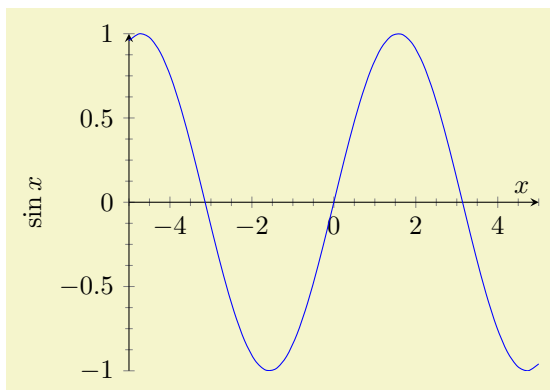


```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
\begin{axis}[
    minor tick num=3,
    axis y line=left,
    axis x line=middle,
    xlabel=$x$,ylabel=$\sin x$
    ]
    \addplot[smooth,blue,mark=none,
        domain=-5:5,samples=40]
        {sin(deg(x))};
\end{axis}
\end{tikzpicture}
```

In case `middle`, the style `every inner axis x line` allows to adjust the appearance.

Note that three dimensional axes only support to use the same value for every axis, i.e. three dimensional axes support only the `axis lines` key (or, preferably for 3D axes, the `axis lines*` key – check what looks best). See Section 4.11.4 for examples of three dimensional axis line variations.

/pgfplots/**every inner x axis line**   (no value)
/pgfplots/**every inner y axis line**   (no value)
/pgfplots/**every inner z axis line**   (no value)

A style key which can be redefined to customize the appearance of *inner* axis lines. Inner axis lines are those drawn by the `middle` (or `center`) choice of `axis x line`, see above.

This style affects *only* the line as such.
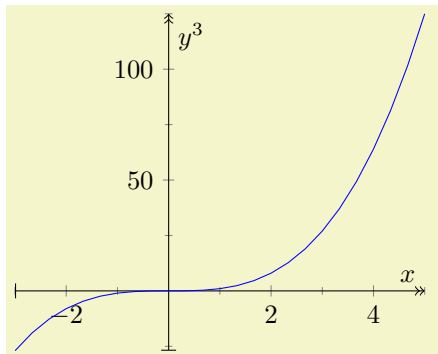
```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
\begin{axis}[
    minor tick num=1,
    axis x line=middle,
    axis y line=middle,
    every inner x axis line/.append style=
        {|->>},
    every inner y axis line/.append style=
        {|->>},
    xlabel=$x$,ylabel=$y^3$
]
\addplot[blue,domain=-3:5] {x^3};
\end{axis}
\end{tikzpicture}
```

/pgfplots/**every outer x axis line**   (no value)
/pgfplots/**every outer y axis line**   (no value)
/pgfplots/**every outer z axis line**   (no value)

Similar to **every inner x axis line**, this style configures the appearance of all axis lines which are part of the outer box.
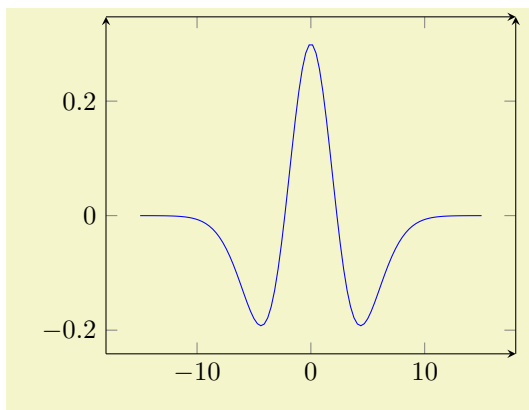
```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
\begin{axis}[
    separate axis lines, % important !
    every outer x axis line/.append style=
        {-stealth},
    every outer y axis line/.append style=
        {-stealth},
]
\addplot[blue,id=DoG,
        samples=100,
        domain=-15:15]
  gnuplot{1.3*exp(-x**2/10) - exp(-x**2/20)};
\end{axis}
\end{tikzpicture}
```

/pgfplots/**axis line style**={⟨*key-value-list*⟩}

A command which appends ⟨*key-value-list*⟩ to *all* axis line appearance styles.

/pgfplots/**inner axis line style**={⟨*key-value-list*⟩}

A command which appends ⟨*key-value-list*⟩ to both, **every inner x axis line** and the y variant.

/pgfplots/**outer axis line style**={⟨*key-value-list*⟩}

A command which appends ⟨*key-value-list*⟩ to both, **every outer x axis line** and the y variant.

/pgfplots/**x axis line style**={⟨*key-value-list*⟩}
/pgfplots/**y axis line style**={⟨*key-value-list*⟩}
/pgfplots/**z axis line style**={⟨*key-value-list*⟩}

A command which appends ⟨*key-value-list*⟩ to all axis lines styles for either x or y axis.

/pgfplots/**every boxed x axis**   (no value)
/pgfplots/**every boxed y axis**   (no value)

/pgfplots/**every boxed z axis**   (no value)

A style which will be installed as soon as `axis x line`=box (`y`) is set.

The default is simply empty.

/pgfplots/**every non boxed x axis**   (no value)
/pgfplots/**every non boxed y axis**   (no value)
/pgfplots/**every non boxed z axis**   (no value)

A style which will be installed as soon as `axis x line` (`y`) will be set to something different than `box`.

The default is

```
\pgfplotsset{
    every non boxed x axis/.style={
        xtick align=center,
        enlarge x limits=false,
        x axis line style={-stealth}}}
```

with similar values for the y-variant. Feel free to redefine this style to your needs and taste.

/pgfplots/**separate axis lines**={⟨*true,false*⟩}   (default `true`)

Enables or disables separate path commands for every axis line. This option affects *only* the case if axis lines are drawn as a *box*.

Both cases have their advantages and disadvantages, I fear there is no reasonable default (suggestions are welcome).

The case `separate axis lines`=true allows to draw arrow heads on each single axis line, but it can't close edges very well – in case of thick lines, unsatisfactory edges occur.
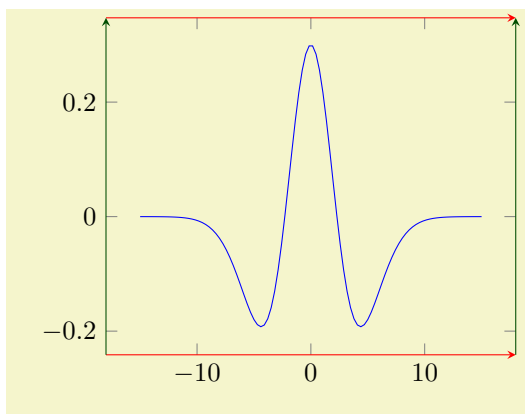

```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
\begin{axis}[
    separate axis lines,
    every outer x axis line/.append style=
        {-stealth,red},
    every outer y axis line/.append style=
        {-stealth,green!30!black},
]
\addplot[blue,
        samples=100,
        domain=-15:15]
    {1.3*exp(0-x^2/10) - exp(0-x^2/20)};
  % Unfortunately, there is a bug in PGF 2.00
  % something like exp(-10^2)
  % must be written as exp(0-10^2) :-(
\end{axis}
\end{tikzpicture}
```

The case `separate axis lines`=false issues just *one* path for all axis lines. It draws a kind of rectangle, where some parts of the rectangle may be skipped over if they are not wanted. The advantage is that edges are closed properly. The disadvantage is that at most one arrow head is added to the path (and yes, only one drawing color is possible).
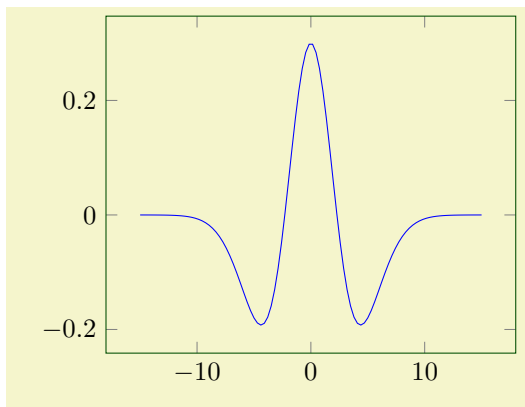

```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
\begin{axis}[
    separate axis lines=false,
    every outer x axis line/.append style=
        {-stealth,red},
    every outer y axis line/.append style=
        {-stealth,green!30!black},
]
\addplot[blue,id=DoG,
        samples=100,
        domain=-15:15]
  gnuplot{1.3*exp(-x**2/10) - exp(-x**2/20)};
\end{axis}
\end{tikzpicture}
```

4.9.10 Moving Axis Lines

PGFPLOTS offers styles to shift axis lines along their normal vector:

/pgfplots/**axis x line shift**={⟨*dimension or unit*⟩}   (initially **empty**)
/pgfplots/**axis y line shift**={⟨*dimension or unit*⟩}   (initially **empty**)
/pgfplots/**axis z line shift**={⟨*dimension or unit*⟩}   (initially **empty**)
/pgfplots/**axis line shift**={⟨*dimension or unit*⟩}   (initially **empty**)

Allows to shift one or more axis lines together with all their descriptions.
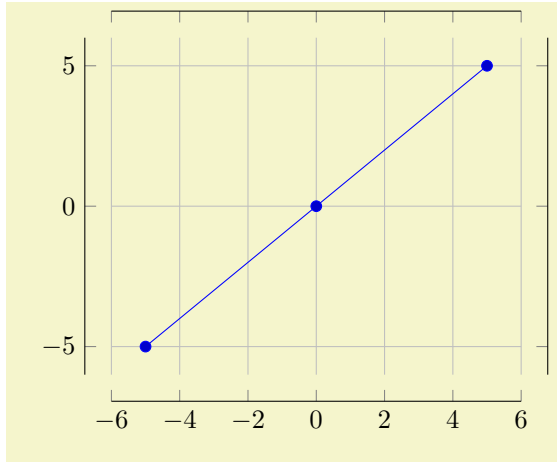

```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
    \begin{axis}[
        axis line shift=10pt,
        grid=major]
    \addplot+[samples=3] {x};
    \end{axis}
\end{tikzpicture}
```

The option takes the axis lines and shifts them along their "outer normal vectors". This direction is known for every axis; it is the direction which points away from the center.

The operation is often combined with the **axis lines** variations, for example
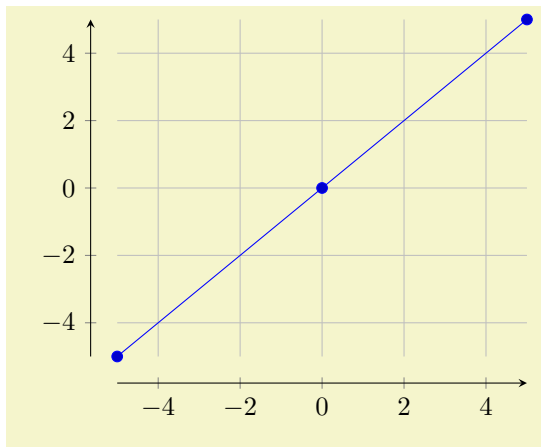

```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
    \begin{axis}[
        axis lines=left,
        axis line shift=10pt,
        grid=major]
    \addplot+[samples=3] {x};
    \end{axis}
\end{tikzpicture}
```

Keep in mind that **axis lines**=left also reconfigures the axis such that it has an arrow head and **enlargelimits**=false (see also **axis lines***=left). Customizations are, of course possible, for example an arrow tip which shows the end of the axis:
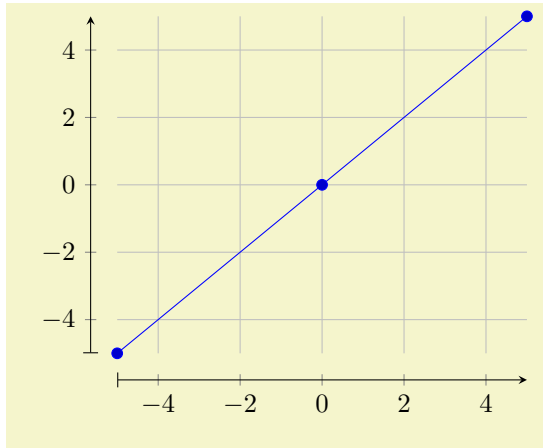
```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
    \begin{axis}[
        axis lines=left,
        axis line style={|-stealth},
        axis line shift=10pt,
        grid=major]
    \addplot+[samples=3] {x};
    \end{axis}
\end{tikzpicture}
```

The argument ⟨*dimension or unit*⟩ can be a dimension like `10pt` (as in the previous examples). However, it can also be given in terms of axis units:
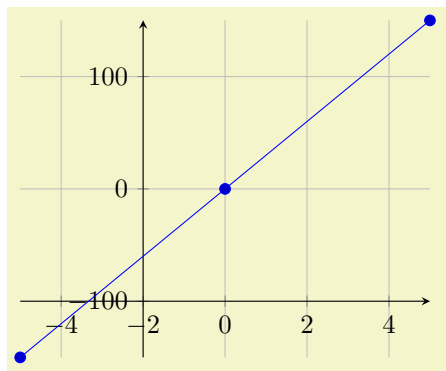

```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
    \begin{axis}[
        axis lines=center,
        axis y line shift=2,
        axis x line shift=100,
        grid=major]
    \addplot+[samples=3] {30*x};
    \end{axis}
\end{tikzpicture}
```

In this context, `axis y line shift`=2 shifts the y axis by 2 units along the x axis since the x axis (with negative sign) is the "outer normal". Shifting by axis units is only possible for two–dimensional plots since the outer normal is well-defined here: it is the other available axis.

The feature `axis line shift` can also be applied to three dimensional axes (with a ⟨*dimension*⟩ argument, not a unit). In this case, the shift is also along the "outer normal vector". Note that this vector is a combination of the two other axes, so the resulting axis is no longer aligned with grid lines! Handle this option with care as it easily results in confusion when one tries to align the axis descriptions with grid lines.
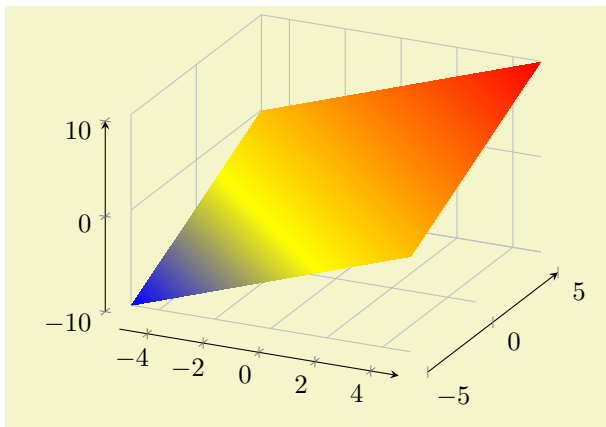
```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
    \begin{axis}[
        axis lines=left,
        axis line shift=10pt,
        grid=major]
    \addplot3[surf,shader=interp,samples=2] {x+y};
    \end{axis}
\end{tikzpicture}
```

The option `axis line shift` is a style which configures a shifts of ⟨*dimension*⟩ for each axis.

Note that `axis line shift` implies `separate axis lines` and will implicitly configure `hide obscured x ticks`=false and its variants..

4.9.11   Two Ordinates (y axis) or Multiple Axes

In some applications, more than one y axis is used if the x range is the same. This section demonstrates how to create them. The idea in PGFPLOTS is to draw two axes on top of each other, one with descriptions only on the left and the second with descriptions only on the right:
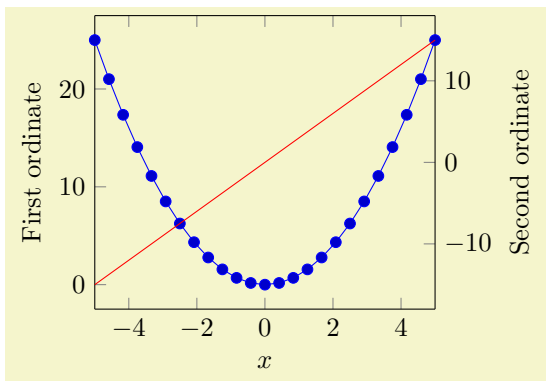

```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
  % let both axes use the same layers
  \pgfplotsset{set layers}
  \begin{axis}[
    scale only axis,
    xmin=-5,xmax=5,
    axis y line*=left,% the '*' avoids arrow heads
    xlabel=$x$,
    ylabel=First ordinate]
  \addplot {x^2};
  \end{axis}

  \begin{axis}[
    scale only axis,
    xmin=-5,xmax=5,
    axis y line*=right,
    axis x line=none,
    ylabel=Second ordinate]
  \addplot[red] {3*x};
  \end{axis}
\end{tikzpicture}
```

Thus, the two axes are drawn "on top" of each other – one, which contains the x axis and the left y axis, and one which has *only* the right y axis. Since PGFPLOTS does not really know what it's doing here, user attention in the following possibly non-obvious aspects is required:

1. Scaling. You should set `scale only axis` because this forces equal dimensions for both axis, without respecting any labels.

2. Same x limits. You should set those limits explicitly.

3. You need to tell PGFPLOTS that it should share the same graphics layers for both axes. In this case, PGFPLOTS will draw plots of the first axis and of the second axis onto the same layer. It will also draw background(s) into the background layer and descriptions into the foreground layer. Use the key `\pgfplotsset{set layers}` in front of the first axis to prepare the complete picture for layered graphics.

You may want to consider different legend styles. It is also possible to use only the axis, without any plots:
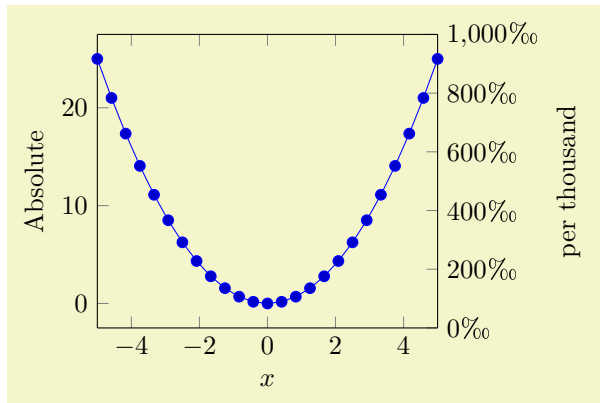
```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
% \usepackage{textcomp}
\begin{tikzpicture}
  % let both axes use the same layers
  \pgfplotsset{set layers}
  \begin{axis}[
    scale only axis,
    xmin=-5,xmax=5,
    axis y line*=left,%'*' avoids arrow heads
    xlabel=$x$,
    ylabel=Absolute]
  \addplot {x^2};
  \end{axis}

  \begin{axis}[
    scale only axis,
    xmin=-5,xmax=5,
    ymin=0,ymax=1000,
    yticklabel=
{$\pgfmathprintnumber{\tick}$\textperthousand},
    axis y line*=right,
    axis x line=none,
    ylabel=per thousand]
  \end{axis}
\end{tikzpicture}
```

4.9.12   Axis Discontinuities

An extension by Pascal Wolkotte

In case the range of either of the axis do not include the zero value, it is possible to visualize this with a discontinuity decoration on the corresponding axis line.

/pgfplots/axis x discontinuity=crunch|parallel|none   (initially none)
/pgfplots/axis y discontinuity=crunch|parallel|none   (initially none)
/pgfplots/axis z discontinuity=crunch|parallel|none   (initially none)

Insert a discontinuity decoration on the x (or y, respectively) axis. This is to visualize that the y axis does cross the x axis at its 0 value, because the minimum x axis value is positive or the maximum value is negative.

The description applies to axis y discontinuity and axis z discontinuity as well, simply substitute x by y or z, respectively.
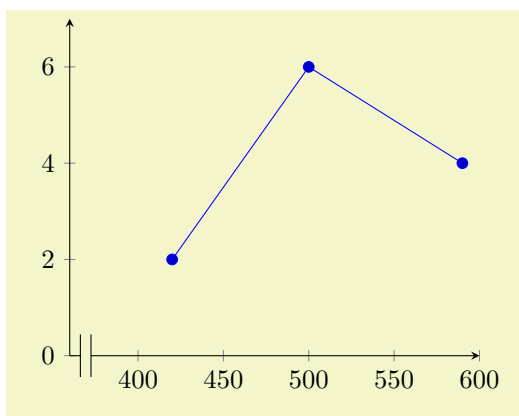

```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
\begin{axis}[
    axis x line=bottom,
    axis x discontinuity=parallel,
    axis y line=left,
    xmin=360, xmax=600,
    ymin=0, ymax=7,
     enlargelimits=false
]
    \addplot coordinates {
        (420,2)
        (500,6)
        (590,4)
    };
\end{axis}
\end{tikzpicture}
```
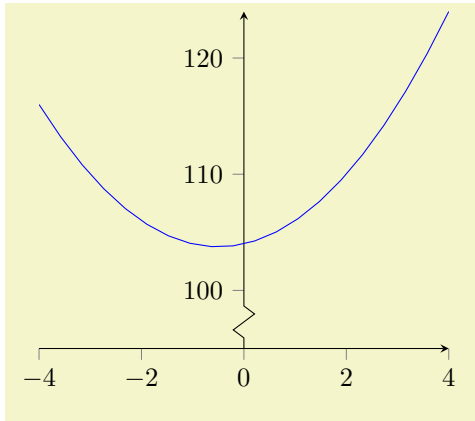
```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
\begin{axis}[
    axis x line=bottom,
    axis y line=center,
    tick align=outside,
    axis y discontinuity=crunch,
    ymin=95, enlargelimits=false
]
    \addplot[blue,mark=none,
        domain=-4:4,samples=20]
        {x*x+x+104};
\end{axis}
\end{tikzpicture}
```

A problem might occur with the placement of the ticks on the axis. This can be solved by specifying the minimum or maximum axis value for which a tick will be placed.

/pgfplots/**xtickmin**={⟨*coord*⟩}	(default `axis limits`)
/pgfplots/**ytickmin**={⟨*coord*⟩}	(default `axis limits`)
/pgfplots/**ztickmin**={⟨*coord*⟩}	(default `axis limits`)
/pgfplots/**xtickmax**={⟨*coord*⟩}	(default `axis limits`)
/pgfplots/**ytickmax**={⟨*coord*⟩}	(default `axis limits`)
/pgfplots/**ztickmax**={⟨*coord*⟩}	(default `axis limits`)

The options xtickmin, xtickmax and ytickmin, ytickmax allow to define the axis tick limits, i.e. the axis values before respectively after no ticks will be placed. Everything outside of the axis tick limits will be not drawn. Their default values are equal to the axis limits.
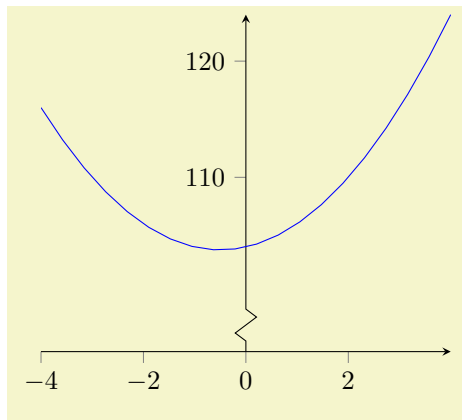

```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
\begin{axis}[
    axis x line=bottom,
    axis y line=center,
    tick align=outside,
    axis y discontinuity=crunch,
    xtickmax=3,
    ytickmin=110,
    ymin=95, enlargelimits=false
]
    \addplot[blue,mark=none,
        domain=-4:4,samples=20]
        {x*x+x+104};
\end{axis}
\end{tikzpicture}
```

/pgfplots/**hide x axis**=true|false	(initially `false`)
/pgfplots/**hide y axis**=true|false	(initially `false`)
/pgfplots/**hide z axis**=true|false	(initially `false`)
/pgfplots/**hide axis**=true|false	(initially `false`)

Allows to hide either a selected axis or all of them. No outer rectangle, no tick marks and no labels will be drawn. Only titles and legends will be processed as usual.

Axis scaling and clipping (!) will be done as if you did not use hide axis.
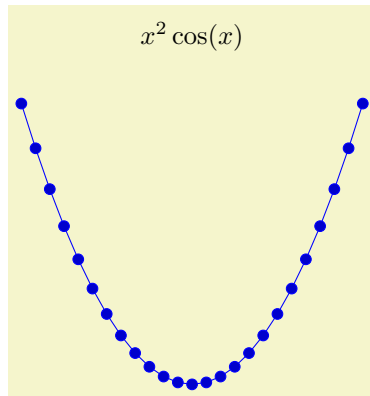
```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
    \begin{axis}[
        hide x axis,
        hide y axis,
        title={$x^2\cos(x)$}]
    \addplot {cos(x)*x^2};
    \end{axis}
\end{tikzpicture}% <- eliminate space.
```
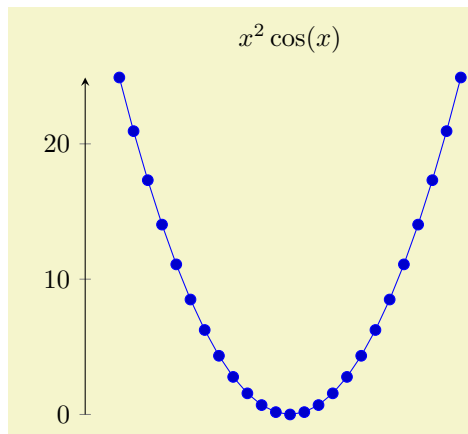


```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
    \begin{axis}[
        hide x axis,
        axis y line=left,
        title={$x^2\cos(x)$}]
    \addplot {cos(x)*x^2};
    \end{axis}
\end{tikzpicture}% <- eliminate space
```

Note that a hidden axis contributes nothing to the resulting picture's bounding box[50], see `clip bounding box`.
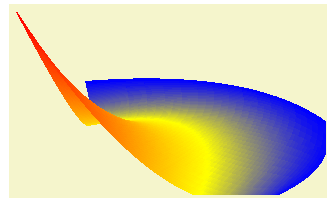

```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
% requires \usepgfplotslibrary{patchplots}
% and compat=1.8 or newer
\begin{tikzpicture}
\begin{axis}[
    hide axis,
]
\addplot3[patch,
    patch type=biquadratic,
    shader=interp]
coordinates {
    (0,0,1) (6,1,0) (5,5,0) (-1,5,0)
    (3,1,0) (6,3,0) (2,6,0) (0,3,0)
    (3,3.75,0)
};
\end{axis}
\end{tikzpicture}% <- eliminate space
```

This can be used to embed a PGFPLOTS path which needs an axis to a standard TikZ picture. See also Section 4.26 for details how to synchronize the alignment between a PGFPLOTS figure (which typically rescales its coordinates) to that of a standard `tikzpicture`.

Note that PGFPLOTS uses the input coordinates to determine the bounding box of the picture. In this case, the bounding box is slightly smaller than the shading. A cure would be to increase the bounding box manually.

You may want to disable the `clip` path using the option `clip`=false.

4.9.13 Color Bars

PGFPLOTS supports mesh, surface and scatter plots which can use color maps. While color maps can be chosen as described in Section 4.7.6, they can be visualized using color bars.

---

[50]Since version 1.8.

/pgfplots/colorbar=true|false   (initially `false`)

Activates or deactivates color bars.
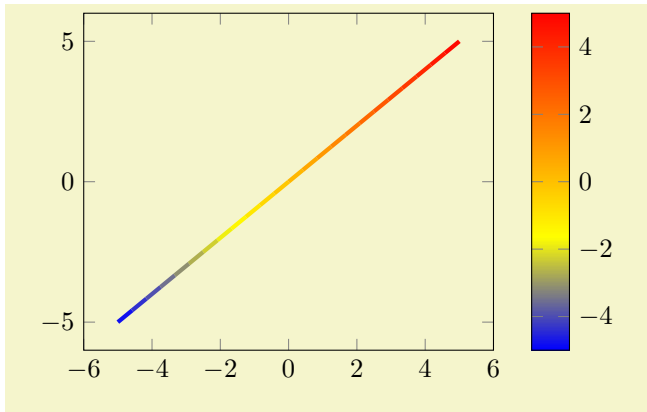

```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
    \begin{axis}[colorbar]
        \addplot[mesh,ultra thick] {x};
    \end{axis}
\end{tikzpicture}
```
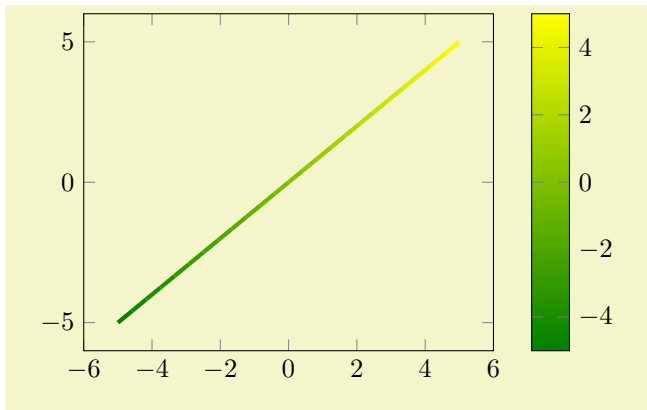


```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
    \begin{axis}[colorbar,colormap/greenyellow]
        \addplot[mesh,ultra thick] {x};
    \end{axis}
\end{tikzpicture}
```
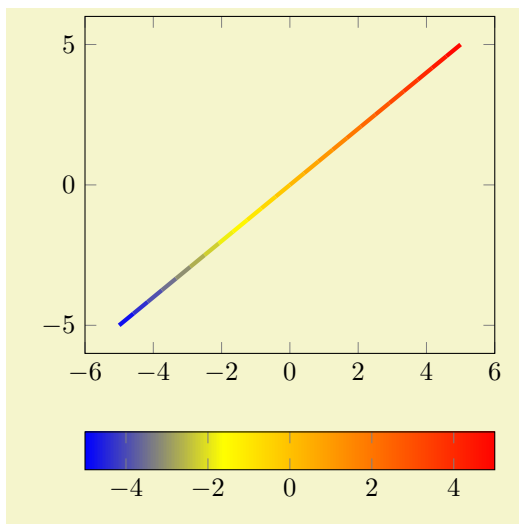


```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
    \begin{axis}[colorbar horizontal]
        \addplot[mesh,ultra thick] {x};
    \end{axis}
\end{tikzpicture}
```

A color bar is only useful for plots with non–zero color data range, more precisely, for which minimum and maximum `point meta` data is available. Usually, this is the case for `scatter`, `mesh` or `surf` (or similar) plots, but you can also set `point meta min` and `point meta max` manually in order to draw a `colorbar`.

Color bars are just normal axes which are placed right besides their parent axes. The only difference is that they inherit several styles such as line width and fonts and they contain a bar shaded with the color map of the current axis.

Color bars are drawn internally with

```
\axis[every colorbar,colorbar shift,colorbar=false]
    \addplot graphics {};
\endaxis
```

where the placement, alignment, appearance and other options are done by the two styles `every colorbar` and `colorbar shift`. These styles and the possible placement and alignment options are described below.

Remarks for special cases:

- Since there is always only one color bar per plot, this color bar uses the axis wide configurations of color map and color data. Consider using `colorbar source` to select color data limits of a particular `\addplot` command instead.

- If someone needs more than one color bar, the draw command above needs to be updated. See the key `colorbar/draw/.code` for this special case.

/pgfplots/`colorbar right` (style, no value)

A style which redefines `every colorbar` and `colorbar shift` such that color bars are placed right of their parent axis.

This is the initial configuration.
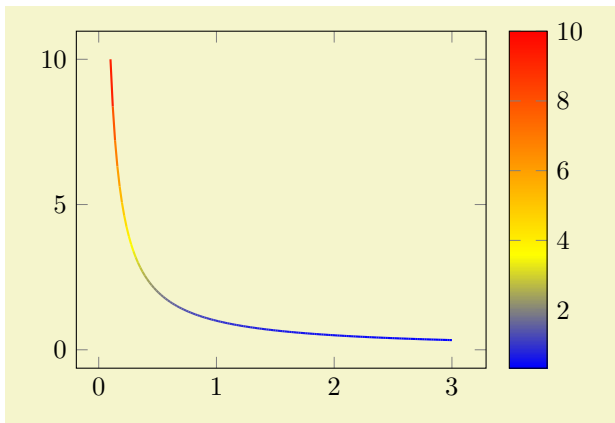

```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
    \begin{axis}[colorbar right]
    \addplot[mesh,thick,samples=150,domain=0.1:3]
        {1/x};
    \end{axis}
\end{tikzpicture}
```

The style `colorbar right` is defined as

```
\pgfplotsset{
    colorbar right/.style={
        /pgfplots/colorbar=true,
        /pgfplots/colorbar shift/.style={xshift=0.3cm},
        /pgfplots/every colorbar/.style={
            title=,
            xlabel=,
            ylabel=,
            zlabel=,
            legend entries=,
            axis on top,
            at={(parent axis.right of north east)},
            anchor=north west,
            xmin=0,
            xmax=1,
            ymin=\pgfkeysvalueof{/pgfplots/point meta min},
            ymax=\pgfkeysvalueof{/pgfplots/point meta max},
            plot graphics/xmin=0,
            plot graphics/xmax=1,
            plot graphics/ymin=\pgfkeysvalueof{/pgfplots/point meta min},
            plot graphics/ymax=\pgfkeysvalueof{/pgfplots/point meta max},
            enlargelimits=false,
            scale only axis,
            height=\pgfkeysvalueof{/pgfplots/parent axis height},
            x=\pgfkeysvalueof{/pgfplots/colorbar/width},
            yticklabel pos=right,
            xtick=\empty,
            colorbar vertical/lowlevel,
        }
    },
    /pgfplots/colorbar vertical/lowlevel/.style={
        plot graphics/lowlevel draw/.code 2 args={%
            \pgfuseshading{...} % some advanced basic level shading operations
        }
    },
}
```

Attention: `colorbar right` *re*defines `every colorbar`. That means any user customization must take place *after* `colorbar right`:

```
% correct:
\begin{axis}[colorbar right, colorbar style={<some customization>}]
% wrong, colorbar right resets the customization:
\begin{axis}[colorbar style={<some customization>}, colorbar right]
```

/pgfplots/**colorbar left**   (style, no value)

A style which re-defines `every colorbar` and `colorbar shift` such that color bars are placed left of their parent axis.

```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
    \begin{axis}[colorbar left]
    \addplot[mesh,thick,samples=150]
        {x*sin(deg(4*x))};
    \end{axis}
\end{tikzpicture}
```
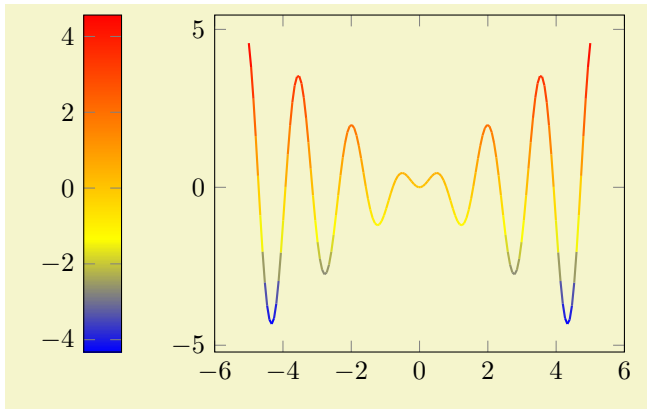
The style `colorbar left` is defined as

```
\pgfplotsset{
    colorbar left/.style={
        /pgfplots/colorbar right,
        /pgfplots/colorbar shift/.style={xshift=-0.3cm},
        /pgfplots/every colorbar/.append style={
            at={(parent axis.left of north west)},
            anchor=north east,
            yticklabel pos=left,
        }
    }
}
```

Attention: `colorbar left` *re*defines `every colorbar`. That means any user customization must take place *after* `colorbar left` (see also the documentation for `colorbar right`).

/pgfplots/`colorbar horizontal` (style, no value)

A style which re-defines `every colorbar` and `colorbar shift` such that color bars are placed below their parent axis, with a horizontal bar.
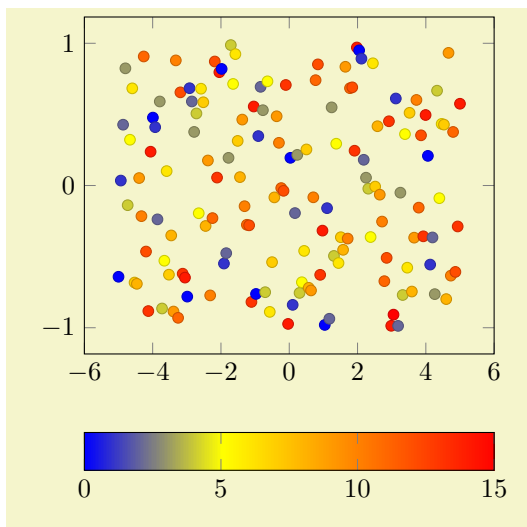

```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
    \begin{axis}[colorbar horizontal]
    \addplot[only marks,scatter,
        scatter src={mod(\coordindex,15)},samples=150]
        {rand};
    \end{axis}
\end{tikzpicture}
```

This style is defined as

```
\pgfplotsset{
    colorbar horizontal/.style={
        /pgfplots/colorbar=true,
        /pgfplots/colorbar shift/.style={yshift=-0.3cm},
        /pgfplots/every colorbar/.style={
            title=,
            xlabel=,
            ylabel=,
            zlabel=,
            legend entries=,
            axis on top,
            at={(parent axis.below south west)},
            anchor=north west,
            ymin=0,
            ymax=1,
            xmin=\pgfkeysvalueof{/pgfplots/point meta min},
            xmax=\pgfkeysvalueof{/pgfplots/point meta max},
            plot graphics/ymin=0,
            plot graphics/ymax=1,
            plot graphics/xmin=\pgfkeysvalueof{/pgfplots/point meta min},
            plot graphics/xmax=\pgfkeysvalueof{/pgfplots/point meta max},
            enlargelimits=false,
            scale only axis,
            width=\pgfkeysvalueof{/pgfplots/parent axis width},
            y=\pgfkeysvalueof{/pgfplots/colorbar/width},
            xticklabel pos=left,
            ytick=\empty,
            colorbar horizontal/lowlevel,
        }%
    },%
    /pgfplots/colorbar horizontal/lowlevel/.style={%
        plot graphics/lowlevel draw/.code 2 args={%
            \pgfuseshading{...} % some advanced basic level shading operations
        },%
    },%
}
```

Attention: colorbar horizontal *re*-defines every colorbar. That means any user customization must take place *after* colorbar horizontal:

```
% correct:
\begin{axis}[colorbar horizontal, colorbar style={<some customization>}]
% wrong, colorbar horizontal resets the customization:
\begin{axis}[colorbar style={<some customization>}, colorbar horizontal]
```

/pgfplots/every colorbar   (style, no value)

This style governs the placement, alignment and appearance of color bars. Any desired detail changes for color bars can be put into this style. Additionally, there is a style colorbar shift which is set after every colorbar. The latter style is intended to contain only shift transformations like xshift or yshift (making it easier to overwrite or deactivate them).

While a color bar is drawn, the predefined node parent axis can be used to align at the parent axis.

Predefined node parent axis

A node for the parent axis of a color bar. It is only valid for color bars.

Thus,

```
\pgfplotsset{
    colorbar style={
        at={(parent axis.right of north east)},
        anchor=north west,
    },
    colorbar shift/.style={xshift=0.3cm}
}
```

places the colorbar in a way that its top left (north west) corner is aligned right of the top right corner (right of north east) of its parent axis. Combining this with the colorbar shift is actually the same as the initial setting.

Since color bars depend on some of its parent's properties, these properties are available as values of the following keys:

/pgfplots/**point meta min**   (no value)
/pgfplots/**point meta max**   (no value)

> The values of these keys contain the lower and upper bound of the color map, i.e. the lower and upper limit for the color bar.
>
> The value is `\pgfkeysvalueof{/pgfplots/point meta min}` inside of `every colorbar`.
>
> The value is usually determined using the axis wide point meta limits, i.e. they are computed as minimum and maximum value over all plots (unless the user provided limits manually). Consider the `colorbar source` key if you'd like to select point meta limits of one specific `\addplot` command.

/pgfplots/**colorbar source**={⟨*true,false*⟩}   (initially `false`)

> Allows to select a specific `\addplot` command whose point meta limits are taken as upper and lower limit of a `colorbar`'s data range. This affects the tick descriptions of the `colorbar`. It needs to be provided as argument to `\addplot`, i.e. using

```
\addplot[...,colorbar source] ...
% or
\addplot+[colorbar source] ...
```

> or as key inside of a `cycle list`.
>
> Using `colorbar source` automatically implies `point meta rel`=`per plot` for that specific plot.
>
> If there are more than one `\addplot` commands with `colorbar source`, the last one is selected.

/pgfplots/**parent axis width**   (no value)
/pgfplots/**parent axis height**   (no value)

> The values of these keys contain the size of the parent axis. They can be used as `width` and/or `height` arguments for `every colorbar` with `\pgfkeysvalueof{/pgfplots/parent axis width}`.
>
> These values are only valid inside of color bars.

Besides these values, each color bar inherits a list of styles of its parent axis, namely

- `every tick`,
- `every minor tick`,
- `every major tick`,
- `every axis grid`,
- `every minor grid`,
- `every major grid`,
- `every tick label`.

This can be used to inherit line width and/or fonts.

Customization: "colorbar top"
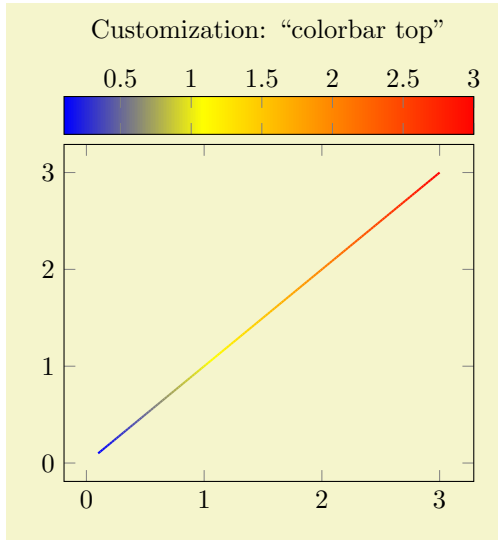
```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
\begin{axis}[
    colorbar horizontal,
    colorbar style={
      at={(0.5,1.03)},anchor=south,
      xticklabel pos=upper
    },
    title style={yshift=1cm},
    title=Customization: ``colorbar top'']

    \addplot[mesh,thick,samples=150,domain=0.1:3]
        {x};
\end{axis}
\end{tikzpicture}
```

More Customization: "colorbar top"
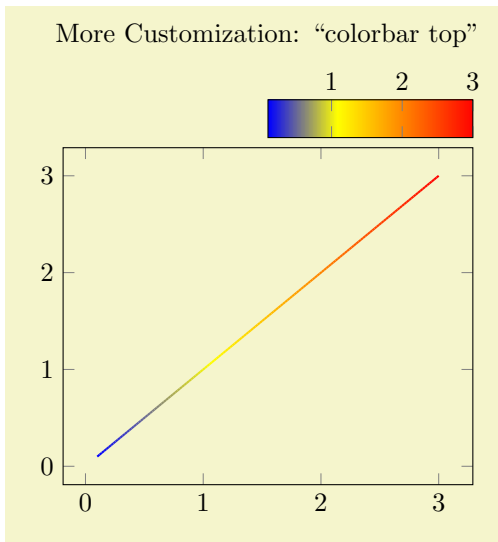
```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
\begin{axis}[
    colorbar horizontal,
    colorbar style={
      at={(1,1.03)},anchor=south east,
      width=0.5*
        \pgfkeysvalueof{/pgfplots/parent axis width},
      xticklabel pos=upper,
    },
    title style={yshift=1cm},
    title=More Customization: ``colorbar top'']

    \addplot[mesh,thick,samples=150,domain=0.1:3]
        {x};
\end{axis}
\end{tikzpicture}
```

Please take a look at the predefined styles colorbar right, colorbar left and colorbar horizontal for more details about configuration possibilities for every colorbar.

Remark: A color bar is just a normal axis. That means every colorbar can contain specifications where to place tick labels, extra ticks, scalings and most other features of a normal axis as well (except nested color bars).

/pgfplots/colorbar style={⟨key-value list⟩}

A shortcut for every colorbar/.append style={⟨key-value list⟩}. It appends options to the colorbar style.

/pgfplots/colorbar/width={⟨dimension⟩}   (initially 0.5cm)

Sets the width of a color bar.
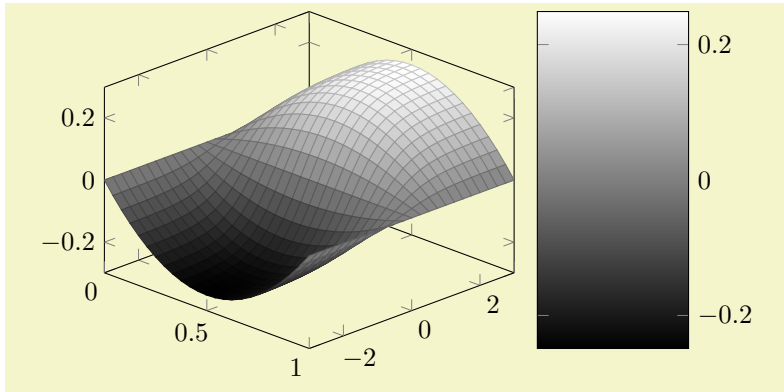
```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
    \begin{axis}[
        view/az=45,
        colorbar,
        colorbar/width=2cm,
        colormap/blackwhite]

    \addplot3[surf,domain=0:1,y domain=-3:3] {x*(1-x)*tanh(y)};
    \end{axis}
\end{tikzpicture}
```

For horizontal color bars, this sets the height.

/pgfplots/colorbar shift   (style, no value)

This style is installed after `every colorbar`. It is intended to contain only shift transformations like `xshift` and/or `yshift`. The reason to provide two separate styles is to allow easier deactivation of shift transformations.

```
\pgfplotsset{
    colorbar shift/.style={xshift=1cm}
}
```

Predefined node `current colorbar axis`

A predefined node for the color bar of an axis. After `\end{axis}`, this node can be used to align further graphical elements at the color bar. Note that `current axis` refers to the axis as such while `current colorbar axis` refers to the color bar (which is an axis itself).

/pgfplots/colorbar/draw/.code={⟨...⟩}

This code key belongs to the low level interface of color bars. It is invoked whenever a color bar needs to be drawn. Usually, it won't be necessary to use or modify this key explicitly.

When this key is invoked, the styles inherited from the parent axis are already set and the required variables (see the documentation of `every colorbar`) are initialized.

This code key can be replaced if one needs more than one color bar (or other wrinkles).

The initial configuration is

```
\pgfplotsset{colorbar/draw/.code={%
    \axis[every colorbar,colorbar shift,colorbar=false]
    \addplot graphics {};
    \endaxis
    }
}
```

Please note that a color bar axis is nothing special as such – it is just a normal axis with one `plot graphics` command and it is invoked with a special set of options. The only special thing is that a set of styles and some variables are inherited from its parent axis.

/pgfplots/colorbar sampled={⟨*optional options*⟩}   (style, default `surf,mark=none,shader=flat`)

A style which installs a discretely sampled color bar.
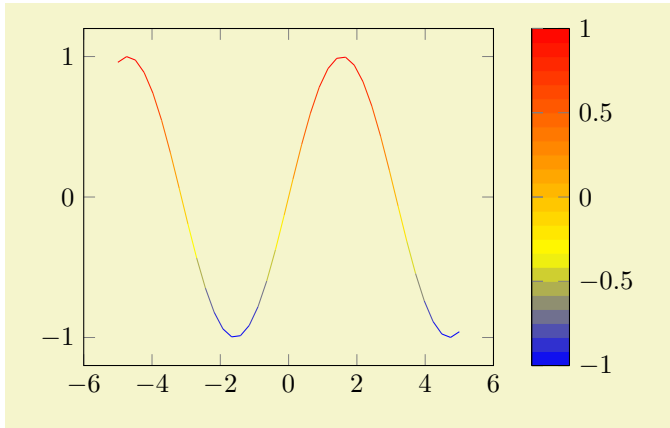
```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
    \begin{axis}[colorbar sampled]
    \addplot[mesh,samples=40] {sin(deg(x))};
    \end{axis}
\end{tikzpicture}
```

Attention: this style merely changes the appearance of the `colorbar`. The way `colormap`s are used to determine plot colors is unrelated to this key. See also `colormap access`=direct for ways to affect the color selection.

The style uses `\addplot3[`⟨*options*⟩`]` to draw the `colorbar`, with `domain` set to the color range and the current value of the `samples` key to determine the number of samples. In other words: it uses `plot expression` and a surface plot to visualize the `colorbar`. Use `colorbar style`={`samples`=10} to change the number of samples.
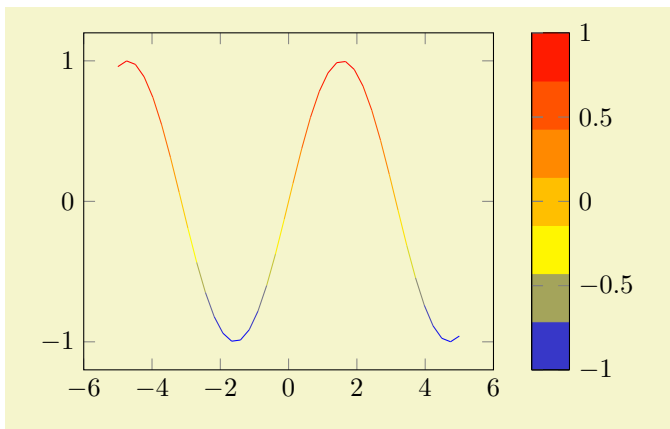

```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
    \begin{axis}[colorbar sampled,colorbar style={samples=8}]
    \addplot[mesh,samples=40] {sin(deg(x))};
    \end{axis}
\end{tikzpicture}
```

The ⟨*options*⟩ can be used to change the `\addplot3` options used for the colorbar visualization. For example, `colorbar sampled`={surf,shader=interp} will use Gouraud shading which has visually the same effect as the standard color bar.

/pgfplots/**colorbar sampled line**={⟨*optional options*⟩}   (style, default `scatter,only marks`)

A style which draws a discrete colorbar. In contrast to `colorbar sampled`, it visualizes the `colorbar` using a line plot, not a `surf` plot.
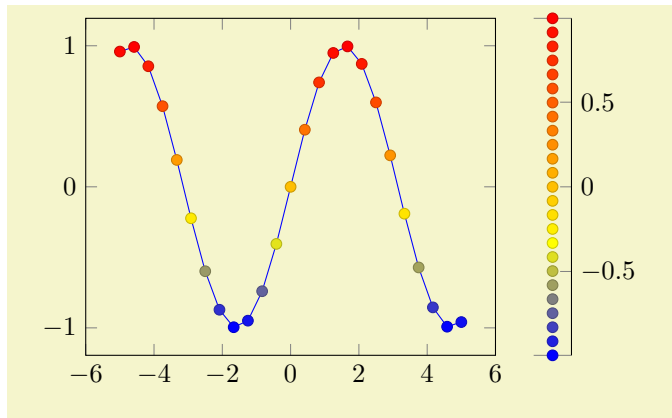
```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
    \begin{axis}[colorbar sampled line]
    \addplot+[scatter] {sin(deg(x))};
    \end{axis}
\end{tikzpicture}
```

Attention: this style merely changes the appearance of the `colorbar`. The way `colormap`s are used to determine plot colors is unrelated to this key. See also `colormap access`=direct for ways to affect the color selection.

The initial configuration uses a `scatter` plot to visualize the `colorbar`, it can be changed by specifying ⟨*options*⟩.

Furthermore, the axis appearance is changed using `axis y line*`=left|right, depending on the position of the color bar (or `axis x line*`=bottom for `colorbar horizontal`).

Consider the `tick align`=outside feature if you prefer tick lines outside of the colorbar instead of inside.

/pgfplots/**every colorbar sampled line**   (style, no value)

A style which is used by `colorbar sampled line` to change the color of the line without ticks.

It is initially set to `help lines`.

/pgfplots/**colorbar as legend**   (style, no value)

A `colorbar` which uses the same place for each color. It is useful for `colormap`s with non-uniform positions where each item has to be documented in the `colorbar`, even if it is only relevant for a "small" portion of the data range.

The following example shows a non-uniform `colormap` with the default (proportional) display: each color receives as much "room" as its interval occupies.
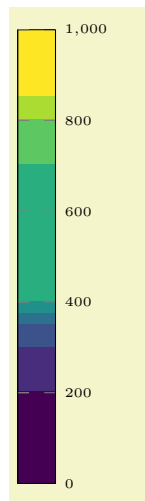

```
\pgfplotscolorbardrawstandalone[
    colorbar style={
        ticklabel style={font=\tiny}},
    colormap access=const,
    colormap={CM}{
        of colormap={
            viridis,
            target pos={0,200,300,350,375,
                400,700,800,850,1000},
            sample for=const,
        }
    }]
```

If we use the very same `colormap` but visualize it as `colorbar as legend`, we get the same "room" for each color, independent of the underlying position interval – it is more like a legend than a normal `colorbar`:
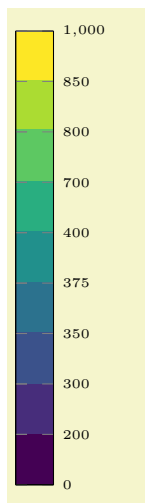
```
\pgfplotscolorbardrawstandalone[
    colorbar as legend,
    colorbar style={ticklabel style={font=\tiny}},
    colormap access=const,
    colormap={CM}{
        of colormap={
            viridis,
            target pos={0,200,300,350,375,
                400,700,800,850,1000},
            sample for=const,
        }
    }]
```

Clearly, such a `colorbar` looses the capability to interpolate positions; it becomes a lookup table (which, again, is more like a legend).

Limitations: This style has its best fit for `colormap access`=const, especially in conjunction with `sample for=const`[51] It may produce unexpected results when used for continuous mappings.

4.9.14 Color Bars Outside Of an Axis

Occasionally, one has multiple adjacent plots, each with the same `colormap` and the same `point meta min` and `point meta max` values and we'd like to show a *single* `colorbar`. PGFPLOTS supports the `colorbar to name` feature which is similar to the related method for legends, `legend to name`:

/pgfplots/`colorbar to name`={⟨*name*⟩}   (initially `empty`)

Enables to detach a `colorbar` from its parent axis: instead of drawing the `colorbar`, a self–contained, independent set of drawing commands will be stored using the label ⟨*name*⟩. The label is defined using `\label`{⟨*name*⟩}, just as for any other LATEX label. The name can be referenced using

`\ref`{⟨*name*⟩}.

Thus, typing `\ref`{⟨*name*⟩} somewhere outside of the axis, maybe even outside of any picture, will cause the `colorbar` to be drawn.

---
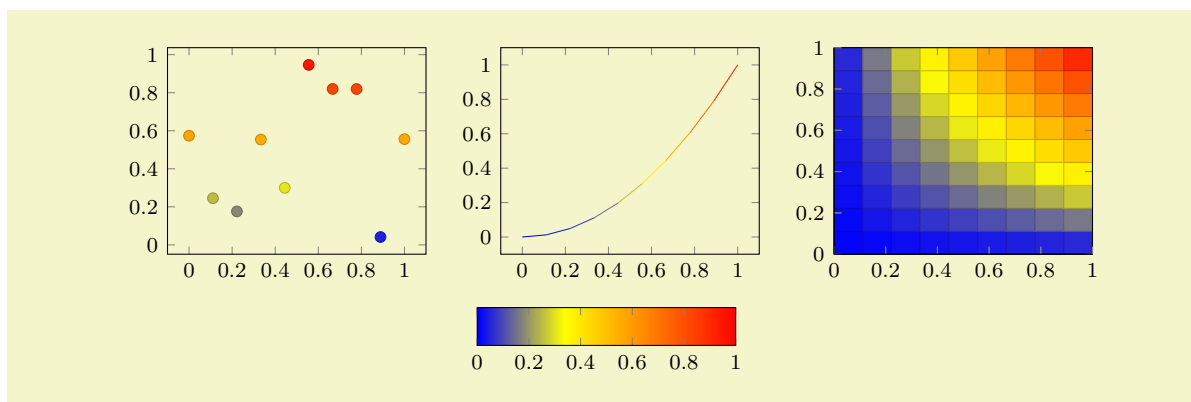
[51]Note that `sample for=const` adds a dummy color. This dummy color is omitted when displaying `colorbar as legend`, assuming it is a dummy color for the last interval. This may produce unexpected effects when used with a continuous colormap.

```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\pgfplotsset{footnotesize,samples=10, domain=0:1,point meta min=0, point meta max=1}
\begin{center}% note that \centering uses less vspace...
\begin{tikzpicture}
    \begin{axis}[colorbar,colorbar horizontal,colorbar to name={storedcolorbar}]
    \addplot[scatter,only marks,mark=*] {rnd};
    \end{axis}
\end{tikzpicture}
%
\begin{tikzpicture}
    \begin{axis}
    \addplot+[domain=0:1,mark=none,mesh] {x^2};
    \end{axis}
\end{tikzpicture}
%
\begin{tikzpicture}
    \begin{axis}[view={0}{90}]
    \addplot3[surf] {x*y};
    \end{axis}
\end{tikzpicture}
\\

\ref{storedcolorbar}
\end{center}
```

The feature works in the same way as described for `legend to name`, please refer to its description on page 262 for the details. We only summarize the differences here.

\pgfplotscolorbarfromname{⟨*name*⟩}

> This command poses an equivalent alternative for `\ref{⟨`*name*`⟩}`: it has essentially the same effect, but it does not create links when used with the `hyperref` package.

/pgfplots/every colorbar to name picture (style, no value)

> A style which is installed when `\ref` is used outside of a picture: a new picture will be created with `\tikz[/pgfplots/every colorbar to name picture]`.

> See also the `every legend to name picture` style.

4.10   Scaling Options

There are a various options which control or change the scaling of an axis. Here, "scaling" typically means two aspects: first, the unit vector size in each direction and second, the displayed limits in each direction. Both together control the size of the axis box. In addition, axis descriptions change the size. However, PGFPLOTS scales only units and determines limits. It does not scale axis descriptions by default in order to keep consistent font sizes between the text and the figure.

Often, one wishes to provide the target size only and let PGFPLOTS do the rest. This is the default; it scales the axis to `width` and `height`. If you provide one of these options, the axis will be rescaled while keeping the aspect ratio.

Occasionally, one wants to provide unit vectors explicitly to ensure that one unit takes a prescribed amount of space. This is possible by means of the `x`, `y`, and `z` keys. In such a case, the `width` and `height` options will be ignored (or only applied for the unspecified unit vectors).

Another common approach is to enforce specific `unit vector ratio`s: for example by specifying that each unit should take the same amount of space using `axis equal`. Here, PGFPLOTS scales the lengths of all vectors uniformly, i.e. it applies the same scale to each vector. This is done by means of the `scale mode` configuration which is basically one of `scale mode`=stretch to fill or `scale mode`=scale uniformly: PGFPLOTS tries to satisfy the prescribed `width` and `height` arguments by finding a *common* scaling factor. In addition, it attempts to enlarge the limits individually to fit into the prescribed dimensions.

In addition, you can use the option `/pgfplots/scale` to simply scale all final units up by some prescribed factor. This does not change text labels.

If needed, you can also supply `/tikz/scale` to an axis. This will scale the complete resulting image, including all text labels.

4.10.1   Common Scaling Options

All common options mentioned in the previous paragraphs are described here.

/pgfplots/width={⟨*dimen*⟩}   (initially `empty`)

Sets the width of the final picture to {⟨*dimen*⟩}.

Any non-empty dimension like `width`=5cm sets the desired target width. Any TEX unit is accepted (like 200pt or 5in).

An empty value `width`={} means "use default width or rescale proportionally to `height`". In this case, PGFPLOTS uses the value of `\axisdefaultwidth` as target quantity. However, if the `height` key has been set, PGFPLOTS will rescale the `\axisdefaultwidth` in a way which keeps the ratio between `\axisdefaultwidth` and `\axisdefaultheight`. This allows to specify just one of `width` and `height` and keep aspect ratios.

Consequently, if you specify just `width`=5cm but leave the default `height`={}, the scaling will respect the initial aspect ratio.

The scaling affects the unit vectors for x, y, and z. It does not change the size of text labels or axis descriptions.
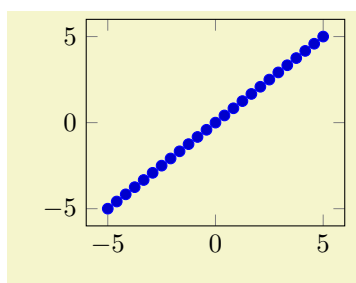
```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
\begin{axis}[width=5cm]
    \addplot {x};
\end{axis}
\end{tikzpicture}
```

Please note that PGFPLOTS only estimates the size needed for axis- and tick labels. The estimate assumes a fixed amount of space for anything which is outside of the axis box. This has the effect that the final images may be slightly larger or slightly smaller than the prescribed dimensions. However, the fixed amount is always the same; it is set to 45pt. That means that multiple pictures with the same target dimensions will have the same size for their axis boxes – even if the size for descriptions varies.

It is also possible to scale the *axis box* to the prescribed width/height. In that case, the total width will be larger due to the axis descriptions. However, the axis box fills the desired dimensions exactly.
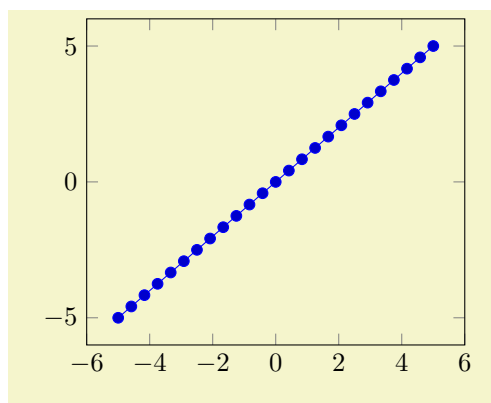
```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
\begin{axis}[width=5cm,scale only axis]
    \addplot {x};
\end{axis}
\end{tikzpicture}
```

Note: changing `width` and/or `height` changes *only* the unit vector sizes. In particular, it does not change the font size for any axis description, nor does it change the default spacing between adjacent tick labels. It is best-practice to use `width`/`height` for "small" changes, i.e. changes for which the font size should remain the same. Consider using one of the styles `normalsize`, `small`, `footnotesize`, or `tiny` which are described in Section 4.10.2 on page 299, and *then* change to your desired dimensions if you need a different "quality" of scaling.

`\axisdefaultwidth`

This macro defines the default width. It is preset to 240pt.

This default width defines the aspect ratio which will be used whenever just one of `width` or `height` is specified: the aspect ratio is the ratio between `\axisdefaultwidth` and `\axisdefaultheight`. You can change it using

```
\def\axisdefaultwidth{10cm}
```

/pgfplots/`height`={⟨*dimen*⟩}   (initially `empty`)

Works in the same way as `width` except that an empty value `height={}` defaults to "use either `\axisdefaultheight` or scale proportionally if just `width` has been changed".

`\axisdefaultheight`

This macro defines the default height. It is preset to `207pt`.

See `\axisdefaultwidth`.

/pgfplots/`scale only axis`=`true`|`false`   (initially `false`)

If `scale only axis` is enabled, `width` and `height` apply only to the axis rectangle. Consequently, the resulting figure is larger that `width` and `height` (because of any axis descriptions). However, the axis box has exactly the prescribed target dimensions.

If `scale only axis`=`false` (the default), PGFPLOTS will try to produce the desired width *including* labels, titles and ticks.

/pgfplots/`x`={⟨*dimen*⟩}   (initially `empty`)
/pgfplots/`y`={⟨*dimen*⟩}   (initially `empty`)
/pgfplots/`z`={⟨*dimen*⟩}   (initially `empty`)
/pgfplots/`x`={(⟨*x*⟩,⟨*y*⟩)}
/pgfplots/`y`={(⟨*x*⟩,⟨*y*⟩)}
/pgfplots/`z`={(⟨*x*⟩,⟨*y*⟩)}

Allows to assign zero, one, two, or three of the target unit vectors.

In this context, a "unit vector" is a two–dimensional vector which defines the projection onto the canvas: every logical plot coordinate (x, y) is drawn at the canvas position

$$x \cdot \begin{bmatrix} e_{xx} \\ e_{xy} \end{bmatrix} + y \cdot \begin{bmatrix} e_{yx} \\ e_{yy} \end{bmatrix}.$$

The unit vectors e_x and e_y determine the paper position in the current (always two dimensional) image. For a standard three–dimensional axis, a plot coordinate (x, y, z) is drawn at

$$x \cdot \begin{bmatrix} e_{xx} \\ e_{xy} \end{bmatrix} + y \cdot \begin{bmatrix} e_{yx} \\ e_{yy} \end{bmatrix} + z \cdot \begin{bmatrix} e_{zx} \\ e_{zy} \end{bmatrix}.$$

The initial setting assigns empty values to each of these keys, i.e. `x={}`,`y={}`,`z={}`. In this case, PGFPLOTS is free to choose these vectors as best. To this end, it uses `width`, `height`, `scale mode`, `plot box ratio`, `unit vector ratio`, `view`, and the axis limits.

The key `x`={⟨*dimen*⟩} simply sets $e_x = (⟨dimen⟩, 0)^T$ while `y`={⟨*dimen*⟩} sets $e_y = (0, ⟨dimen⟩)^T$. Using `z`={⟨*dimen*⟩} results in $e_z = (⟨dimen⟩, ⟨dimen⟩)^T$. In this context, ⟨*dimen*⟩ is any TEX size like `1mm`, `2cm` or `5pt`. Note that you should not use negative values for ⟨*dimen*⟩ (consider using `x dir` and its variants to reverse axis directions).
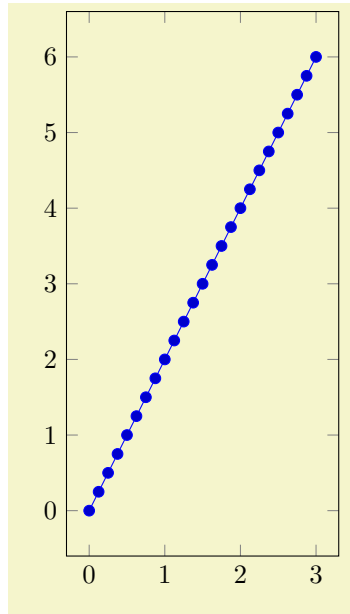
```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
\begin{axis}[x=1cm,y=1cm]
\addplot expression[domain=0:3] {2*x};
\end{axis}
\end{tikzpicture}
```
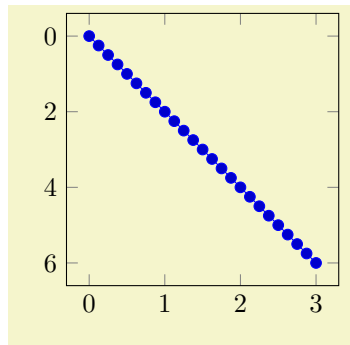


```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
\begin{axis}[x=1cm,y=0.5cm,y dir=reverse]
\addplot expression[domain=0:3] {2*x};
\end{axis}
\end{tikzpicture}
```

Note that if you change the unit vector for just one direction, the other vector(s) will be chosen by PGFPLOTS – and scaled in order to fill the prescribed width and height as best as PGFPLOTS can (but see remarks for three–dimensional plots at the end of this key).
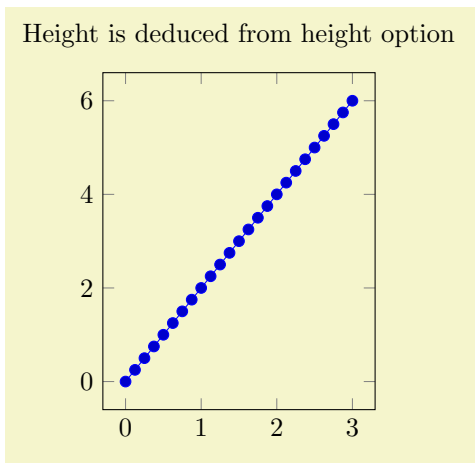

```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
\begin{axis}[x=1cm,
    title=Height is deduced from height option]
\addplot expression[domain=0:3] {2*x};
\end{axis}
\end{tikzpicture}
```

The second syntax, x={($\langle x \rangle$,$\langle y \rangle$)} sets $e_x = (\langle x \rangle, \langle y \rangle)^T$ explicitly[52]. The corresponding keys for y and z work in a similar way. This allows to define skewed or rotated axes.

---

[52]Please note that you need extra curly braces around the vector. Otherwise, the comma will be interpreted as separator for the next key-value pair.
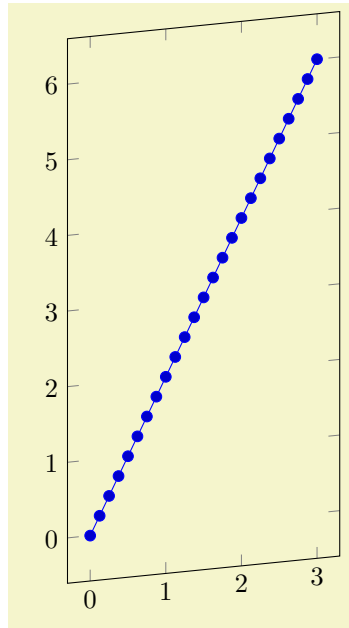
```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
\begin{axis}[x={(1cm,0.1cm)},y=1cm]
\addplot expression[domain=0:3] {2*x};
\end{axis}
\end{tikzpicture}
```
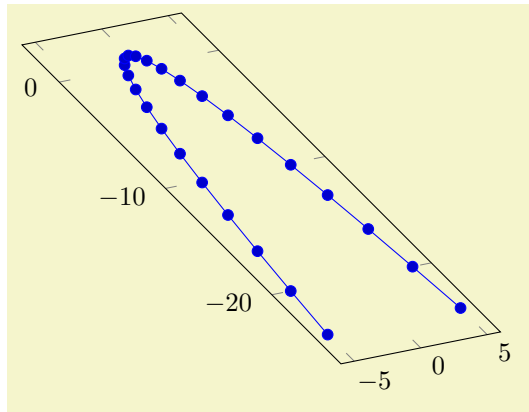


```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
\begin{axis}[
        x={(5pt,1pt)},
        y={(-4pt,4pt)}]
\addplot {1-x^2};
\end{axis}
\end{tikzpicture}
```

Setting x and/or y for logarithmic axis will set the dimension used for $1 \cdot e \approx 2.71828$ (or whatever has been set as log basis x).

Please note that it is *not* possible to specify x as argument to tikzpicture. The option

```
\begin{tikzpicture}[x=1.5cm]
\begin{axis}
    ...
\end{axis}
\end{tikzpicture}
```

does not have any effect because an axis rescales its coordinates (see the width option).

Note that providing unit vectors explicitly usually causes PGFPLOTS to ignore any other scaling options. In other words: if you say y=0.1cm, PGFPLOTS will use $(0\mathrm{cm}, 0.1\mathrm{cm})$ as y projection vector. However, if you add scale mode=scale uniformly, you allow PGFPLOTS to change the *lengths* of your vectors. Of course, it will keep their relative directions and relative sizes. In this case, PGFPLOTS will try to determine a good common scaling factor *and* it will try to change the axis limits in order to fill the prescribed width and height (see the documentation for scale mode for details).

Allow to rescale *lengths*

```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
\begin{axis}[
    title=Allow to rescale \emph{lengths},
    x={(0.1cm,-0.05cm)},
    y=0.1cm,
    z=0cm,
    axis on top,
    scale mode=scale uniformly,
    ]
    \addplot3[surf,shader=interp] {x*y};
\end{axis}
\end{tikzpicture}
```
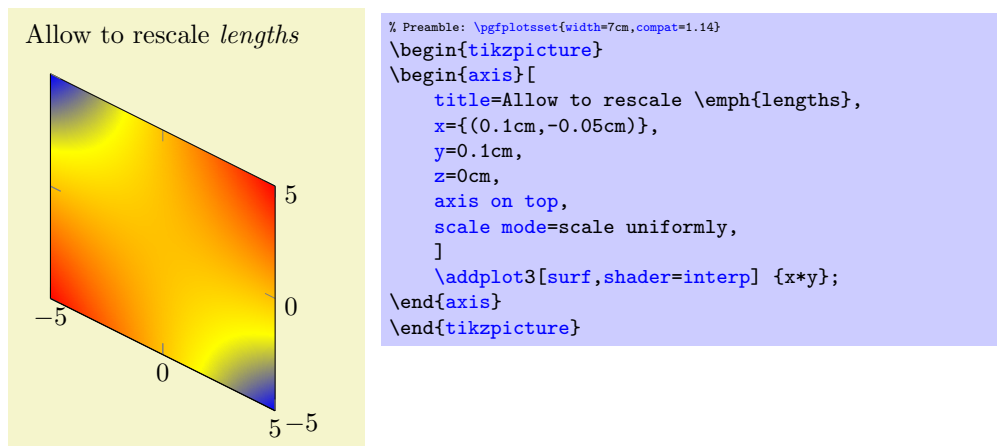
In the example above, PGFPLOTS decided that it should only rescale units – at the expensive of the `width` constraint.

Changes to font sizes: see also Section 4.10.2 if you want to change font sizes or the density of tick labels in a simple way.

Explicit units for 3D axes: As of version 1.5, it is also possible to supply unit vectors to three-dimensional axes. In this case, the following extra assumptions need to be satisfied:

1. If you want to control three-dimensional units, you need to provide *all* of `x`, `y`, and `z` keys. For two–dimensional axes, it is also supported to supply just one of `x` or `y`.

2. Any provided three-dimensional unit vectors are assumed to form a *right–handed coordinate system.* In other words: take your right hand, let the thumb point into the `x` direction, the index finger in `y` direction and the middle finger in `z` direction. If that is impossible, the PGFPLOTS output will be wrong. The reason for this assumption is that PGFPLOTS needs to compute the view direction out of the provided units (see below).

   Consider using `x dir`=reverse or its variants in case you want to reverse directions.

3. For three-dimensional axes, PGFPLOTS computes a view direction out of the provided unit vectors. The view direction is required to allow the `z buffer` feature (i.e. to decide about depths)[53].

This feature is used to for the `\addplot3 graphics` feature, compare the examples in Section 4.3.8 on page 66.

Limitations: Unfortunately, skewed axes are **not available for bar plots**.

/pgfplots/xmode=normal|linear|log   (initially **normal**)
/pgfplots/ymode=normal|linear|log   (initially **normal**)
/pgfplots/zmode=normal|linear|log   (initially **normal**)

Allows to choose between linear (=normal) or logarithmic axis scaling or logplots for each x, y, z-combination.

Logarithmic plots use the current setting of `log basis x` and its variants to determine the basis (default is e).

/pgfplots/x dir=normal|reverse   (initially **normal**)
/pgfplots/y dir=normal|reverse   (initially **normal**)
/pgfplots/z dir=normal|reverse   (initially **normal**)

Allows to reverse axis directions such that values are given in decreasing order.

This key is documented in all detail on page 323.

---

[53]PGFPLOTS provides a debug option called `view dir`={$\langle x \rangle$}{$\langle y \rangle$}{$\langle z \rangle$} to override the view direction, should that ever be interesting.

/pgfplots/axis equal={⟨*true,false*⟩}   (initially `false`)

Each unit vector is set to the same length while the axis dimensions stay constant. Afterwards, the size ratios for each unit in x and y will be the same.

Axis limits will be enlarged to compensate for the scaling effect.
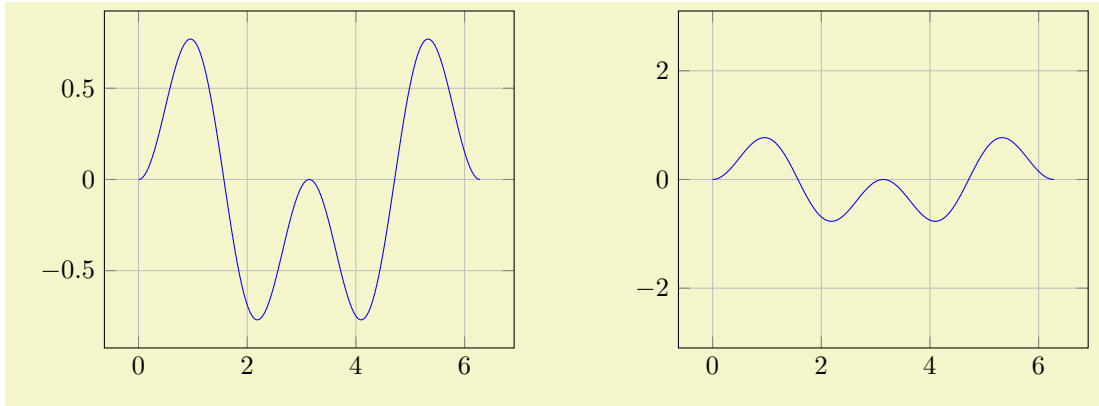

```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
    \begin{axis}[axis equal=false,grid=major]
        \addplot[blue] expression[domain=0:2*pi,samples=300] {sin(deg(x))*sin(2*deg(x))};
    \end{axis}
\end{tikzpicture}
\hspace{1cm}
\begin{tikzpicture}
    \begin{axis}[axis equal=true,grid=major]
        \addplot[blue] expression[domain=0:2*pi,samples=300] {sin(deg(x))*sin(2*deg(x))};
    \end{axis}
\end{tikzpicture}
```
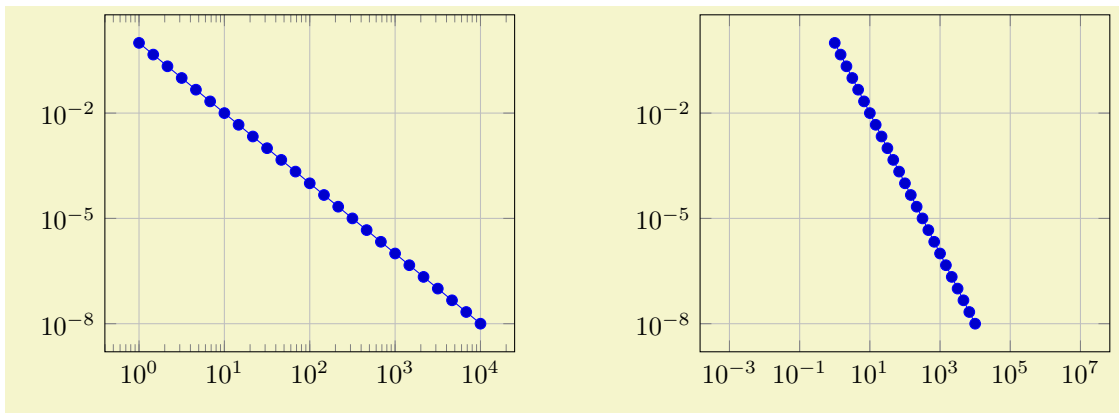


```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
    \begin{loglogaxis}[axis equal=false,grid=major]
        \addplot expression[domain=1:10000] {x^-2};
    \end{loglogaxis}
\end{tikzpicture}
\hspace{1cm}
\begin{tikzpicture}
    \begin{loglogaxis}[axis equal=true,grid=major]
        \addplot expression[domain=1:10000] {x^-2};
    \end{loglogaxis}
\end{tikzpicture}
```
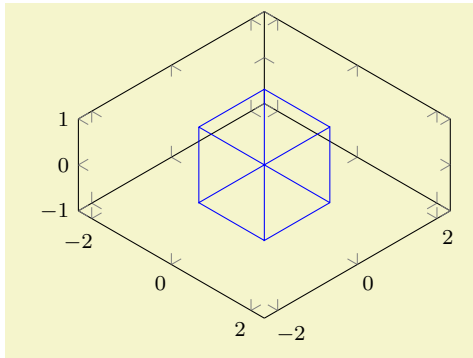
```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
\begin{axis}[axis equal,small,view={45}{35.26}]
\addplot3[mark=cube, blue, mark size=1cm]
    coordinates {(0,0,0)};
\end{axis}
\end{tikzpicture}
```

The configuration `axis equal`=`true` is actually just a style which sets `unit vector ratio`=`1 1 1`,`unit rescale keep size`=`true`.

/pgfplots/axis equal image={⟨*true,false*⟩}   (initially `false`)

Similar to `axis equal`, but the axis limits will stay constant as well (leading to smaller images).


```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
    \begin{axis}[axis equal image=false,grid=major]
        \addplot[blue] expression[domain=0:2*pi,samples=300] {sin(deg(x))*sin(2*deg(x))};
    \end{axis}
\end{tikzpicture}
\hspace{1cm}
\begin{tikzpicture}
    \begin{axis}[axis equal image=true,grid=major]
        \addplot[blue] expression[domain=0:2*pi,samples=300] {sin(deg(x))*sin(2*deg(x))};
    \end{axis}
\end{tikzpicture}
```

```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
    \begin{loglogaxis}[axis equal image=false,grid=major]
        \addplot expression[domain=1:10000] {x^-2};
    \end{loglogaxis}
\end{tikzpicture}
\hspace{1cm}
\begin{tikzpicture}
    \begin{loglogaxis}[axis equal image=true,grid=major]
        \addplot expression[domain=1:10000] {x^-2};
    \end{loglogaxis}
\end{tikzpicture}
```
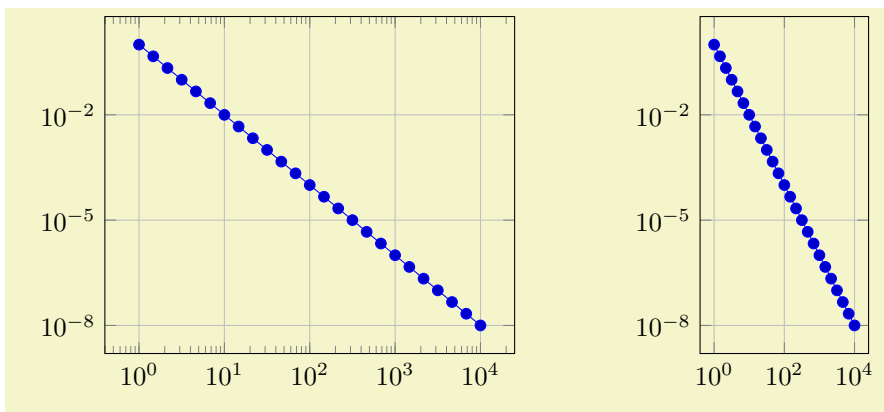
The configuration `axis equal image`=true is actually just a style which sets `unit vector ratio`=1 1 1,`unit rescale keep size`=false.

/pgfplots/**unit vector ratio**={⟨*rx ry rz*⟩}   (initially `empty`)

Allows to provide custom unit vector ratios.

The key allows to tell PGFPLOTS that, for example, one unit in x direction should be twice as long as one unit in y direction:
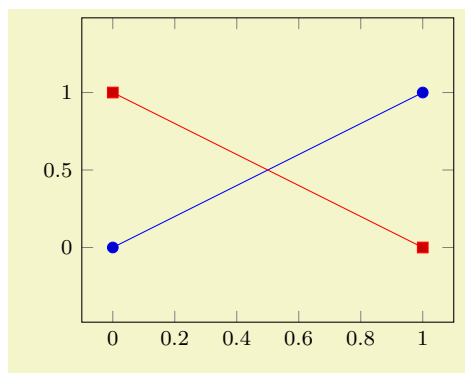

```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
    \begin{axis}[unit vector ratio=2 1,small]
        \addplot coordinates {(0,0) (1,1)};
        \addplot table[row sep=\\,col sep=&] {
            x & y \\
            0 & 1 \\
            1 & 0 \\
        };
    \end{axis}
\end{tikzpicture}
```

Providing `unit vector ratio`=2 1 means that $\frac{e_x}{e_y} = 2$ where each coordinate (x, y) is placed at $xe_x + ye_y \in \mathbb{R}^2$ (see the documentation for `x` and `y` options). Note that `axis equal` is nothing but `unit vector ratio`=1 1 1.

The arguments ⟨*rx*⟩, ⟨*ry*⟩, and ⟨*rz*⟩ are ratios for x, y and z vectors, respectively. For two–dimensional axes, only ⟨*rx*⟩ and ⟨*ry*⟩ are considered; they are provided relative to the y axis. In other words: the x unit vector will be ⟨*rx*⟩ / ⟨*ry*⟩ times longer than the y unit vector. For three-dimensional axes, all three arguments can be provided; they are interpreted relative to the z unit vector. Thus, a three dimensional axis with `unit vector ratio`=1 2 4 will have an x unit which is ¹/₄ the length of the z unit, and a y unit which is ²/₄ the length of the z unit.

Trailing values of 1 can be omitted, i.e. `unit vector ratio`=2 1 is the same as `unit vector ratio`=2; and `unit vector ratio`=3 2 1 is the same as `unit vector ratio`=3 2. An empty value `unit vector ratio`={} disables unit vector rescaling.

Note that an active `unit vector ratio` will implicitly set `scale mode`=scale uniformly[54].

/pgfplots/**unit vector ratio***={⟨*rx ry rz*⟩}
/pgfplots/**unit rescale keep size**=true|false|unless limits declared   (initially `unless limits declared`)

In the default configuration, PGFPLOTS maintains the original axis dimensions even though `unit vector ratio` involves different scalings.

It does so by enlarging the limits.

---

[54]This has been introduced in version 1.6. For older versions, the axis equal feature produced wrong results for three–dimensional axes.

```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
    \begin{axis}[footnotesize,xlabel=$x$,ylabel=$y$,unit vector ratio=]
    \addplot3[surf,z buffer=sort,samples=15,
        variable=\u, variable y=\v,
        domain=0:180, y domain=0:360]
            ({cos(u)*sin(v)}, {sin(u)*sin(v)}, {cos(v)});
    \end{axis}
\end{tikzpicture}
\begin{tikzpicture}
    \begin{axis}[footnotesize,xlabel=$x$,ylabel=$y$,unit vector ratio=1 1 1]
    \addplot3[surf,z buffer=sort,samples=15,
        variable=\u, variable y=\v,
        domain=0:180, y domain=0:360]
            ({cos(u)*sin(v)}, {sin(u)*sin(v)}, {cos(v)});
    \end{axis}
\end{tikzpicture}
\begin{tikzpicture}
    \begin{axis}[footnotesize,xlabel=$x$,ylabel=$y$,unit vector ratio=0.25 0.5]
    \addplot3[surf,z buffer=sort,samples=15,
        variable=\u, variable y=\v,
        domain=0:180, y domain=0:360]
            ({cos(u)*sin(v)}, {sin(u)*sin(v)}, {cos(v)});
    \end{axis}
\end{tikzpicture}
```

The example above has the same plot, with three different unit ratios. The first has no limitations (it is the default configuration). The second uses the same length for each unit vector and enlarges the limits in order to maintain the same dimensions. The third example has an x unit which is $1/4$ the length of a z unit, and an y unit which is $1/2$ the length of a z unit.

PGFPLOTS does its best to respect the involved scaling options (the prescribed `width` and `height`, the `unit vector ratio`, and any specified axis limits). In the case above, it enlarged the horizontal limits and kept the z limit as-is. See `scale mode` and its documentation for details about the involved algorithm and its parameters.

The `unit rescale keep size`=false key, or, equivalently, `unit vector ratio*`=..., does not enlarge limits:
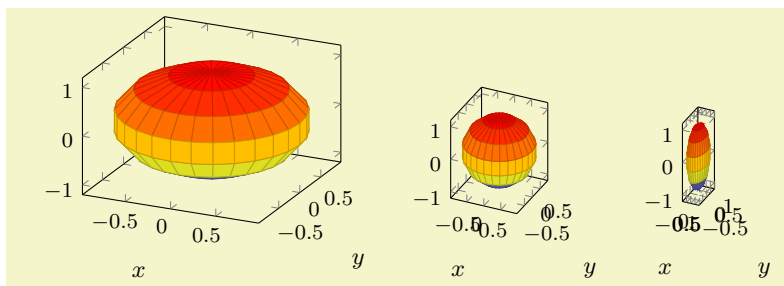
```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
    \begin{axis}[footnotesize,xlabel=$x$,ylabel=$y$,unit vector ratio=]
    \addplot3[surf,z buffer=sort,samples=15,
        variable=\u, variable y=\v,
        domain=0:180, y domain=0:360]
            ({cos(u)*sin(v)}, {sin(u)*sin(v)}, {cos(v)});
    \end{axis}
\end{tikzpicture}
\begin{tikzpicture}
    \begin{axis}[footnotesize,xlabel=$x$,ylabel=$y$,
        unit rescale keep size=false,
        unit vector ratio=1 1 1]
    \addplot3[surf,z buffer=sort,samples=15,
        variable=\u, variable y=\v,
        domain=0:180, y domain=0:360]
            ({cos(u)*sin(v)}, {sin(u)*sin(v)}, {cos(v)});
    \end{axis}
\end{tikzpicture}
\begin{tikzpicture}
    \begin{axis}[footnotesize,xlabel=$x$,ylabel=$y$,
        unit vector ratio*=0.25 0.5, % the '*' implies 'unit rescale keep size=false'
    ]
    \addplot3[surf,z buffer=sort,samples=15,
        variable=\u, variable y=\v,
        domain=0:180, y domain=0:360]
            ({cos(u)*sin(v)}, {sin(u)*sin(v)}, {cos(v)});
    \end{axis}
\end{tikzpicture}
```

The key `unit rescale keep size` also affects `scale mode`=`scale uniformly` (which is closely related to `axis equal`).

Here is the reference of the value of `unit rescale keep size`: the value `true` means that PGF-PLOTS will enlarge limits in order to keep the size. It will try to respect user provided limits, but if the user provided *all* limits, it will *override* the user-provided limits and will rescale them. Thus, `true` gives higher priority to the axis size than to user-provided limits. The choice `false` will never rescale axis limits. The choice `unless limits declared` is a mixture: it will enlarge limits unless the user provided them. If the user provides all limits explicitly, this choice is the same as `false`.

/pgfplots/x post scale={⟨*scale*⟩}   (initially empty)
/pgfplots/y post scale={⟨*scale*⟩}   (initially empty)
/pgfplots/z post scale={⟨*scale*⟩}   (initially empty)
/pgfplots/scale={⟨*scale*⟩}   (initially empty)

Lets PGFPLOTS compute the axis scaling based on `width`, `height`, `view`, `plot box ratio`, `axis equal` or explicit unit vectors with `x`, `y`, `z` and *rescales* the resulting vector(s) according to ⟨*scale*⟩.

The `scale` key sets all three keys to the same ⟨*uniform scale*⟩ value. This is effectively the same as if you rescale the complete axis (without changing sizes of descriptions).

The other keys allow individually rescaled axes.
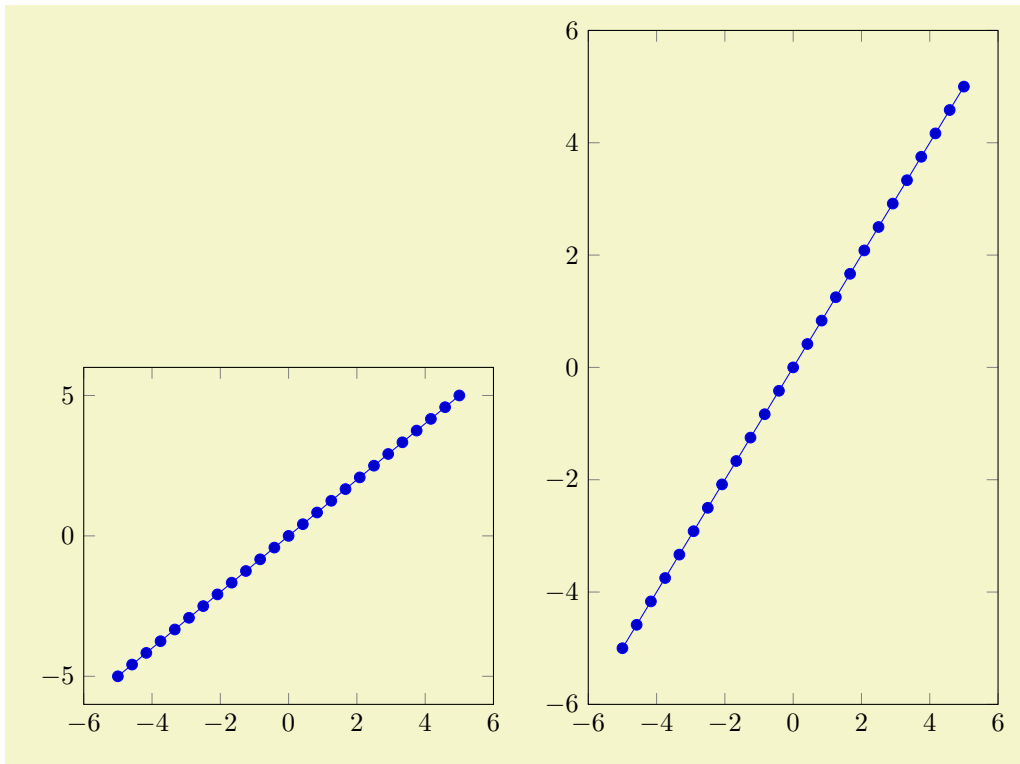
```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
    \begin{axis}[y post scale=1]
    \addplot {x};
    \end{axis}
\end{tikzpicture}
\begin{tikzpicture}
    \begin{axis}[y post scale=2]
    \addplot {x};
    \end{axis}
\end{tikzpicture}
```

Thus, the axis becomes *larger*. This overrules any previous scaling.
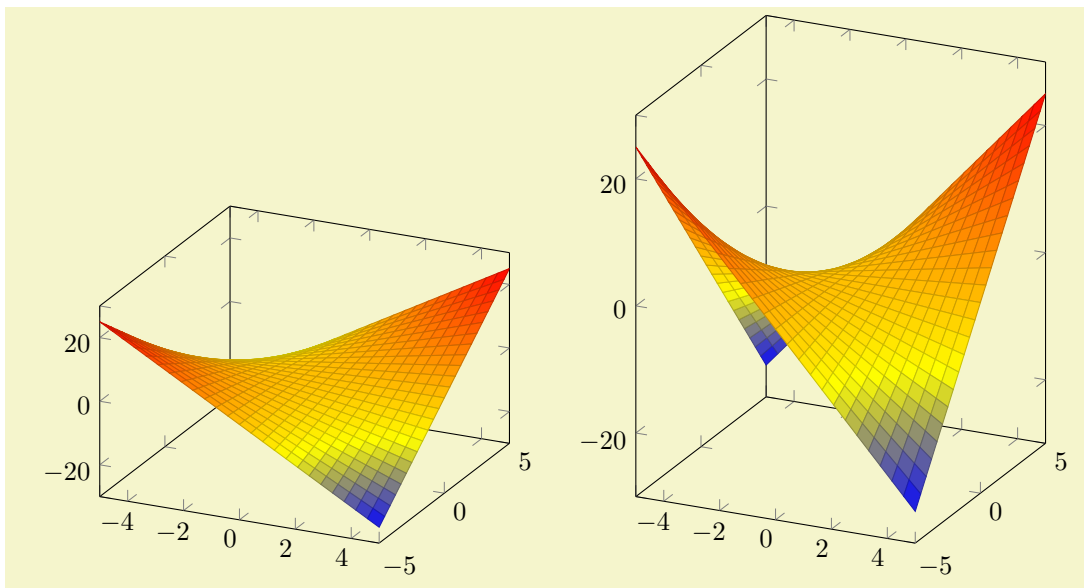
```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
    \begin{axis}[z post scale=1]
        \addplot3[surf] {x*y};
    \end{axis}
\end{tikzpicture}
\begin{tikzpicture}
    \begin{axis}[z post scale=2]
        \addplot3[surf] {x*y};
    \end{axis}
\end{tikzpicture}
```

4.10.2 Scaling Descriptions: Predefined Styles

It is reasonable to change font sizes, marker sizes etc. together with the overall plot size: Large plots should also have larger fonts and small plots should have small fonts and a smaller distance between ticks.

/tikz/**font**=\normalfont|\small|\tiny|...
/pgfplots/**max space between ticks**={⟨*integer*⟩}
/pgfplots/**try min ticks**={⟨*integer*⟩}
/tikz/**mark size**={⟨*integer*⟩}

These keys should be adjusted to the figure's dimensions. Use

```
\pgfplotsset{tick label style={font=\footnotesize},
    label style={font=\small},
    legend style={font=\small}
}
```

to provide different fonts for different descriptions.

The keys `max space between ticks` and `try min ticks` are described on page 345 and configure the approximate distance and number of successive tick labels (in `pt`). Please omit the `pt` suffix here.

There are a couple of predefined scaling styles which set some of these options:

/pgfplots/**normalsize** (style, no value)

Re-initialises the standard scaling options of PGFPLOTS.
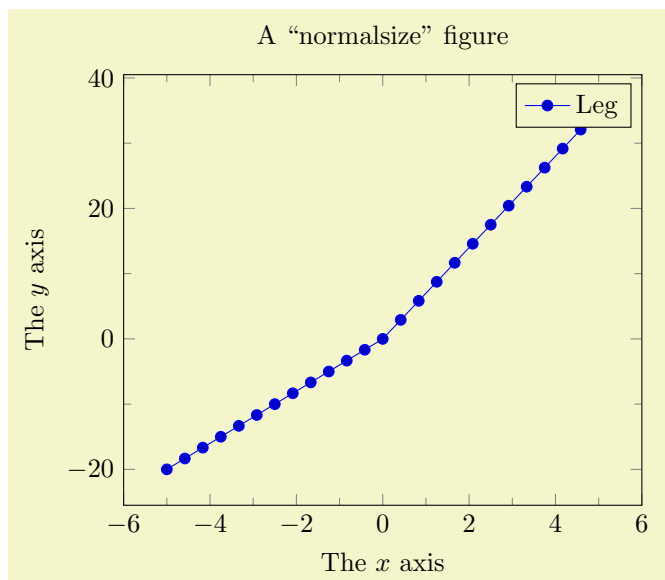
```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
    \begin{axis}[normalsize,
        title=A ''normalsize'' figure,
        xlabel=The $x$ axis,
        ylabel=The $y$ axis,
        minor tick num=1,
        legend entries={Leg}]
        \addplot {max(4*x,7*x)};
    \end{axis}
\end{tikzpicture}
```

The initial setting is

```
\pgfplotsset{
    normalsize/.style={
        /pgfplots/width=240pt,
        /pgfplots/height=207pt,
        /pgfplots/max space between ticks=35
    }
}
```

/pgfplots/small   (style, no value)

Redefines several keys such that the axis is "smaller".
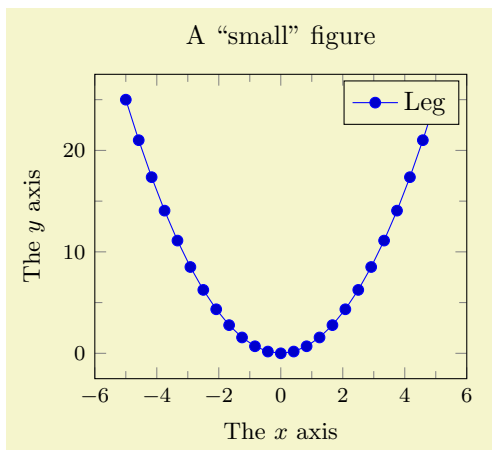

```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
    \begin{axis}[small,
        title=A ''small'' figure,
        xlabel=The $x$ axis,
        ylabel=The $y$ axis,
        minor tick num=1,
        legend entries={Leg}]
        \addplot {x^2};
    \end{axis}
\end{tikzpicture}
```

The initial setting is

```
\pgfplotsset{
    small/.style={
        width=6.5cm,
        height=,
        tick label style={font=\footnotesize},
        label style={font=\small},
        max space between ticks=25,
    }
}
```

Feel free to redefine the scaling – the option may still be useful to get more ticks without typing too much. You could, for example, set `small,width=6cm`.

/pgfplots/footnotesize   (style, no value)

Redefines several keys such that the axis is even smaller. The tick labels will have \footnotesize.
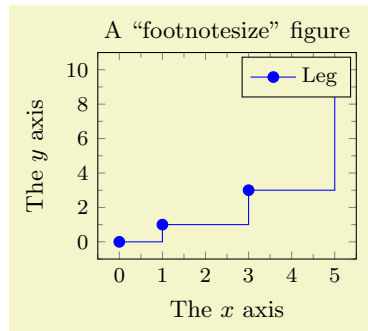
```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
    \begin{axis}[footnotesize,
        title=A ''footnotesize'' figure,
        xlabel=The $x$ axis,
        ylabel=The $y$ axis,
        minor tick num=1,
        legend entries={Leg}]
        \addplot+[const plot]
            coordinates {
            (0,0) (1,1) (3,3) (5,10)
        };
    \end{axis}
\end{tikzpicture}
```

The initial setting is

```
\pgfplotsset{
    footnotesize/.style={
        width=5cm,
        height=,
        legend style={font=\footnotesize},
        tick label style={font=\footnotesize},
        label style={font=\small},
        title style={font=\small},
        every axis title shift=0pt,
        max space between ticks=15,
        every mark/.append style={mark size=8},
        major tick length=0.1cm,
        minor tick length=0.066cm,
    },
}
```

As for `small`, it can be convenient to set `footnotesize` and set `width` afterwards.

You will need `compat`=1.3 or newer for this to work.

/pgfplots/tiny   (style, no value)

Redefines several keys such that the axis is very small. Most descriptions will have \tiny as fontsize.
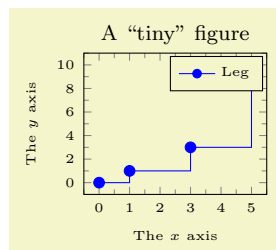

```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
    \begin{axis}[tiny,
        title=A ''tiny'' figure,
        xlabel=The $x$ axis,
        ylabel=The $y$ axis,
        minor tick num=1,
        legend entries={Leg}]
        \addplot+[const plot]
            coordinates {
            (0,0) (1,1) (3,3) (5,10)
        };
    \end{axis}
\end{tikzpicture}
```

The initial setting is

```
\pgfplotsset{
    tiny/.style={
        width=4cm,
        height=,
        legend style={font=\tiny},
        tick label style={font=\tiny},
        label style={font=\tiny},
        title style={font=\footnotesize},
        every axis title shift=0pt,
        max space between ticks=12,
        every mark/.append style={mark size=6},
        major tick length=0.1cm,
        minor tick length=0.066cm,
        every legend image post/.append style={scale=0.8},
    },
}
```

As for `small`, it can be convenient to use `tiny`,`width`=4.5cm to adjust the width.

You will need `compat`=1.3 or newer for this to work.

4.10.3   Scaling Strategies

The content of this section is quite involved – and its knowledge is typically unnecessary because by default, PGFPLOTS controls the involved stuff automatically. You may want to skip this section.

/pgfplots/**scale mode**=auto|none|stretch to fill|scale uniformly   (initially `auto`)

Specifies how to choose the (individual) unit vector scaling factors, their length ratios, and perhaps the axis limits in order to fill the prescribed `width` and `height`.

The `scale mode` implementation expects some "initial" set of unit vectors. This initial set of unit vectors is determined as follows: for standard two–dimensional axes, it is simply the unit cube $e_x = (1\mathrm{pt}, 0\mathrm{pt})^T$, $e_y = (0\mathrm{pt}, 1\mathrm{pt})^T$, $e_z = 0$. For three–dimensional axes, it is the outcome of the two keys `view` and `plot box ratio`. If you provided units explicitly by means of one of `x`, `y`, or `z`, this value is the initial unit vector.

In addition, it expects "initial" axis limits (i.e. values of `xmin`, `xmax`, etc.). The initial axis limits are those limits which have been deduced from your data or which have been provided explicitly. Furthermore, the initial axis limits already include changes of the `enlargelimits` key.

Given the initial set of unit vectors and the initial axis limits, the `scale mode` implementation is a kind of "post–processor" which creates modified unit vectors and modified axis limits in order to satisfy all specified constraints. These constraints are `width`, `height`, and `unit vector ratio`.

The initial choice `auto` tells PGFPLOTS to take full control over this key. It chooses one of the other possible choices depending on the actual context. The choice `auto` evaluates to `scale uniformly` if `unit vector ratio` is set. Otherwise it evaluates to `stretch to fill`.

The choice `none` does not apply any rescaling at all. Use this if prescribed lengths of `x`, `y` (and perhaps `z`) should be used. In other words: it ignores `width` and `height`. In this case, you may want to set `x post scale` and its variants to rescale units manually. See also `disabledatascaling`.

The choice `stretch to fill` takes the initial unit vectors and rescales the unit vectors with two *separate* scales: one which results in the proper `width` and one which results in the proper `height`. As a consequence, the unit vectors are modified and distorted such that the final image fits into the prescribed dimensions. This is usually what one expects unless one provides unit directions explicitly. This mode does not change axis limits. Note that if one of the unit vectors has been provided explicitly, PGFPLOTS will not change it. It will only change the remaining axis limits. This mode contradicts `axis equal` or `unit vector ratio`.

The choice `scale uniformly` takes the initial unit vectors and applies only *one* scaling factor to all units. In this case, there is just *one* common scaling factor for both `width` and `height`. Naturally, this will result in unsatisfactory results because either the final width or the final height will not be met. Therefore, this choice will adjust axis limits to get the desired dimensions. Thus, the unit vectors have exactly the same size *relations and angles* as they had before the scaling; only their magnitude is changed uniformly. In addition, axis limits may be changed (with individual scaling factors for each axis limit). Note that if unit vectors have been provided explicitly, PGFPLOTS can still rescale it with this choice – it will keep the relative directions and size ratios. The choice `scale uniformly` tries its best to modify the degrees of freedom in a "useful" way. The precise meaning of "useful" is the `scale uniformly strategy` key.

/pgfplots/**scale uniformly strategy**=auto|units only|change vertical limits|
change horizontal limits   (initially `auto`)

The `scale uniformly` method requires to determine one *common* scaling factor which rescales every axis *unit*. In addition, it allows one scaling factor *for each axis limit*, i.e. up to three.

The constraints for this search are that we want to satisfy the `width`/`height` constraint, have as few rescaling as possible and that we do not want to reduce limits (as this could possibly hide data points).

The choice `auto` chooses one of the other possibilities automatically. Depending on whether we have two dimensions or three dimensions, it compares the available methods and chooses the one which does not reduce limits and which involves the fewest rescaling (i.e. it may compare the outcome of

the other strategies). This is the default. If you keep the choice `auto`, you do not have to worry about the remaining choices. Note that manually provided axis limits will not be modified.

The choice `units only` will not enlarge axis limits. It will only rescale the units. To this end, it chooses the scaling factor such that the *smaller* target dimension is filled as desired. In other words: if `width` < `height`, it will scale to satisfy the `width` constraint. The `height` constraint will be ignored. The case > will be done the other way round. The choice `units only` typically results in a square axis as it takes the initial set of unit vectors (which are typically the unit box) and scales them with a common scaling factor. Consequently, you can choose `units only` if you want a boxed axis. You can still change axis limits manually, however.

The choice `change vertical limits` chooses a common scaling factor for the unit vectors on order to satisfy the `width` (!) constraint. This common scaling factor is similar to `units only` – but `units only` can also decide to satisfy the `height` constraint whereas `change vertical limits` will scale unit vectors to satisfy `width`. In order to satisfy the `height` constraint, `change vertical limits` modifies just the vertical limits. For two–dimensional axes, this is `ymin` and `ymax`. For three–dimensional axes, this is `zmin` and `zmax`. Clearly, there is a chance that it will *decrease* the displayed range – in this case, parts of the image will be clipped away. This method *assumes* that the vertical axis has not been rotated (i.e. that $e_{yx} = 0$ or $e_{zx} = 0$, respectively). It refuses to work and falls back to `units only` for rotates axes. Choose `change vertical limits` if you want the image (i.e. the actual content) as wide as possible. You can modify `width` and `height` to improve its outcome. Note that manually specified axis limits will not be changed, see below for details.

The choice `change horizontal limits` attempts a similar approach, but for the horizontal limits: it determines one suitable scaling factor which is applied to all unit vectors and modifies horizontal axis limits to satisfy the remaining constraints. For two–dimensional axes, this is quite simple because we typically have $e_{xy} = 0$ (i.e. the x unit vector has vanishing y component) and $e_{yx} = 0$ such that PGFPLOTS can change axis limits easily. If a two–dimensional axis has an x unit with $e_{xy} \neq 0$, the method is not applicable and falls back to `units only`. For three–dimensional axes, it assumes that the z vector is not rotated, i.e. $e_{zy} = 0$ and tries to change limits for both x and y. This choice is much more involved because here, x and y components are coupled. Consequently, the common unit scaling factor and the two involved axis limit compensation factors for x and y are tightly coupled as well. PGFPLOTS solves a system of non–linear equations iteratively to arrive at a suitable solution for all three scalings. Use this method if `change vertical limits` would clip away parts of the image (because it reduced the displayed range) and you do not want to change `width` and `height`. The choice `change horizontal limits` will typically result in more empty space in the resulting figure. But it will not clip away content. Manually specified axis limits will not be changed, see below for details.

Manually provided axis limits: Any manually provided arguments for `xmin` and its variants are considered to be immutable; PGFPLOTS will not change them. If you assign `xmin`, PGFPLOTS will only change `xmax` and vice–versa. If you assign both `xmin` and `xmax`, PGFPLOTS will not change x limits at all. Note that if you assign both `xmin` and `xmax`, PGFPLOTS will simply skip the scaling and will give up on the constraints. It will not try to compensate the lack of scaling opportunities by changing y limits, for example. This has the positive effect that assigning limits does not change the complete appearance of your axis. The allowed set of changes to axis limits can be configured with the following key.

Interaction with `enlargelimits`: Note that `enlargelimits` and `scale mode` are independent of another: the outcome of `enlargelimits` is used as "initial axis limits" and these limits may be changed by `scale mode` (even if you said `enlargelimits`=false). See the documentation of `enlargelimits` for details on this interaction.

/pgfplots/**unit rescale keep size**=true|false|unless limits declared   (initially `unless limits declared`)

In the default configuration `unless limits declared`, unit rescaling may cause changes to the axis limits in order to keep the figure's size intact. However, only those limits which have not been declared manually are subject to rescaling: if you say `xmin`=1, only `xmax` and the limits for y and z are free to change.

Setting `unit rescale keep size`=false will *disable* the modification of axis limits altogether, i.e. axis limits will not be rescaled to compensate scalings on unit vectors.

Setting `unit rescale keep size`=`true` will always rescale limits, even if they have been declared manually.

This key mainly affects `scale mode`=scale uniformly. This, in turn, is used for `axis equal` and `\addplot`3 graphics.

See also the addition documentation for this key and related examples on page 295.

The `scale uniformly` choice is implicitly used for `axis equal` and for the `\addplot`3 graphics feature, see the documentation in Section 4.3.8 on page 66 for its examples. Note that the common case is that the initial unit vectors form the unit cube (i.e. those before scaling, see above). In this case, `scale uniformly` is the same as `axis equal`.

4.11   3D Axis Configuration

This section described keys which are used to configure the appearance of three dimensional figures. Some of them apply for two–dimensional plots as special case as well, and they will also be discussed in the respective sections of this manual.

4.11.1   View Configuration

/pgfplots/`view`={⟨*azimuth*⟩}{⟨*elevation*⟩}   (initially {25}{30})

Changes both view angles of a 3D axis. The azimuth (first argument) is the horizontal angle which is rotated around the z axis. For a 3D plot, the z axis always points to the top. The elevation (second argument) is the vertical rotation around the (rotated) x axis. Positive elevation values indicate a view from above, negative a view from below. All values are measured in degree (but see `trig format`).
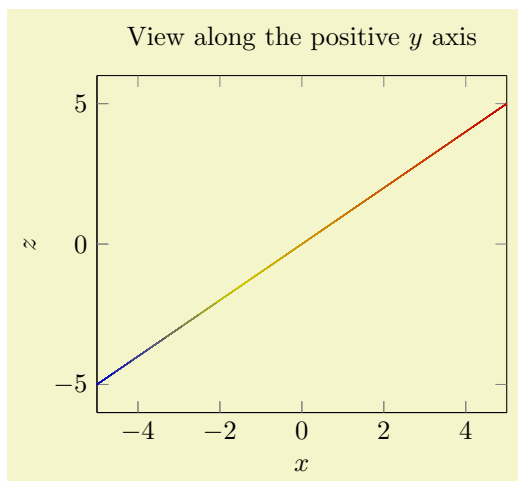

```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
    \begin{axis}[view={0}{0},
        xlabel=$x$,
        zlabel=$z$,
        title=View along the positive $y$ axis]
        \addplot3[surf] {x};
    \end{axis}
\end{tikzpicture}
```
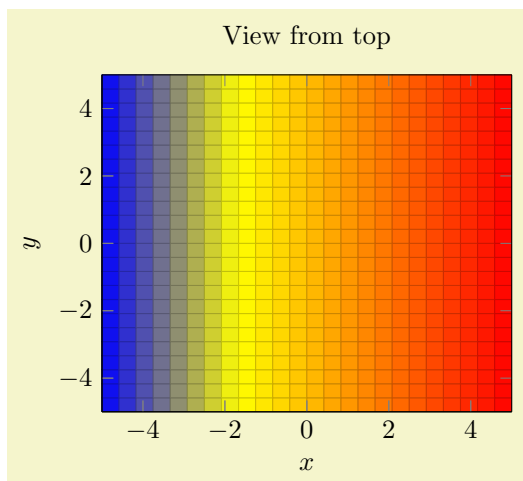


```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
    \begin{axis}[view={0}{90},
        xlabel=$x$,
        ylabel=$y$,
        title=View from top]
        \addplot3[surf] {x};
    \end{axis}
\end{tikzpicture}
```
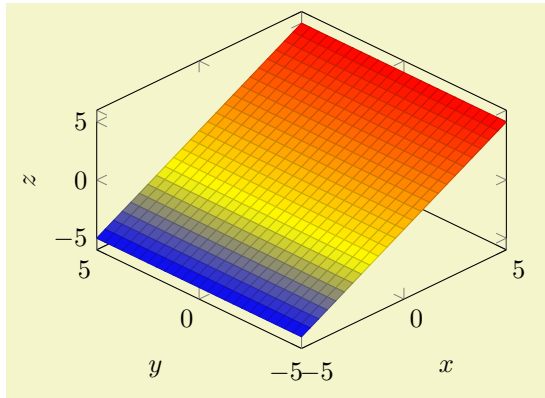
```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
    \begin{axis}[view={-45}{45},
        xlabel=$x$,ylabel=$y$,zlabel=$z$]
        \addplot3[surf] {x};
    \end{axis}
\end{tikzpicture}
```

The `view` is computed as follows. The view is defined by two rotations: the first rotation uses the ⟨*azimuth*⟩ angle to rotate around the z axis. Afterwards, the view is rotated ⟨*elevation*⟩ degrees around the *rotated* x axis (more precisely, it is rotated −⟨*elevation*⟩ degrees). The resulting transformed x–z– plane is the viewport, i.e. the view direction is always the transformed positive y axis.

The `view` argument is compatible with the argument of the Matlab (Ⓡ) view command, i.e. you can use

`[h,v] = view`

in matlab and pack the resulting arguments into PGFPLOTS[55].

If you work with `gnuplot`, you can convert the view arguments as follows: the `gnuplot` command

`set view v,h`

is *equivalent* to `view={h}{90-v}`. For example, the default `gnuplot` configuration `set view 60,60` is equivalent to `view={60}{30}` in PGFPLOTS.

The `view` is (currently) always an orthogonal projection, no perspective is possible, yet. You can, however, specify projection unit vectors for `x`, `y`, and `z` explicitly to get a skewed three–dimensional axis.

/pgfplots/**view/az**={⟨*azimuth*⟩}
/pgfplots/**view/h**={⟨*azimuth*⟩}   (initially 25)

Changes only the azimuth view angle, i.e. the horizontal (first) view angle which is rotated around the z axis.
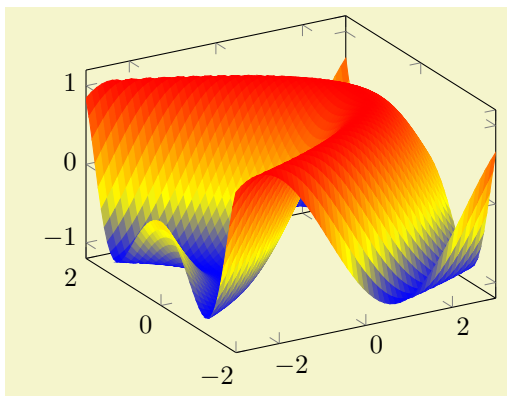

```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
    \begin{axis}[view/h=-30]
    \addplot3[
        surf,
        %shader=interp,
        shader=flat,
        samples=50,
        domain=-3:3,y domain=-2:2]
        {sin(deg(x+y^2))};
    \end{axis}
\end{tikzpicture}
```

---

[55]In case it does not work, try `h` and `-v` in PGFPLOTS.
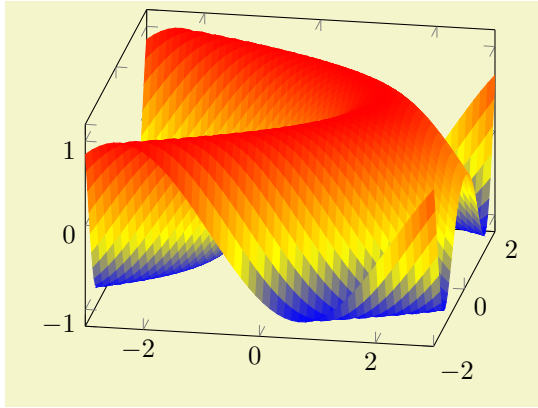
```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
    \begin{axis}[view/h=10]
    \addplot3[
        surf,
        %shader=interp,
        shader=flat,
        samples=50,
        domain=-3:3,y domain=-2:2]
        {sin(deg(x+y^2))};
    \end{axis}
\end{tikzpicture}
```
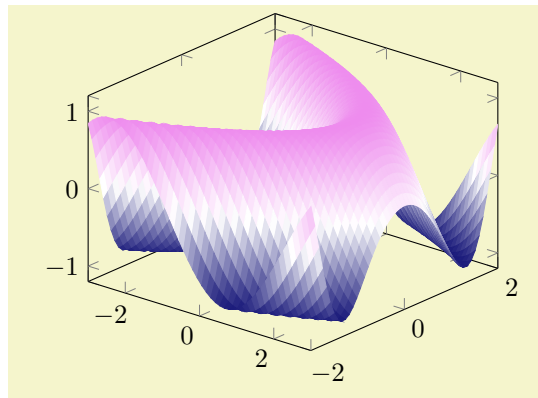


```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
    \begin{axis}[view/h=40,colormap/violet]
    \addplot3[
        surf,
        %shader=interp,
        shader=flat,
        samples=50,
        domain=-3:3,y domain=-2:2]
        {sin(deg(x+y^2))};
    \end{axis}
\end{tikzpicture}
```
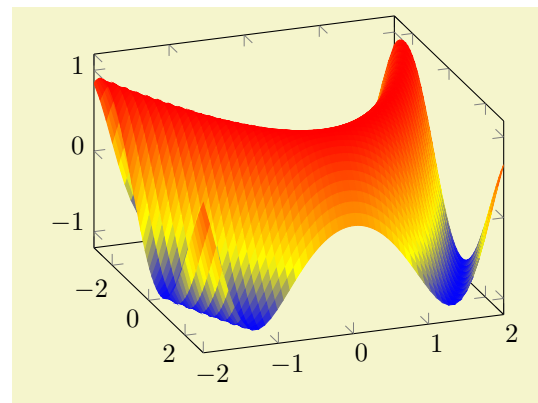


```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
    \begin{axis}[view/h=70]
    \addplot3[
        surf,
        %shader=interp,
        shader=flat,
        samples=50,
        domain=-3:3,y domain=-2:2]
        {sin(deg(x+y^2))};
    \end{axis}
\end{tikzpicture}
```

/pgfplots/view/el={⟨elevation⟩}
/pgfplots/view/v={⟨elevation⟩}   (initially 30)

Changes only the vertical elevation, i.e. the second argument to view. Positive values view from above, negative values from below.

4.11.2   Styles Used Only For 3D Axes

/pgfplots/every 3d description   (style, no value)

This style allows to change the appearance of *descriptions* for three dimensional axes. Naturally, a three dimensional axis will display axis labels for x and y differently than a two dimensional axis (for example, the y axis label won't be rotated by 90 degrees). The every 3d description style installs the necessary display options for three dimensional axis descriptions.

The initial value is:

```
\pgfkeys{
    /pgfplots/every 3d description/.style={
        % Only these description styles can be changed here:
        every axis x label/.style={at={(ticklabel cs:0.5)},
            anchor=near ticklabel},
        every axis y label/.style={at={(ticklabel cs:0.5)},
            anchor=near ticklabel},
        every x tick scale label/.style={
            at={(xticklabel cs:0.95,5pt)},
            anchor=near xticklabel,inner sep=0pt},
        every y tick scale label/.style={
            at={(yticklabel cs:0.95,5pt)},
            anchor=near yticklabel,inner sep=0pt},
        try min ticks=3,
    }%
}
```

As the name suggests, every 3d description can only be used to set styles for axis labels, tick labels and titles. It has *not* been designed to reset other styles, you will need to change these options either for each axis separately or by means of user defined styles. The reason for this limitation is: other options can (and, in many cases, needs to) be set before the axis is processed. However, the decision whether we have a two dimensional or a three dimensional axis has to be postponed until the processing is more or less complete – so only some remaining keys can be set.

/pgfplots/every 3d view {⟨*h*⟩}{⟨*v*⟩}   (style, no value)

A style which can be used for fine-tuning of the output for specific views.

This style will be installed right after every 3d description, but before other axis description related keys are set (in other words: it has higher precedence than every 3d description, but lower precedence than keys provided to the axis directly).

One example is preconfigured for view={0}{90} (from top):

```
\pgfplotsset{
    /pgfplots/every 3d view {0}{90}/.style={
        xlabel near ticks,
        ylabel near ticks,
        axis on top=true
    }
}
```

4.11.3   Appearance Of The 3D Box

/pgfplots/plot box ratio={⟨⟨*x stretch*⟩ ⟨*y stretch*⟩ ⟨*z stretch*⟩⟩}   (initially 1 1 1)

Allows to customize the aspect ratio between the three different axes in a three dimensional plot.

Note that this key is different from the related unit vector ratio: the plot box is only useful for three dimensional axes, and it will usually distort the unit vector ratios. If you want equal unit ratios, consider using unit vector ratio.

The plot box ratio is applied before any rotations and stretch–to–fill routines have been invoked. Thus, the initial setting[56] 1 1 1 makes all axes equally long before the stretch–to–fill routine is applied.

---

[56]Note that you can also use the syntax {1}{1}{1} instead of space-separation.

Initial `plot box ratio`
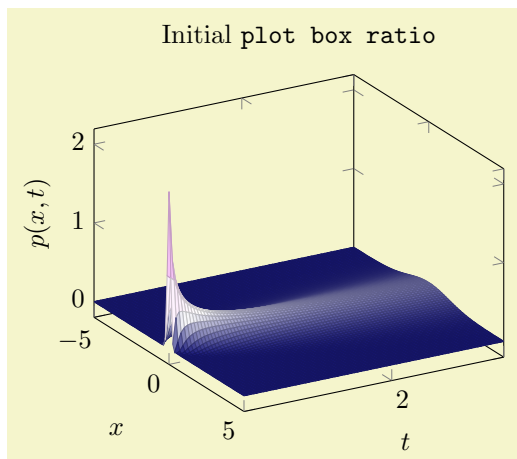
```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
\begin{axis}[
    view/h=60,
    plot box ratio=1 1 1,
    colormap={violet}{[1cm] rgb255(0cm)=(25,25,122)
        color(1cm)=(white) rgb255(5cm)=(238,140,238)},
    xlabel=$x$,
    ylabel=$t$,
    zlabel={$p(x,t)$},
    shader=faceted,
    title=Initial \texttt{plot box ratio},
]
    \addplot3[surf,y domain=0.02:3.5,samples=81]
        {1/(2*sqrt(pi*y)) * exp(0-x^2/y)};
    % the '0' is a work-around for a bug in PGF 2.00
\end{axis}
\end{tikzpicture}
```
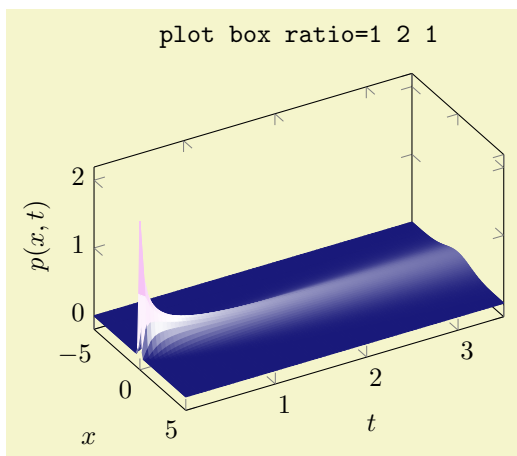
`plot box ratio=1 2 1`

```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
\begin{axis}[
    view/h=60,
    plot box ratio=1 2 1,
    colormap={violet}{[1cm] rgb255(0cm)=(25,25,122)
        color(1cm)=(white) rgb255(5cm)=(238,140,238)},
    xlabel=$x$,
    ylabel=$t$,
    zlabel={$p(x,t)$},
    shader=flat,
    title=\texttt{plot box ratio=1 2 1},
]
    \addplot3[surf,y domain=0.02:3.5,samples=81]
        {1/(2*sqrt(pi*y)) * exp(0-x^2/y)};
    % the '0' is a work-around for a bug in PGF 2.00
\end{axis}
\end{tikzpicture}
```

This key applies only to three dimensional axes. After the scaling, the axes will be stretched to fill the `width` and `height` for this plot. Thus, the effects of `plot box ratio` might be undone by this stretching for particular views.

/pgfplots/3d box=background|complete|complete*   (initially `background`)

Allows to configure the appearance of boxed three dimensional axes.

Type only `3d box` (without value) as alias for `3d box`=complete.

The choice `background` is the initial setting, it does not draw axis lines (and grid lines) which are in the foreground.
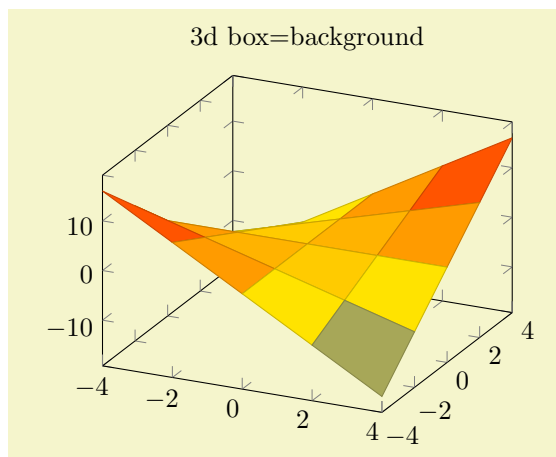
3d box=background

```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
    \begin{axis}[
        3d box=background,
        % pretty printing, but irrelevant:
        title={3d box=background},
        samples=5,
        domain=-4:4,
        xtick=data,
        ytick=data,
    ]
        \addplot3[surf] {x*y};
    \end{axis}
\end{tikzpicture}
```

The choice `complete` also draws axis lines and tick lines in the foreground, but it doesn't draw grid lines in the foreground. The result yields a complete box:
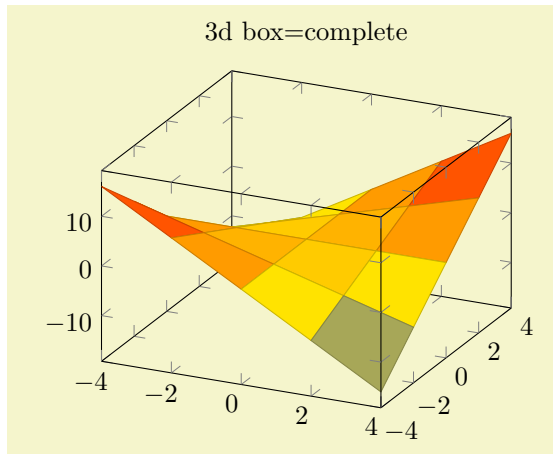
3d box=complete

```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
    \begin{axis}[
        3d box,% same as 3d box=complete
        % pretty printing, but irrelevant:
        title={3d box=complete},
        samples=5,
        domain=-4:4,
        xtick=data,
        ytick=data,
    ]
        \addplot3[surf] {x*y};
    \end{axis}
\end{tikzpicture}
```

Finally, the choice `complete*` is the same as `complete`, but it also draws grid lines in the foreground.
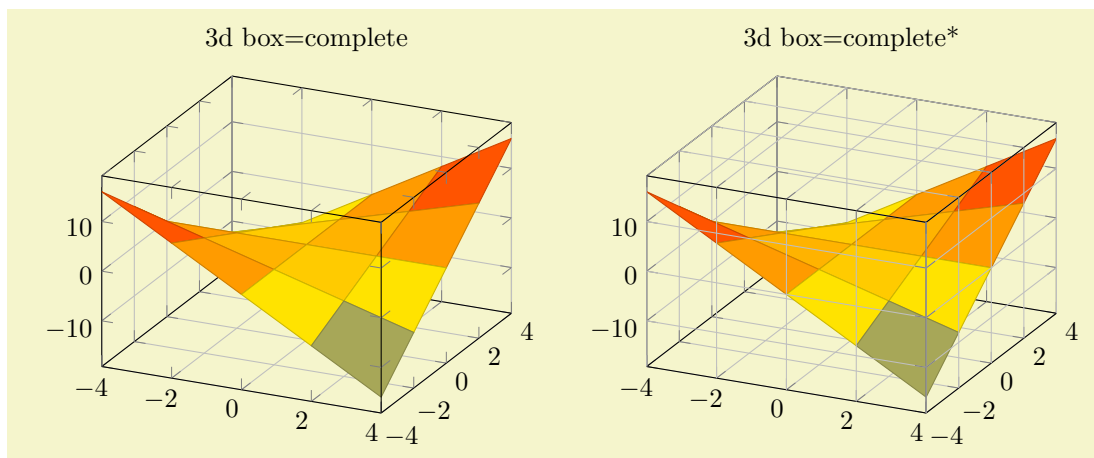
3d box=complete ___ 3d box=complete*

```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
    \begin{axis}[
        3d box=complete,
        grid=major,
        title={3d box=complete},
        samples=5, domain=-4:4,
        xtick=data, ytick=data,
    ]
        \addplot3[surf] {x*y};
    \end{axis}
\end{tikzpicture}%
~
\begin{tikzpicture}
    \begin{axis}[
        3d box=complete*,
        grid=major,
        title={3d box=complete*},
        samples=5, domain=-4:4,
        xtick=data, ytick=data,
    ]
        \addplot3[surf] {x*y};
    \end{axis}
\end{tikzpicture}
```

Before any foreground parts are actually processed, the style `every 3d box foreground` will be installed. This allows to change the appearance of foreground axis components like `tick style` or `axis line style` separately from the background components.

Note that `3d box`=complete is *only* available for boxed axes, i.e. together with `axis lines`=box. It is an error to use a different combination.

4.11.4   Axis Line Variants

Three dimensional axes also benefit from the `axis lines`=box or `axis lines`=center styles discussed in Section 4.9.9. The choice `axis lines`=box is standard, it draws a box (probably affected by the `3d box`=complete key). The choice `axis lines`=center draws all three axes such that they pass through the origin. It might be necessary to combine this key with `axis on top` as there is no depth information.
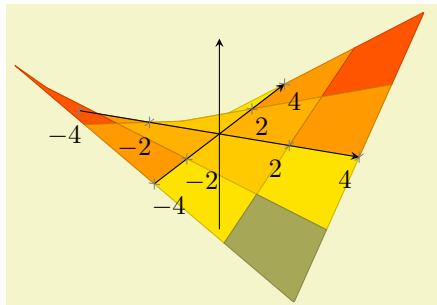

```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
% Attention: use compat=1.8 or higher
% to repair label positions
\begin{tikzpicture}
    \begin{axis}[
        axis lines=center,
        axis on top,
        samples=5, domain=-4:4,
        xtick=data, ytick=data,
        ztick=\empty, % no z ticks here
    ]
        \addplot3[surf] {x*y};
    \end{axis}
\end{tikzpicture}
```

The remaining choices `axis lines*`=left and `axis lines*`=right select different sets of axes in a way such that tick labels and axis label won't disturb the plot's content. The '*' suppresses the use of special styles which are mainly adequate for two-dimensional axes, see the documentation of `axis lines`. Such a set of axes is always on the boundary of the two-dimensional projection.

The choice `axis lines*`=left chooses a set of axes which are on the left (or bottom, respectively) whereas the choice `axis lines*`=right chooses a set of axes which are on the right (or top, respectively):
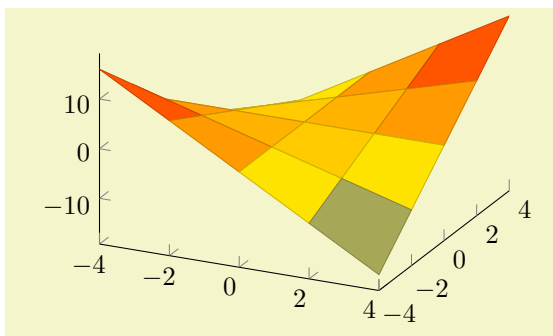

```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
    \begin{axis}[
        axis lines*=left,
        samples=5, domain=-4:4,
        xtick=data, ytick=data,
    ]
        \addplot3[surf] {x*y};
    \end{axis}
\end{tikzpicture}
```
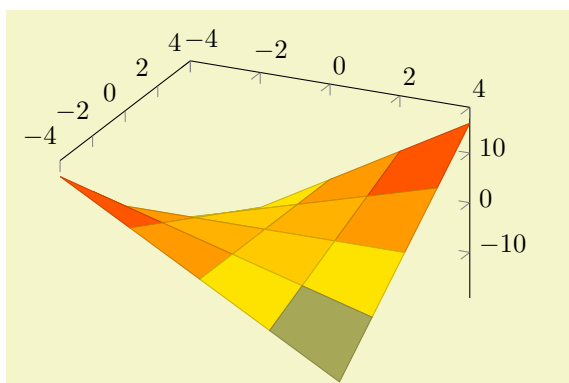


```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
    \begin{axis}[
        axis lines*=right,
        samples=5, domain=-4:4,
        xtick=data, ytick=data,
    ]
        \addplot3[surf] {x*y};
    \end{axis}
\end{tikzpicture}
```

It is not possible to mix different styles like `axis x line`=center,axis z line=top.

4.12   Error Bars

An error bar is used to indicate the reliability of a data point. Typically, a data point is just (x, y). The reliability would be indicated by additional values, i.e. by means of an error bound ϵ_x which characterizes the difference between the coordinate x provided in the plot data and the precise value $\tilde{x}$ (which is unknown). The reliability can be indicated for both x and y independently (although y might be the typical candidate). Error bounds can be expressed as *absolute* errors, i.e. of the form

$$|x - \tilde{x}| \le \epsilon_x, \quad |y - \tilde{y}| \le \epsilon_y$$

where $\tilde{x}$ and $\tilde{y}$ are the (unknown) precise values and x and y are the actual values of the plot. However, they can also be provided relative to the input values, i.e. of the form

$$\frac{|x - \tilde{x}|}{|\tilde{x}|} \leq \epsilon_x, \quad \frac{|y - \tilde{y}|}{|\tilde{y}|} \leq \epsilon_y.$$

A relative error of 10% would result in an error value of 0.1 (relative to the precise quantity $\tilde{y}$). Clearly, relative errors are only useful if the precise value if not zero, i.e. $\tilde{x}, \tilde{y} \neq 0$.

PGFPLOTS allows to provide the "error values" for each coordinate independently. Thus, it may find some value ϵ_x and/or ϵ_y. Depending on the configuration, it interprets the encountered value as absolute or relative error. The error value can be the same for every coordinate, for example if you know that each y coordinate has a fixed error of 10%. The error value can also be different for every coordinate in which it is said to be "explicitly provided". In fact, PGFPLOTS also features *asymmetric* error values, i.e. the lower bound on the error can be different from the upper bound. Thus, a two–dimensional data point (x, y) can have up to four distinct error values which have to be provided by the end–user.

Thus, the end–user has to provide all needed error values and a configuration to express if these values are to be interpreted as relative or absolute error and if the values are to be expected explicitly for every data point or if they are fixed.
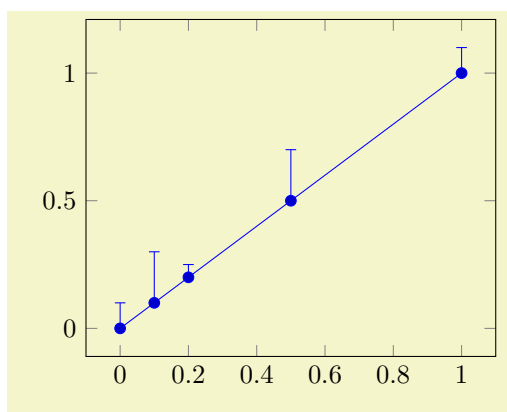
```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
\begin{axis}
\addplot+[error bars/.cd,
    y dir=plus,y explicit]
coordinates {
    (0,0)     +- (0.5,0.1)
    (0.1,0.1) +- (0.05,0.2)
    (0.2,0.2) +- (0,0.05)
    (0.5,0.5) +- (0.1,0.2)
    (1,1)     +- (0.3,0.1)};
\end{axis}
\end{tikzpicture}
```

The preceding example has two keys: `y dir=plus` configures PGFPLOTS to *activate* error bars for y coordinates, but only upper bounds. The key `y explicit` tells PGFPLOTS to expect *absolute* values in the input data stream. In our case above, the input data stream is an `\addplot coordinates` which uses the special error–value–syntax `+-` (ϵ_x, ϵ_y), see the Section 4.12.1 for details.

It is allowed if the input data contains more error values than needed: our example above has error values for both x and y and it also contains lower bounds (since `+-` defines upper- and lower bounds simultaneously). Consequently, the remaining values can be visualized as well:
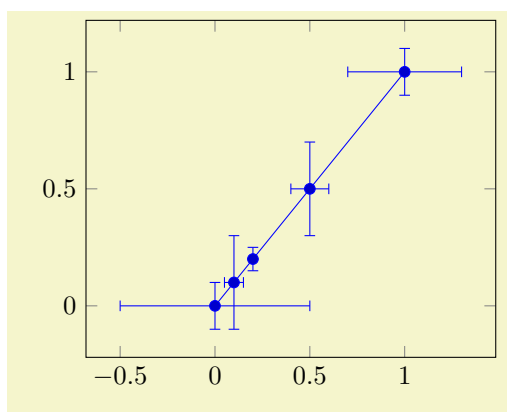
```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
\begin{axis}
\addplot+[error bars/.cd,
    y dir=both,y explicit,
    x dir=both,x explicit,
]
coordinates {
    (0,0)     +- (0.5,0.1)
    (0.1,0.1) +- (0.05,0.2)
    (0.2,0.2) +- (0,0.05)
    (0.5,0.5) +- (0.1,0.2)
    (1,1)     +- (0.3,0.1)};
\end{axis}
\end{tikzpicture}
```

Error bars inherit all drawing options of the associated plot, but they use their own `error mark` and additional style arguments.

/pgfplots/**error bars/x dir**=none|plus|minus|both (initially **none**)
/pgfplots/**error bars/y dir**=none|plus|minus|both (initially **none**)

/pgfplots/error bars/z dir=none|plus|minus|both   (initially none)

The initial configuration **none** draws no error bars at all in the provided direction.

The configuration **plus** draws only upper bounds in the direction of interest.

The configuration **minus** draws only lower bounds in the direction of interest.

The configuration **both** draws upper and lower bounds in the direction of interest.

In every case, the actual error value and its character (absolute or relative) is to be determined by other options (see below). If, for some reason, the error value is missing, the error bar is omitted.

/pgfplots/error bars/x fixed={⟨*value*⟩}   (initially 0)
/pgfplots/error bars/y fixed={⟨*value*⟩}   (initially 0)
/pgfplots/error bars/z fixed={⟨*value*⟩}   (initially 0)

Provides a common, absolute error $\epsilon_x = \langle value \rangle$ for all input coordinates.
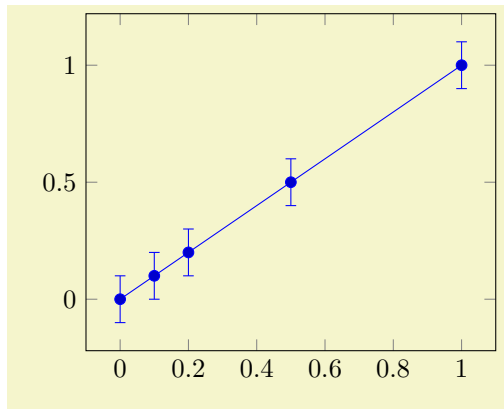

```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
\begin{axis}
\addplot+[error bars/.cd,
    y dir=both,y fixed=0.1,
]
coordinates {
    (0,0)
    (0.1,0.1)
    (0.2,0.2)
    (0.5,0.5)
    (1,1)
};
\end{axis}
\end{tikzpicture}
```

For linear x axes, the error mark is drawn at $x \pm \epsilon_x$ while for logarithmic x axes, it is drawn at $\log(x \pm \epsilon_x)$.

/pgfplots/error bars/x fixed relative={⟨*percent*⟩}   (initially 0)
/pgfplots/error bars/y fixed relative={⟨*percent*⟩}   (initially 0)
/pgfplots/error bars/z fixed relative={⟨*percent*⟩}   (initially 0)

Provides a common, relative error $\epsilon_x = \langle percent \rangle \cdot x$ for all input coordinates. The argument ⟨*percent*⟩ is thus given relatively to input x coordinates such that ⟨*percent*⟩ = 1 means 100%.

Error marks are thus placed at $x \cdot (1 \pm \epsilon_x)$ for linear axes and at $\log(x \cdot (1 \pm \epsilon_x))$ for logarithmic axes. Computations are performed in floating point for linear axis and using the identity $\log(x \cdot (1 \pm \epsilon_x)) = \log(x) + \log(1 \pm \epsilon_x)$ for logarithmic scales.

The following example shows that fixed error values ϵ_x are independent of the input values.
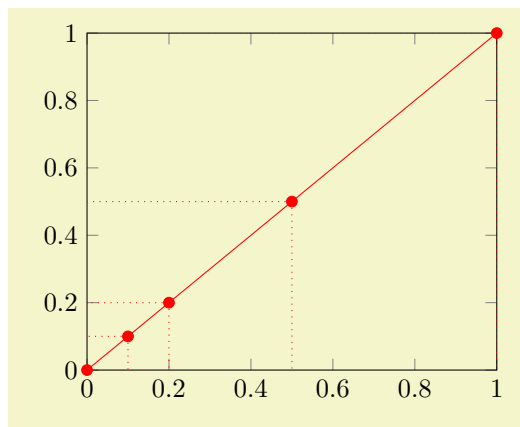

```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
\begin{axis}[enlargelimits=false]
\addplot[red,mark=*]
    plot[error bars/.cd,
    y dir=minus,y fixed relative=1,
    x dir=minus,x fixed relative=1,
    error mark=none,
    error bar style={dotted}]
coordinates
    {(0,0)  (0.1,0.1)  (0.2,0.2)
     (0.5,0.5)  (1,1)};
\end{axis}
\end{tikzpicture}
```

/pgfplots/error bars/x explicit   (no value)
/pgfplots/error bars/y explicit   (no value)
/pgfplots/error bars/z explicit   (no value)

Configures the error bar algorithm to draw x-error bars at any input coordinate for which user-specified errors are available. Each error is interpreted as absolute error, see `x fixed` for details.

The different input formats of errors are described in Section 4.12.1.

/pgfplots/**error bars/x explicit relative**	(no value)
/pgfplots/**error bars/y explicit relative**	(no value)
/pgfplots/**error bars/z explicit relative**	(no value)

Configures the error bar algorithm to draw x-error bars at any input coordinate for which user-specified errors are available. Each error is interpreted as relative error, that means error marks are placed at $x(1 \pm \langle value \rangle(x))$ (works as for `error bars/x fixed relative`).
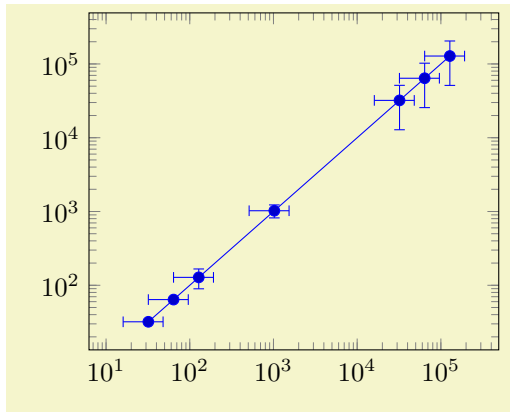

```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
\begin{loglogaxis}
\addplot+[error bars/.cd,
    x dir=both,x fixed relative=0.5,
    y dir=both,y explicit relative,
]
table[x=x,y=y,y error=error]
{
    x       y       error
    32      32      0
    64      64      0
    128     128     0.3
    1024    1024    0.2
    32068   32068   0.6
    64000   64000   0.6
    128000  128000  0.6
};
\end{loglogaxis}
\end{tikzpicture}
```

/pgfplots/**error bars/error mark**=$\langle marker \rangle$

Sets an error marker for any error bar. {$\langle marker \rangle$} is expected to be a valid plot mark, see Section 4.7.
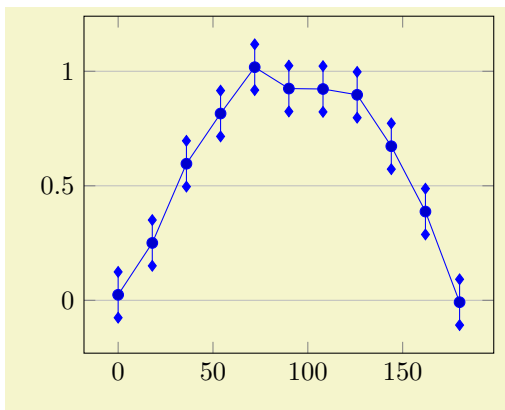

```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
\pgfmathsetseed{42}
\begin{axis}[
    ymajorgrids,
]
\addplot+[
    domain=0:180,
    samples=11,
    error bars/.cd,
    y dir=both, y fixed=0.1,
    error mark=diamond*,
]
    {sin(x) + rand*0.1};
\end{axis}
\end{tikzpicture}
```

/pgfplots/**error bars/error mark options**={$\langle key$-$value$-$list \rangle$}

Sets a key-value list of options for any error mark. This option works similarly to the TikZ '`mark options`' key.

/pgfplots/**error bars/error bar style**={$\langle key$-$value$-$list \rangle$}

Appends the argument to '**/pgfplots/every error bar**' which is installed at the beginning of every error bar.

/pgfplots/**error bars/draw error bar/.code 2 args**={$\langle \ldots \rangle$}

Allows to change the default drawing commands for error bars. The two arguments are

- the source point, (x, y) and
- the target point, $(\tilde{x}, \tilde{y})$.

Both are determined by PGFPLOTS according to the options described above. The default code is

```
\pgfplotsset{
    /pgfplots/error bars/draw error bar/.code 2 args={%
        \pgfkeysgetvalue{/pgfplots/error bars/error mark}%
            {\pgfplotserrorbarsmark}%
        \pgfkeysgetvalue{/pgfplots/error bars/error mark options}%
            {\pgfplotserrorbarsmarkopts}%
        \draw #1 -- #2 node[pos=1,sloped,allow upside down] {%
            \expandafter\tikz\expandafter[\pgfplotserrorbarsmarkopts]{%
                \expandafter\pgfuseplotmark\expandafter{\pgfplotserrorbarsmark}%
                \pgfusepath{stroke}}%
        };
    }
}
```

4.12.1   Input Formats of Error Coordinates

Error bars with explicit error estimations for single data points require some sort of input format. This applies to error bars/x explicit and error bars/x explicit relative.

Error Coordinates and Coordinate Lists

Error bar coordinates can be read from '\addplot coordinates' in which they are expected after data point as such:

```
\addplot coordinates {
    (1,2) +- (0.4,0.2)
    (2,4) +- (1,0)
    (3,5)
    (4,6) +- (0.3,0.001)
}
```

where $(1,2) \pm (0.4, 0.2)$ is the first coordinate, $(2,4) \pm (1,0)$ the second and so forth. The point $(3,5)$ has no error coordinate. The syntax +- defines *symmetric* error values, i.e. both upper and lower bound receive the same value.

Alternatively, one can use one of -= and += to define asymmetric values:
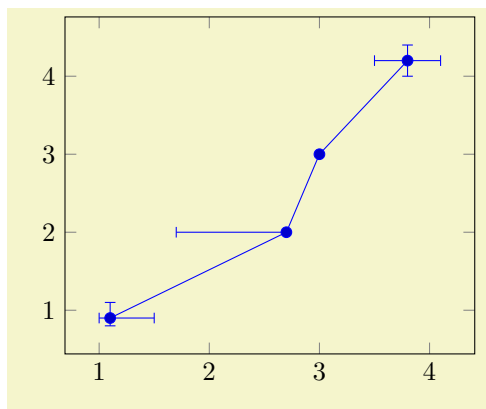

```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
\begin{axis}
\addplot+[
    error bars/.cd,
    x dir=both, x explicit,
    y dir=both, y explicit,
]
coordinates {
    (1.1,0.9) += (0.4,0.2) -= (0.1,0.1)
    (2.7,2) -= (1,0)
    (3,3)
    (3.8,4.2) +- (0.3,0.2)
};
\end{axis}
\end{tikzpicture}
```

If multiple items (like multiple +=) for one coordinate are specified, the last one takes precedence.

Keep in mind that these error values are only displayed as error bars if x dir and y dir are set appropriately.

The input type \addplot coordinates also allows point meta=explicit, i.e. values of the form

```
\addplot coordinates {(0,0) [4]};
```

This can be combined with error values. However, the point meta value in square brackets needs to be the last item:

```
\addplot coordinates {(0,0) +- (0.1,0.2) [4]};
```

Error Coordinates and Table Input

The '\addplot table' format is

/pgfplots/**table/x error**={⟨*column name*⟩}
/pgfplots/**table/y error**={⟨*column name*⟩}
/pgfplots/**table/z error**={⟨*column name*⟩}
/pgfplots/**table/x error index**={⟨*column index*⟩}
/pgfplots/**table/y error index**={⟨*column index*⟩}
/pgfplots/**table/z error index**={⟨*column index*⟩}
/pgfplots/**table/x error expr**={⟨*math expression*⟩}
/pgfplots/**table/y error expr**={⟨*math expression*⟩}
/pgfplots/**table/z error expr**={⟨*math expression*⟩}

These keys define input sources for error bars with explicit error values.

The `x error` method provides an input column name (or alias), the `x error index` method provides input column *indices* and `x error expr` works just as `table/x expr`: it allows arbitrary mathematical expressions which may depend on any number of table columns using `\thisrow{⟨col name⟩}`.


```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
\begin{axis}
\addplot+[
    error bars/.cd,
    x dir=both, x explicit,
    y dir=both, y explicit,
]
table[y error=error]
{
    x   y   error
    1   0.9 0.4
    2   2.1 0.2
    3   3   0.1
    4   4.2 0.3
};
\end{axis}
\end{tikzpicture}
```

In addition, one can provide column *indices* using

```
\addplot table[x error index=COLINDEX,y error index=COLINDEX]
```

These options are used like the '`x`' and '`x index`' options.

If you need to specify math expressions, you can use `x error expr`:

```
\addplot table[x error expr=\thisrow{errorx}^2]
```

This is similar to `x expr`.

/pgfplots/**table/x error plus**={⟨*column name*⟩}
/pgfplots/**table/y error plus**={⟨*column name*⟩}
/pgfplots/**table/z error plus**={⟨*column name*⟩}
/pgfplots/**table/x error plus index**={⟨*column index*⟩}
/pgfplots/**table/y error plus index**={⟨*column index*⟩}
/pgfplots/**table/z error plus index**={⟨*column index*⟩}
/pgfplots/**table/x error plus expr**={⟨*math expression*⟩}
/pgfplots/**table/y error plus expr**={⟨*math expression*⟩}
/pgfplots/**table/z error plus expr**={⟨*math expression*⟩}
/pgfplots/**table/x error minus**={⟨*column name*⟩}
/pgfplots/**table/y error minus**={⟨*column name*⟩}
/pgfplots/**table/z error minus**={⟨*column name*⟩}
/pgfplots/**table/x error minus index**={⟨*column index*⟩}
/pgfplots/**table/y error minus index**={⟨*column index*⟩}
/pgfplots/**table/z error minus index**={⟨*column index*⟩}
/pgfplots/**table/x error minus expr**={⟨*math expression*⟩}

/pgfplots/**table/y error minus expr**={⟨*math expression*⟩}
/pgfplots/**table/z error minus expr**={⟨*math expression*⟩}

These keys define input sources for error bars with *asymmetric* error values, i.e. different values for upper and lower bounds.

They are to be used in the same way as `x error`. In fact, `x error` is just a style which sets both `x error plus` and `x error minus` to the same value.

```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
\begin{axis}
\addplot+[
    error bars/.cd,
    x dir=both, x explicit,
    y dir=both, y explicit,
]
    table[
        x error plus=ex+,
        x error minus=ex-,
        y error plus=ey+,
        y error minus=ey-,
    ] {
    x    y    ex+   ey+   ex-   ey-
    1.1 0.9 0.4   0.2   0.1   0.1
    2.7 2    0     0     1     0
    3    3    0     0     0     0
    3.8 4.2 0.3   0.2   0.3   0.2
    };
\end{axis}
\end{tikzpicture}
```

4.13   Number Formatting Options

PGFPLOTS typesets tick labels rounded to given precision and in configurable number formats. The command to do so is `\pgfmathprintnumber`; it uses the current set of number formatting options. In addition, PGFPLOTS might prepare tick numbers before they are handed over to `\pgfmathprintnumber`.

The options related to number printing as such are described in all detail in the manual for PGFPLOT-STABLE, which comes with PGFPLOTS. This section contains the reference for everything which is specific to an axis, and only a brief survey over the number formatting options as such.

4.13.1   Frequently Used Number Printing Settings

This section provides a brief survey about the most frequently used aspects of number formatting in PGF-PLOTS.

1. PGFPLOTS computes common tick scaling factors like $\cdot 10^2$ and produces only integers as tick labels.

   In order to get numbers like 0.001 as tick labels instead of 1 with a separate label $\cdot 10^{-3}$, you can use `scaled ticks`=false in your axis. See the description of `scaled ticks` for details.

2. In order to customize the way numbers are rounded and/or displayed, use something like `xticklabel style`={/pgf/number format/`.cd`,fixed,precision=5}.

   Here is a short list of possibilities:

123.46	`\pgfmathprintnumber{123.456789}`
12,345.68	`\pgfmathprintnumber{12345.6789}`
12,345.6789	`\pgfmathprintnumber` `    [fixed,precision=5]{12345.6789}`
12,345.67890	`\pgfmathprintnumber` `    [fixed,fixed zerofill,precision=5]{12345.6789}`

12.345,67890	`\pgfmathprintnumber`
	`    [fixed,fixed zerofill,precision=5,use comma]`
	`    {12345.6789}`

$1.23 \cdot 10^4$	`\pgfmathprintnumber` `    [sci]{12345.6789}`
$1.23457 \cdot 10^4$	`\pgfmathprintnumber` `    [sci,sci zerofill,precision=5]{12345.6789}`

1.23×10^1	`\pgfmathprintnumber`
	`    [sci,sci generic=`
	`     {mantissa sep=\times,exponent={10^{#1}}}]`
	`    {12.345}`

$\frac{1}{3}$; $\frac{1}{2}$	`\pgfmathprintnumber[frac]{0.333333333333333};` `    \pgfmathprintnumber[frac]{0.5}`
$+2$	`\pgfmathprintnumber[print sign]{2}`
1 000 000.123456	`\pgfmathprintnumber` `    [1000 sep={\,},fixed,precision=6]{1000000.123456}`

1 000 000.123 456	`\pgfmathprintnumber[`
	`  1000 sep={\,},fixed,precision=6,`
	`  1000 sep in fractionals]`
	`    {1000000.123456}`

Each of these keys requires the prefix '`/pgf/number format/`' when used inside of a PGFPLOTS style (try `/pgf/number format/.cd,`⟨*number formatting keys*⟩ to use the same prefix for many ⟨*number formatting keys*⟩).

The number formatting uses `\pgfmathprintnumber`, a PGF command to typeset numbers. A full reference of all supported options is shipped with PGFPLOTS: it is documented in the reference manual for PGFPLOTSTABLE, Section 'Number Formatting Options'. The same reference can be found in the documentation for PGF.

Note that the number printer knows *nothing* about PGFPLOTS. In particular, it is not responsible for logs and their representation.

3. For a logarithmic axis, one may want to modify the number formatting style for the *exponent only*. In this case, redefine the style `log plot exponent style` (its documentation contains a couple of examples).

4. In order to get `fixed` point tick labels on a logarithmic axis, you can use `log ticks with fixed point` (see below).

4.13.2 PGFPlots-specific Number Formatting

This section contains fine–tuning options to change number formatting aspects – but only things which are specific to PGFPLOTS like peculiarities of tick labels on logarithmic axes. Consider browsing Section 4.13.1 first to see if you need this section.

`\pgfmathprintnumber{`⟨*x*⟩`}`

Generates pretty-printed output for the (real) number ⟨*x*⟩. The input number ⟨*x*⟩ is parsed using `\pgfmathfloatparsenumber` which allows arbitrary precision.

Numbers are typeset in math mode using the current set of number printing options, see below. Optional arguments can also be provided using `\pgfmathprintnumber[`⟨*options*⟩`]{`⟨*x*⟩`}`.

Please refer to the manual of PGFPLOTSTABLE (shipped with this package) for details about options related to number-printing.

/pgfplots/log ticks with fixed point   (style, no value)

Reconfigures PGFPLOTS to display tick labels of logarithmic axes using *fixed point* numbers instead of the exponential style.
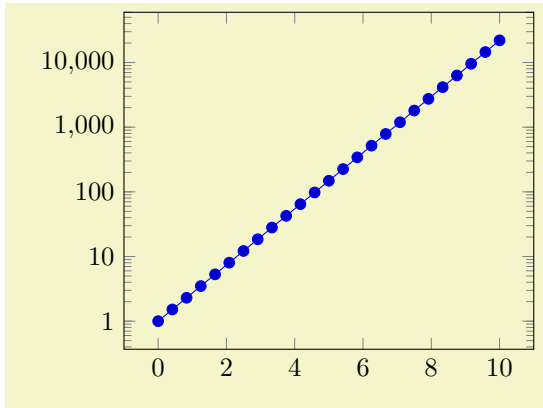

```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
\begin{semilogyaxis}[log ticks with fixed point]
    \addplot+[domain=0:10] {exp(x)};
\end{semilogyaxis}
\end{tikzpicture}
```
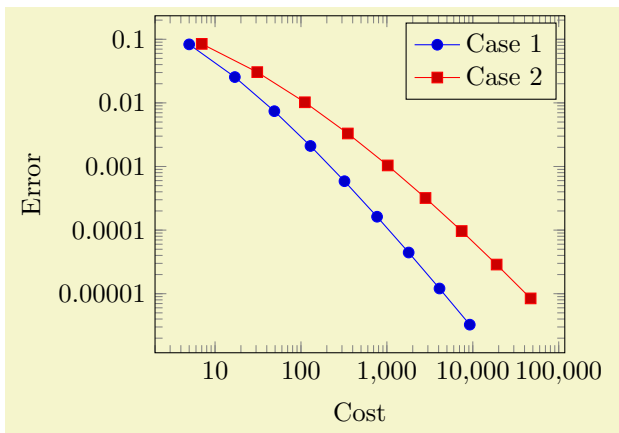


```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
\begin{loglogaxis}[
    log ticks with fixed point,
    xlabel=Cost,ylabel=Error]
\addplot coordinates {
    (5,      8.31160034e-02)
    (17,     2.54685628e-02)
    (49,     7.40715288e-03)
    (129,    2.10192154e-03)
    (321,    5.87352989e-04)
    (769,    1.62269942e-04)
    (1793,   4.44248889e-05)
    (4097,   1.20714122e-05)
    (9217,   3.26101452e-06)
};
\addplot coordinates {
    (7,      8.47178381e-02)
    (31,     3.04409349e-02)
    (111,    1.02214539e-02)
    (351,    3.30346265e-03)
    (1023,   1.03886535e-03)
    (2815,   3.19646457e-04)
    (7423,   9.65789766e-05)
    (18943,  2.87339125e-05)
    (47103,  8.43749881e-06)
};
\legend{Case 1,Case 2}
\end{loglogaxis}
\end{tikzpicture}
```

The style replaces log number format basis.

/pgfplots/log plot exponent style={⟨*key-value-list*⟩}

Allows to configure the number format of log plot exponents. This style is installed just before '`log number format basis`' will be invoked. Please note that this style will be installed within the default code for '`log number format code`'.
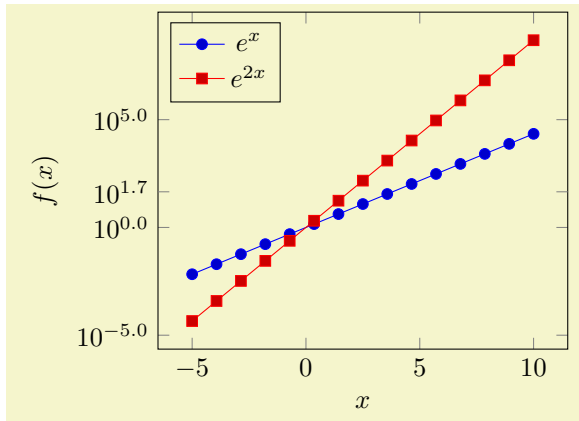

```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\pgfplotsset{
    samples=15,
    width=7cm,
    xlabel=$x$,
    ylabel=$f(x)$,
    extra y ticks={45},
    legend style={at={(0.03,0.97)},
        anchor=north west}}

\begin{tikzpicture}
\begin{semilogyaxis}[
    log plot exponent style/.style={
        /pgf/number format/fixed zerofill,
        /pgf/number format/precision=1},
    domain=-5:10]

    \addplot {exp(x)};
    \addplot {exp(2*x)};

    \legend{$e^x$,$e^{2x}$}
\end{semilogyaxis}
\end{tikzpicture}
```
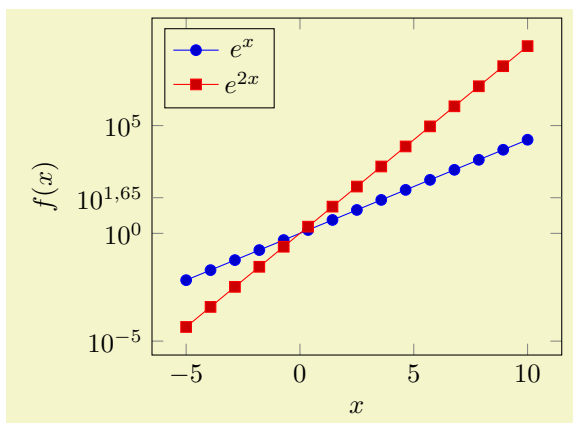


```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\pgfplotsset{
    samples=15,
    width=7cm,
    xlabel=$x$,
    ylabel=$f(x)$,
    extra y ticks={45},
    legend style={at={(0.03,0.97)},
        anchor=north west}}

\begin{tikzpicture}
\begin{semilogyaxis}[
    log plot exponent style/.style={
        /pgf/number format/fixed,
        /pgf/number format/use comma,
        /pgf/number format/precision=2},
    domain=-5:10]

    \addplot {exp(x)};
    \addplot {exp(2*x)};

    \legend{$e^x$,$e^{2x}$}
\end{semilogyaxis}
\end{tikzpicture}
```

/pgfplots/**log identify minor tick positions**=true|false   (initially `false`)

Set this to `true` if you want to identify log–plot tick labels at positions

$$i \cdot 10^j$$

with $i \in \{2, 3, 4, 5, 6, 7, 8, 9\}$, $j \in \mathbb{Z}$. This may be valuable in conjunction with the '`extra x ticks`' and '`extra y ticks`' options.
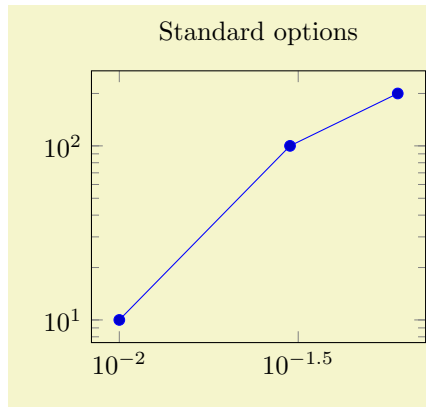
Standard options

```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}%
\begin{loglogaxis}
    [title=Standard options,
    width=6cm]
\addplot coordinates {
    (1e-2,10)
    (3e-2,100)
    (6e-2,200)
};
\end{loglogaxis}
\end{tikzpicture}%
```

with minor tick identification

without minor tick identification
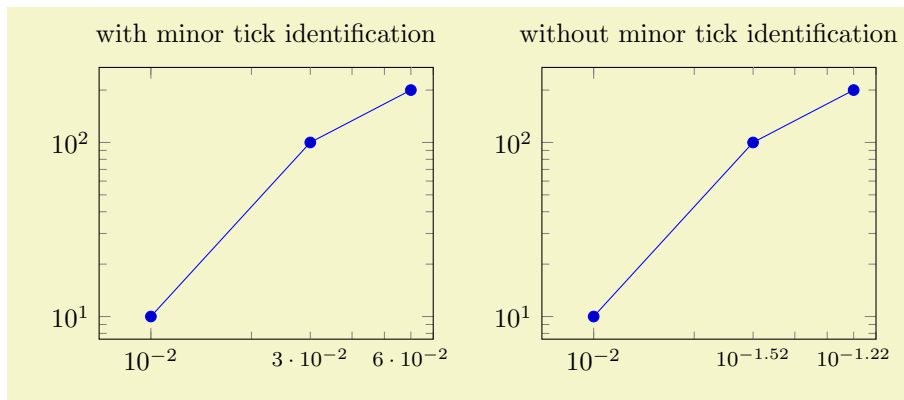
```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\pgfplotsset{every axis/.append style={%
    width=6cm,
    xmin=7e-3,xmax=7e-2,
    extra x ticks={3e-2,6e-2},
    extra x tick style={major tick length=0pt,font=\footnotesize}
}}%

\begin{tikzpicture}%
    \begin{loglogaxis}[
        xtick={1e-2},
        title=with minor tick identification,
        extra x tick style={
            log identify minor tick positions=true}]
    \addplot coordinates {
        (1e-2,10)
        (3e-2,100)
        (6e-2,200)
    };
    \end{loglogaxis}
\end{tikzpicture}%

\begin{tikzpicture}%
    \begin{loglogaxis}[
        xtick={1e-2},
        title=without minor tick identification,
        extra x tick style={
            log identify minor tick positions=false}]
    \addplot coordinates {
        (1e-2,10)
        (3e-2,100)
        (6e-2,200)
    };
    \end{loglogaxis}%
\end{tikzpicture}%
```

This key is set by the default styles for extra ticks.

/pgfplots/log number format code/.code={⟨...⟩}

Provides TeX-code to generate log plot tick labels. Argument '`#1`' is the (natural) logarithm of the tick position. The default implementation invokes `log base 10 number format code` after it changed the log basis to 10. It also checks the other log plot options.

This key will have a different meaning when the log basis has been chosen explicitly, see the `log basis x` key.

`/pgfplots/`**`log base 10 number format code`**`/.code={`⟨...⟩`}`

Allows to change the overall appearance of base 10 log plot tick labels. The default implementation invokes `log number format basis={10}{#1}`.

Use `log plot exponent style` if you only want to change number formatting options for the exponent.

`/pgfplots/`**`log number format basis`**`/.code={`⟨...⟩`}`

Typesets a logarithmic tick. The first supplied argument is the log basis, the second the exponent. The initial configuration is

```
\pgfplotsset{
    /pgfplots/log number format basis/.code 2 args={$#1^{\pgfmathprintnumber{#2}}$}
}
```

Use `log plot exponent style` if you only want to change number formatting options for the exponent.

4.14 Specifying the Plotted Range

4.14.1 Configuration of Limits Ranges

`/pgfplots/`**`xmin`**`={`⟨*coord*⟩`}`
`/pgfplots/`**`ymin`**`={`⟨*coord*⟩`}`
`/pgfplots/`**`zmin`**`={`⟨*coord*⟩`}`
`/pgfplots/`**`xmax`**`={`⟨*coord*⟩`}`
`/pgfplots/`**`ymax`**`={`⟨*coord*⟩`}`
`/pgfplots/`**`zmax`**`={`⟨*coord*⟩`}`
`/pgfplots/`**`min`**`={`⟨*coord*⟩`}`
`/pgfplots/`**`max`**`={`⟨*coord*⟩`}`

These options allow to define the axis limits, i.e. the lower left and the upper right corner. Everything outside of the axis limits will be clipped away.

Attention: these values (and other related keys in this section) merely affect how PGFPLOTS determines the axis' range. The values are *unrelated* to function sampling. Please refer to `domain` in order to define the sampling range for plot expressions. It is valid to sample a larger or smaller range than the displayed portion of the axis. Use `xmin` and its friends to specify which portion of the axis is to be displayed.

Each of these keys is optional, and missing limits will be determined automatically from input data. Here, the `min` and `max` keys set limits for x, y and z to the same ⟨*coord*⟩.

If x-limits have been specified explicitly and y-limits are computed automatically, the automatic computation of y-limits will only considers points which fall into the specified x-range (and vice–versa). The same holds true if, for example, only `xmin` has been provided explicitly: in that case, `xmax` will be updated only for points for which $x \geq$ `xmin` holds. This feature can be disabled using `clip limits`=false.

Axis limits can be increased automatically using the `enlargelimits` option.
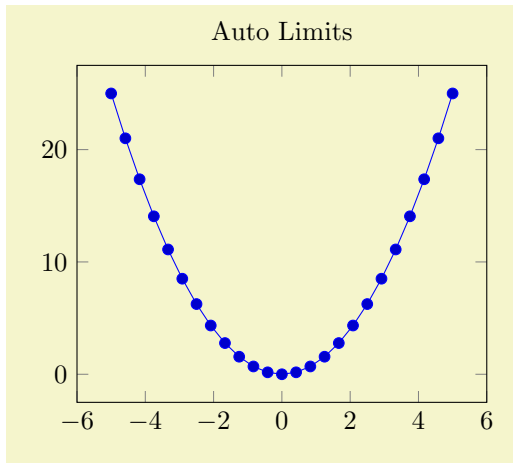
```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
    \begin{axis}[title=Auto Limits]
    \addplot {x^2};
    \end{axis}
\end{tikzpicture}
```
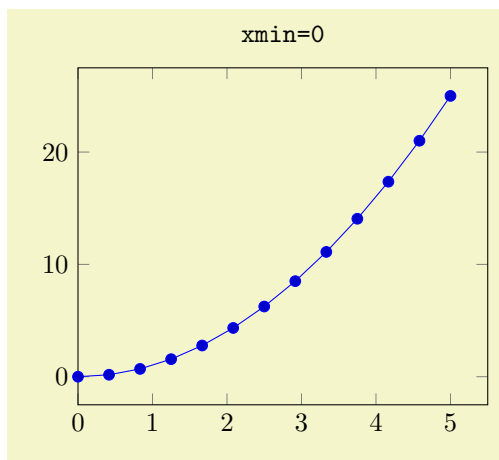


```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
    \begin{axis}[title={\texttt{xmin=0}},xmin=0]
    \addplot {x^2};
    \end{axis}
\end{tikzpicture}
```
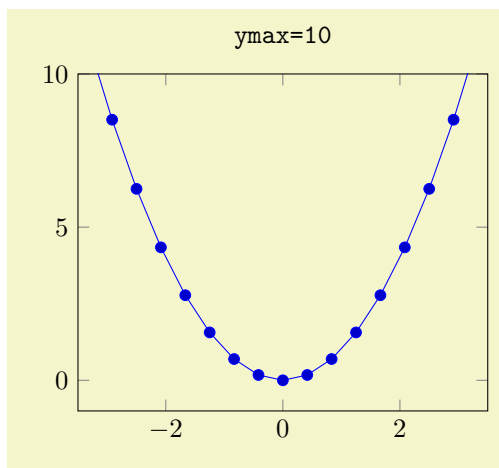


```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
    \begin{axis}[title={\texttt{ymax=10}},ymax=10]
    \addplot {x^2};
    \end{axis}
\end{tikzpicture}
```

Note that even if you provide ymax=10, data points with $y > 10$ will still be visualized – producing a line which leaves the plotted range.

See also the restrict x to domain and restrict x to domain* keys – they allow to discard or clip input coordinates which are outside of some domain, respectively.

During the visualization phase, i.e. during \end{axis}, these keys will be set to the final axis limits. You can access the values by means of \pgfkeysvalueof{/pgfplots/xmin}, for example:

Axis limits are $[-6:6] \times [-2.5:27.5]$
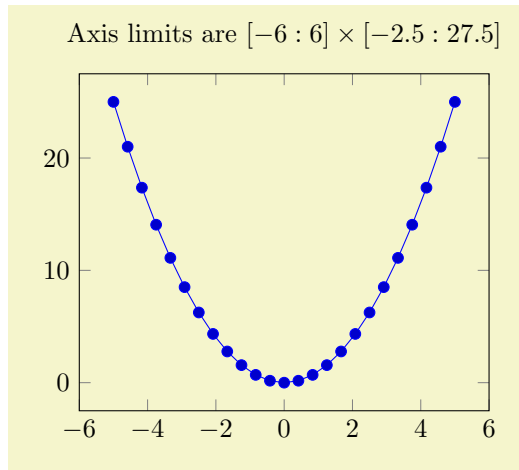
```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
\begin{axis}[
 % Show (automatically) computed limits:
 title={
   Axis limits are
   $
   [\pgfmathprintnumber{\pgfkeysvalueof{/pgfplots/xmin}}
   :\pgfmathprintnumber{\pgfkeysvalueof{/pgfplots/xmax}}
   ] \times
   [\pgfmathprintnumber{\pgfkeysvalueof{/pgfplots/ymin}}
   :\pgfmathprintnumber{\pgfkeysvalueof{/pgfplots/ymax}}
   ]$ },
]
   \addplot {x^2};
\end{axis}
\end{tikzpicture}
```

This access is possible inside of any axis description (like `xlabel`, `title`, `legend entries` etc.) or any annotation (i.e. inside of `\node`, `\draw` or `\path` and coordinates in $(\langle x \rangle, \langle y \rangle)$), but not inside of `\addplot` (limits may not be complete at this stage).

/pgfplots/xmode=normal|linear|log   (initially `normal`)
/pgfplots/ymode=normal|linear|log   (initially `normal`)
/pgfplots/zmode=normal|linear|log   (initially `normal`)

Allows to choose between linear (=normal) or logarithmic axis scaling or logplots for each x, y, z-combination.

Logarithmic plots use the current setting of `log basis x` and its variants to determine the basis (default is e).

/pgfplots/x dir=normal|reverse   (initially `normal`)
/pgfplots/y dir=normal|reverse   (initially `normal`)
/pgfplots/z dir=normal|reverse   (initially `normal`)

Allows to reverse axis directions such that values are given in decreasing order.
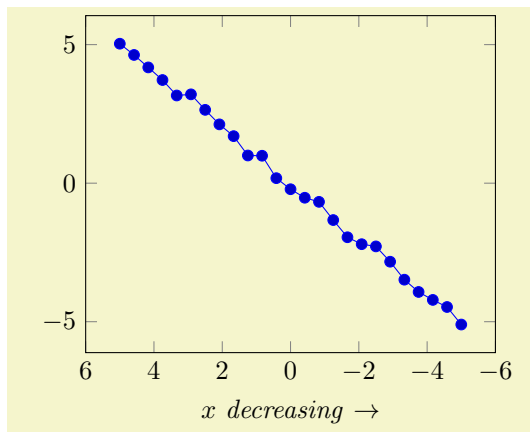
```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
\begin{axis}[
   xlabel=$x$ \emph{decreasing} $\to$,
   x dir=reverse]
   \addplot {x+rand*0.3};
\end{axis}
\end{tikzpicture}
```
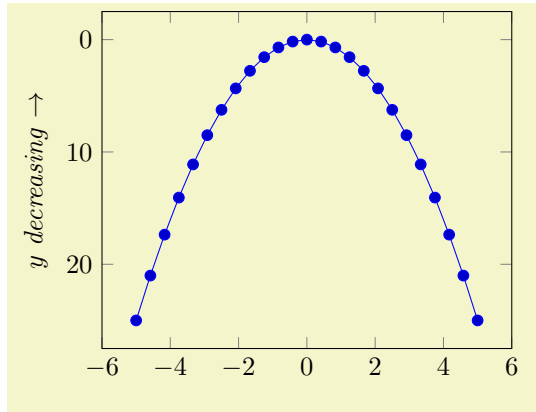
```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
\begin{axis}[
    ylabel=$y$ \emph{decreasing} $\to$,
    y dir=reverse]
    \addplot {x^2};
\end{axis}
\end{tikzpicture}
```

Note that axis descriptions and relative positioning macros will stay at the same place as they would for non–reversed axes.
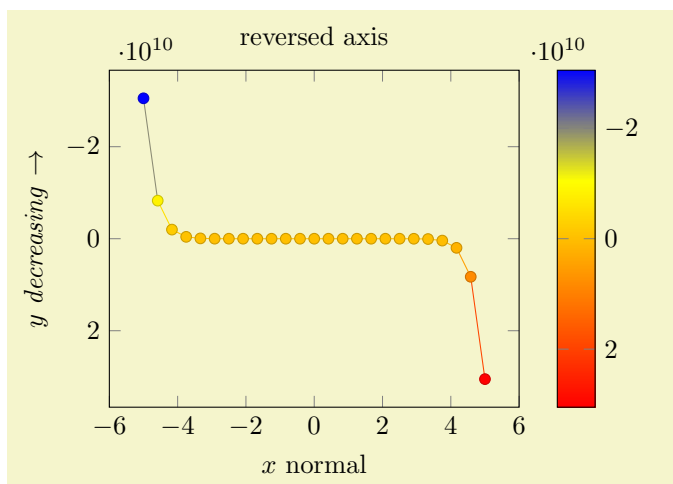

```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
\begin{axis}[
    ylabel=$y$ \emph{decreasing} $\to$,
    xlabel=$x$ normal,
    title=reversed axis,
    y dir=reverse,
    colorbar,
    colorbar style={y dir=reverse}]
    \addplot+[mesh,scatter] {x^15};
\end{axis}
\end{tikzpicture}
```

Note that colorbars won't be reversed automatically, you will have to reverse the sequence of color bars manually in case this is required as in the preceding example.

/pgfplots/clip limits=true|false   (initially true)

Configures what to do if some, but not all axis limits have been specified explicitly. In case clip limits=true, the automatic limit computation will *only* consider points which do not contradict the explicitly set limits.

This option has nothing to do with path clipping, it only affects how the axis limits are computed.

/pgfplots/enlarge x limits=auto|true|false|upper|lower|⟨*val*⟩|value=⟨*val*⟩|abs value=⟨*val*⟩|
    abs=⟨*val*⟩|rel=⟨*val*⟩   (initially auto)
/pgfplots/enlarge y limits=auto|true|false|upper|lower|⟨*val*⟩|value=⟨*val*⟩|abs value=⟨*val*⟩|
    abs=⟨*val*⟩|rel=⟨*val*⟩   (initially auto)
/pgfplots/enlarge z limits=auto|true|false|upper|lower|⟨*val*⟩|value=⟨*val*⟩|abs value=⟨*val*⟩|
    abs=⟨*val*⟩|rel=⟨*val*⟩   (initially auto)
/pgfplots/enlargelimits=⟨*common value*⟩

Enlarges the axis size for one axis (or all of them for `enlargelimits`) somewhat if enabled.

You can set `xmin`, `xmax` and `ymin`, `ymax` to the minimum/maximum values of your data and `enlarge x limits` will enlarge the canvas such that the axis doesn't touch the plots.

The value `true` enlarges the lower and upper limit.

The value `false` uses tight axis limits as specified by the user (or read from input coordinates).

The value `auto` will enlarge limits only for axis for which axis limits have been determined automatically. For three–dimensional figures, the `auto` mechanism applies only for the z axis. The x and y axis won't be enlarged.
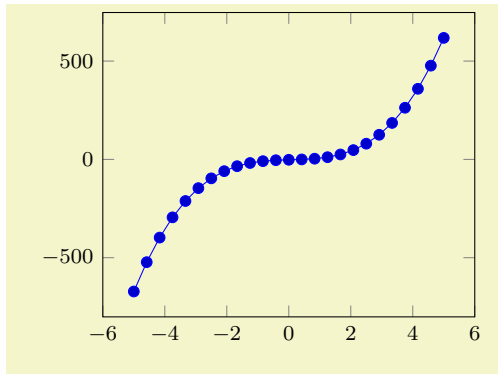

```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
    \begin{axis}[small]
        \addplot {5 * x^3 - x^2 + 4*x -2};
    \end{axis}
\end{tikzpicture}
```

Specifying a number `val`ue like '`enlarge x limits`=0.2' will enlarge lower and upper axis limit relatively. The following example adds 20% of the axis limits on both sides:
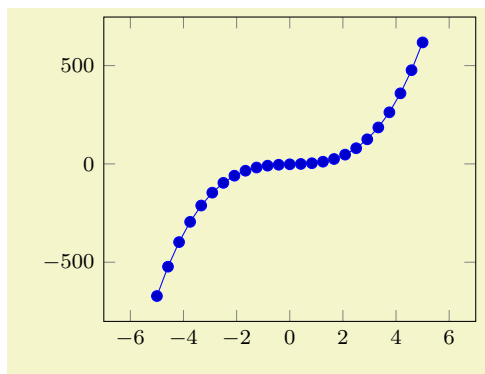

```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
    \begin{axis}[small,enlarge x limits=0.2]
        \addplot {5 * x^3 - x^2 + 4*x -2};
    \end{axis}
\end{tikzpicture}
```

The choice `rel={⟨value⟩}` is the same as `true,value={⟨value⟩}`, i.e. it activates relative enlargement for both `upper` and `lower` limit.

The value `upper` enlarges only the upper axis limit while `lower` enlarges only the lower axis limit. In this case, the amount added to the respective limit can be specified using the `value={⟨val⟩}` key. It can be combined with any of the other possible values. For example,

`\pgfplotsset{enlarge x limits={value=0.2,upper}}`

will enlarge (only) the upper axis limit by 20% of the axis range. Another example is

`\pgfplotsset{enlarge x limits={value=0.2,auto}}`

which changes the default threshold of the `auto` value to 20%.
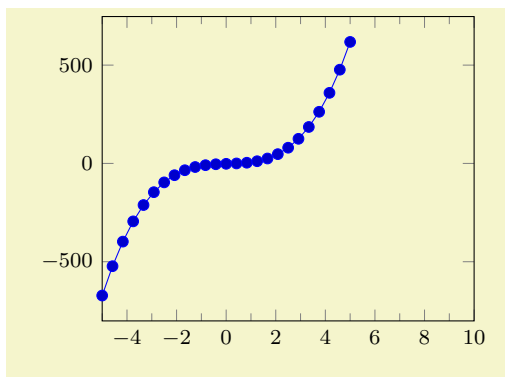
```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
    \begin{axis}[small,minor x tick num=1,
        enlarge x limits={rel=0.5,upper}
    ]
        \addplot {5 * x^3 - x^2 + 4*x -2};
    \end{axis}
\end{tikzpicture}
```

While `value` uses relative thresholds, `abs value` accepts absolute values: it adds an absolute value to the selected axis. The choice `abs={⟨value⟩}` is the same as `true,abs value={⟨value⟩}`, i.e. it adds an absolute value to both `upper` and `lower` limit:
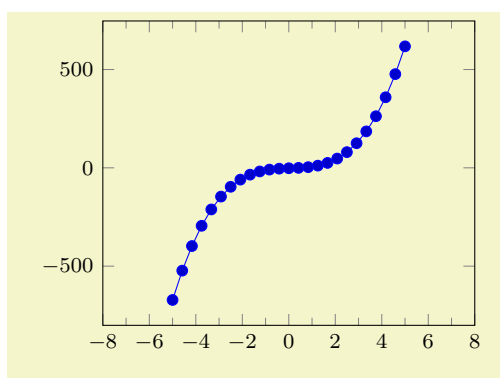

```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
    \begin{axis}[small,minor x tick num=1,
        enlarge x limits={abs=3}
    ]
        \addplot {5 * x^3 - x^2 + 4*x -2};
    \end{axis}
\end{tikzpicture}
```

Here, we enlarged by 3 units of the x axis. Note that you can also specify *dimensions* like `1cm`:
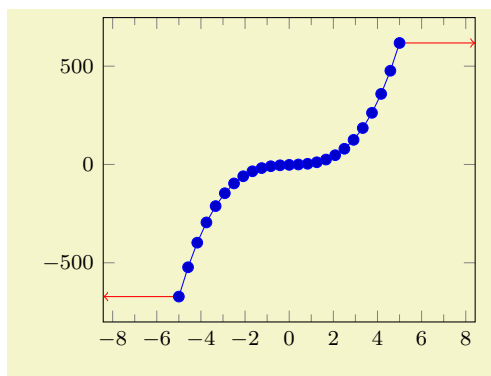

```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
    \begin{axis}[small,minor x tick num=1,
        enlarge x limits={abs=1cm}
    ]
        \addplot {5 * x^3 - x^2 + 4*x -2}
          coordinate[pos=0] (first)
          coordinate[pos=1] (last);

        \draw[red,->] (first) -- ++(-1cm,0pt);
        \draw[red,->] (last) --  ++(1cm,0pt);
    \end{axis}
\end{tikzpicture}
```

Technically, the use of absolute dimensions is a little bit different. For example, it allows to enlarge by more than `width` which is impossible for all other choices. PGFPLOTS will try to fulfill both the provided `width`/`height` and the absolute axis enlargements. If it fails to do so, it will give up on `width`/`height` constraints and print a warning message to your log file. See also the key `enlargelimits respects figure size`.

Attention: `abs value` is applied *multiplicatively* for logarithmic axes! That means `abs value=10` for a logarithmic axis adds $\log 10$ to upper and/or lower axis limits.
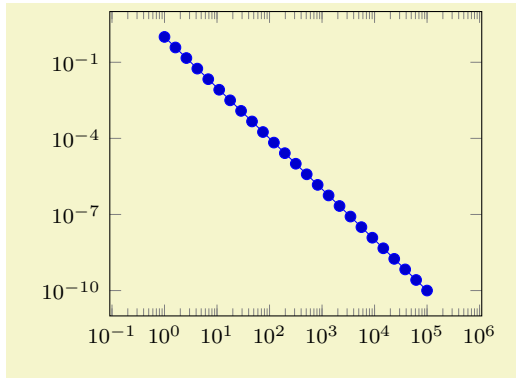
```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
    \begin{loglogaxis}[
        small,
        enlarge x limits={abs=11},
    ]
        \addplot+[domain=1:100000] {x^-2};
    \end{loglogaxis}
\end{tikzpicture}
```

Note that `enlargelimits` is applied before any changes to axis limits are considered as part of `scale mode`: `enlargelimits` will always be applied. Afterwards, the choice `scale mode`=scale uniformly will enlarge limits once more in order to satisfy all scaling constraints. The two limit enlargements are independent of each other, i.e. even if you say `enlargelimits`=false, `scale mode` will still increase axis limits if this seems to be necessary. An exception for this rule is enlarge-by-dimension, i.e. something like abs=1cm (see `enlargelimits respects figure size` for this case). See `scale mode` (especially `scale mode`=units only) and `unit rescale keep size` for detail on how to disable limit enlargement caused by `scale mode`.

/pgfplots/enlargelimits respects figure size=true|false   (initially true)

A key which is *only* used for something like `enlarge x limits`={abs=1cm}, i.e. for enlarge-by-dimension. It controls if PGFPLOTS will try to respect `width`/`height`. You should probably always leave it as its default unless you run into problems.

If PGFPLOTS fails to respect the figure size, it will print a warning message of sorts "enlargelimits respects figure size=true: could not respect the prescribed width/height" to your log file.

/pgfplots/log origin x=0|infty   (initially infty)
/pgfplots/log origin y=0|infty   (initially infty)
/pgfplots/log origin z=0|infty   (initially infty)
/pgfplots/log origin=0|infty   (initially infty)

Allows to choose which coordinate is the logical "origin" of a logarithmic plot (either for a particular axis or for all of them).

The choice `log origin`=infty is probably useful for stacked plots: it defines the "origin" in log–coordinates to be $-\infty$. To be compatibly with older versions, this is the default. Note that $-\infty$ is clipped to be the lowest displayed value on the axis in question.

The choice `log origin`=0 defines the logarithmic origin to be the natural choice $\log(1) = 0$. This is particularly useful for `ycomb` plots.

/pgfplots/update limits=true|false   (initially true)

Can be used to interrupt updates of the data limits (for example, for single `\addplot` commands).

This has the same effect as `\pgfplotsinterruptdatabb` ... `\endpgfplotsinterruptdatabb`.

\begin{pgfplotsinterruptdatabb}
  ⟨*environment contents*⟩
\end{pgfplotsinterruptdatabb}

Everything in ⟨*environment contents*⟩ will not contribute to the data bounding box.

The same effect can be achieved with `update limits`=false inside curly braces.

4.14.2 Accessing Computed Limit Ranges

This section is for those who want or need to access the computed limits programmatically. It lists how to access computed values.

/pgfplots/xmin   (no value)
/pgfplots/ymin   (no value)

/pgfplots/zmin   (no value)
/pgfplots/xmax   (no value)
/pgfplots/ymax   (no value)
/pgfplots/zmax   (no value)

These values are not only the *input*: after the survey phase, their values will be overwritten with the resulting computed values. These may differ according to enlargelimits or scale mode.

If you need to access them, you can write \pgfkeysvalueof{/pgfplots/xmin} somewhere in your code.

4.15   Tick Options

4.15.1   Tick Coordinates and Label Texts

/pgfplots/xtick distance={⟨*empty or numeric*⟩}   (initially empty)
/pgfplots/ytick distance={⟨*empty or numeric*⟩}   (initially empty)
/pgfplots/ztick distance={⟨*empty or numeric*⟩}   (initially empty)

Allows to define the *distance* between generated tick *positions*.
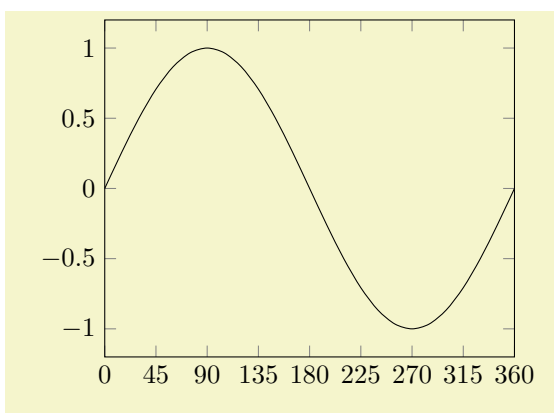
```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
    \begin{axis}[
        xtick distance=45,
        ytick distance=0.5,
        enlarge x limits=false,
    ]
    \addplot[smooth,domain=0:360] {sin(x)};
    \end{axis}
\end{tikzpicture}
```
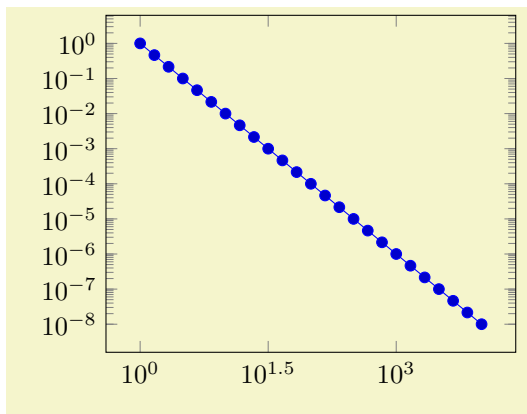
```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
    \begin{loglogaxis}[
        xtick distance=10^(1.5),
        ytick distance=10^1,
    ]
    \addplot expression[domain=1:10000] {x^-2};
    \end{loglogaxis}
\end{tikzpicture}
```

The initial value is empty meaning "generate as needed".

Any other value is interpreted as constant (evaluated using the math expression parser) and is taken as-is. Note that such values should be chosen in a way such that not too many and not too few tick positions are generated.

/pgfplots/xtick=\empty|data|{⟨*coordinate list*⟩}   (initially {⟨⟩})
/pgfplots/ytick=\empty|data|{⟨*coordinate list*⟩}   (initially {⟨⟩})
/pgfplots/ztick=\empty|data|{⟨*coordinate list*⟩}   (initially {⟨⟩})

These options assign a list of *positions* where ticks shall be placed. The argument is either the empty string (which is the initial value), the command \empty, the special string 'data' or a list of coordinates. The initial configuration of an empty string means to generate these positions automatically. The choice \empty will result in no tick at all. The special value 'data' will produce tick marks at every coordinate of the first plot. Otherwise, tick marks will be placed at every coordinate in ⟨*coordinate list*⟩.

The ⟨*coordinate list*⟩ will be used inside of a `\foreach \x in {⟨coordinate list⟩}` statement. The format is as follows:

- `{0,1,2,5,8,1e1,1.5e1}` (a series of coordinates),
- `{0,...,5}` (the same as `{0,1,2,3,4,5}`),
- `{0,2,...,10}` (the same as `{0,2,4,6,8,10}`),
- `{9,...,3.5}` (the same as `{9, 8, 7, 6, 5, 4}`),
- See [7, Section 34] for a more detailed definition of the options.
- Please be careful with white spaces inside of ⟨*coordinate list*⟩ (at least around the dots).

For logplots, PGFPLOTS will apply $\log(\cdot)$ to each element in '⟨*coordinate list*⟩' (similarly, any custom transformations are applied to the argument list).
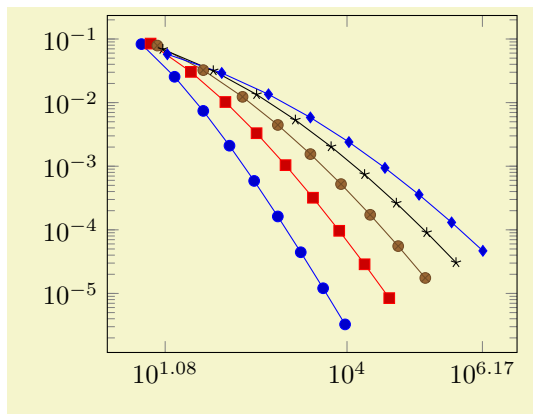

```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
    \begin{loglogaxis}[xtick={12,9897,1468864}]
    % see above for this macro:
    \plotcoords
    \end{loglogaxis}
\end{tikzpicture}
```
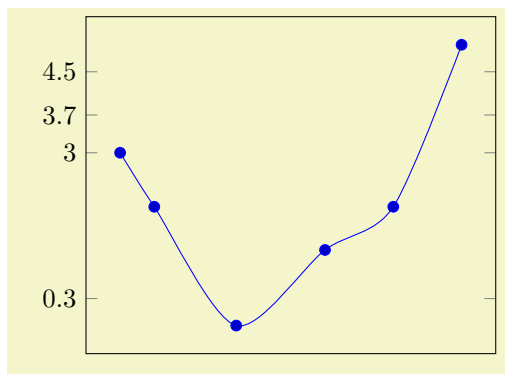


```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
\begin{axis}[
    xtick=\empty,
    ytick={-2,0.3,3,3.7,4.5}]
\addplot+[smooth] coordinates {
    (-2,3) (-1.5,2) (-0.3,-0.2)
    (1,1.2) (2,2) (3,5)};
\end{axis}
\end{tikzpicture}
```

Attention: You can't use the '`...`' syntax if the elements are too large for TEX! For example, '`xtick=1.5e5,2e7,3e8`' will work (because the elements are interpreted as strings, not as numbers), but '`xtick=1.5,3e5,...,1e10`' will fail because it involves real number arithmetics beyond TEX's capacities.

The default choice for tick *positions* in normal plots is to place a tick at each coordinate $i \cdot h$. The step size h depends on the axis scaling and the axis limits. It is chosen from a list of "feasible" step sizes such that neither too much nor too few ticks will be generated. The default for logplots is to place ticks at positions 10^i in the axis' range. The positions depend on the axis scaling and the dimensions of the picture. If log plots contain just one (or two) positions 10^i in their limits, ticks will be placed at positions $10^{i \cdot h}$ with "feasible" step sizes h as in the case of linear axis.

The tick *appearance* can be (re)configured with

```
\pgfplotsset{tick style={very thin,gray}}% modifies the style 'every tick'
\pgfplotsset{minor tick style={black}}   % modifies the style 'every minor tick'
```

These style commands can be used at any time. The tick line width can be configured with '`major tick length`' and '`minor tick length`'.
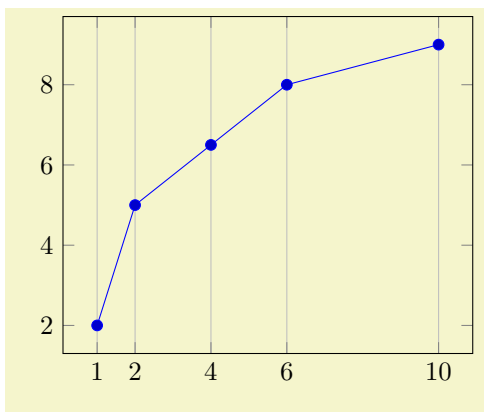
```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
\begin{axis}[xtick=data,xmajorgrids]
    \addplot coordinates {
        (1,2)
        (2,5)
        (4,6.5)
        (6,8)
        (10,9)
    };
\end{axis}
\end{tikzpicture}
```
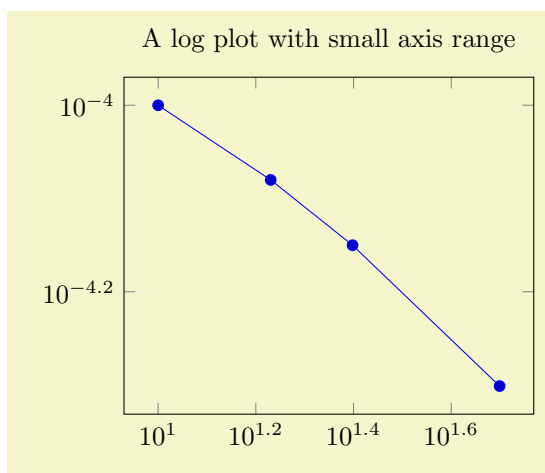


```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
\begin{loglogaxis}[
    title=A log plot with small axis range]

    \addplot coordinates {
        (10,1e-4)
        (17,8.3176e-05)
        (25,7.0794e-05)
        (50,5e-5)
    };
\end{loglogaxis}
\end{tikzpicture}
```

/pgfplots/minor x tick num={⟨*number*⟩}   (initially 0)
/pgfplots/minor y tick num={⟨*number*⟩}   (initially 0)
/pgfplots/minor z tick num={⟨*number*⟩}   (initially 0)
/pgfplots/minor tick num={⟨*number*⟩}

  Sets the number of minor tick lines used either for single axes or for all of them.

  Minor ticks will be disabled if the major ticks don't have the same distance and they are currently only available for linear axes (not for logarithmic ones).
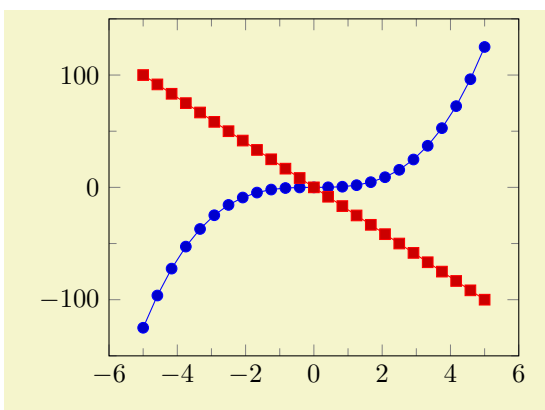

```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
    \begin{axis}[minor tick num=1]
    \addplot {x^3};
    \addplot {-20*x};
    \end{axis}
\end{tikzpicture}
```
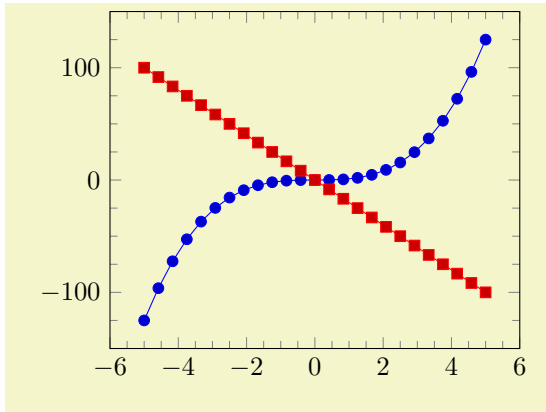
```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
    \begin{axis}[minor tick num=3]
    \addplot {x^3};
    \addplot {-20*x};
    \end{axis}
\end{tikzpicture}
```
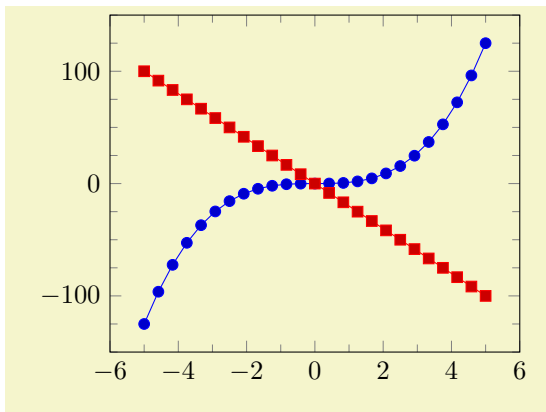


```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
    \begin{axis}[minor x tick num=1,
                 minor y tick num=3]
    \addplot {x^3};
    \addplot {-20*x};
    \end{axis}
\end{tikzpicture}
```

/pgfplots/**minor xtick**=data|{⟨*coordinate list*⟩}   (initially **empty**)
/pgfplots/**minor ytick**=data|{⟨*coordinate list*⟩}   (initially **empty**)
/pgfplots/**minor ztick**=data|{⟨*coordinate list*⟩}   (initially **empty**)
/pgfplots/**minor tick**=data|{⟨*coordinate list*⟩}

Allows to provide a list of minor tick positions manually. The syntax is almost the same as for xtick
or ytick: simply provide either a comma–separated list of tick positions or the special value data.
An empty argument argument disables the minor tick feature (in contrast to xtick where the special
value \empty clears the list and an empty argument causes PGFPLOTS to compute a default tick list).

In contrast to minor x tick num, this key allows to provide *non–uniform* minor tick positions.
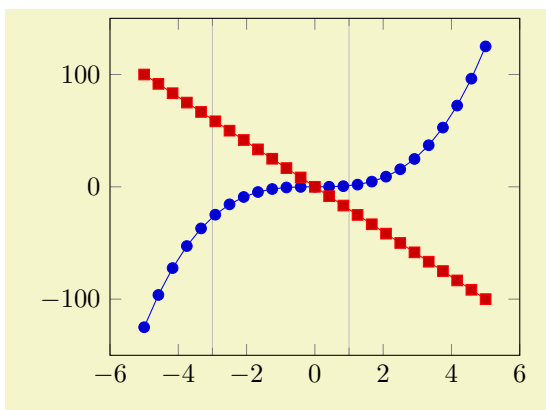

```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
    \begin{axis}[minor xtick={-3,1},grid=minor]
    \addplot {x^3};
    \addplot {-20*x};
    \end{axis}
\end{tikzpicture}
```
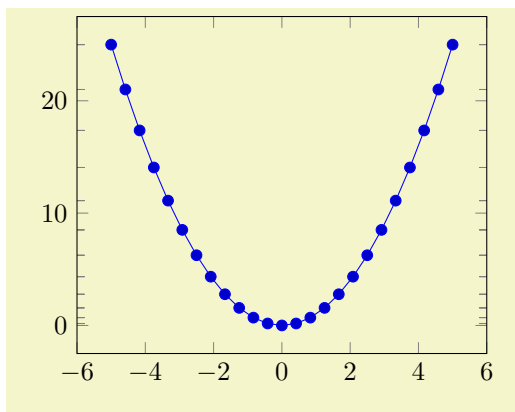
```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
    \begin{axis}[minor ytick=data]
    \addplot {x^2};
    \end{axis}
\end{tikzpicture}
```

This key has precedence over `minor x tick num` and its variants; if both of them are given, `minor xtick` is preferred and `minor x tick num` is ignored.

/pgfplots/**extra x ticks**={⟨*coordinate list*⟩}
/pgfplots/**extra y ticks**={⟨*coordinate list*⟩}
/pgfplots/**extra z ticks**={⟨*coordinate list*⟩}

Adds *additional* tick positions and tick labels to the x or y axis. 'Additional' tick positions do not affect the normal tick placement algorithms, they are drawn after the normal ticks. This has two benefits: first, you can add single, important tick positions without disabling the default tick label generation and second, you can draw tick labels 'on top' of others, possibly using different style flags.
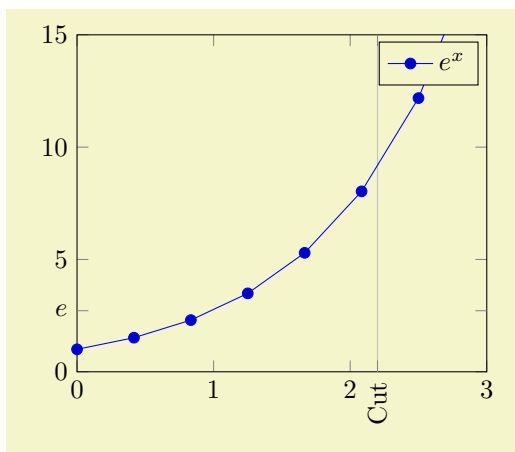

```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
\begin{axis}[
    xmin=0,xmax=3,ymin=0,ymax=15,
    extra y ticks={2.71828},
    extra y tick labels={$e$},
    extra x ticks={2.2},
    extra x tick style={grid=major,
        tick label style={
            rotate=90,anchor=east}},
    extra x tick labels={Cut},
]
    \addplot {exp(x)};
    \addlegendentry{$e^x$}
\end{axis}
\end{tikzpicture}
```


Explicitly Provided Limits
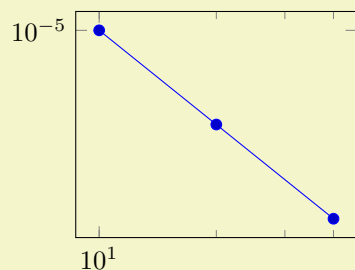
With Extra Ticks
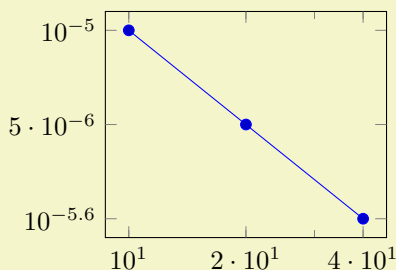
With Extra Ticks; 10^e format
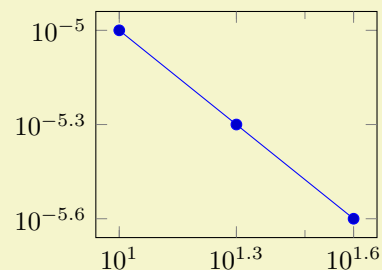
```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\pgfplotsset{every axis/.append style={width=5.3cm}}
\begin{tikzpicture}
\begin{loglogaxis}[
    title=Explicitly Provided Limits,
    xtickten={1,2},
    ytickten={-5,-6}]
\addplot coordinates
    {(10,1e-5) (20,5e-6) (40,2.5e-6)};
\end{loglogaxis}
\end{tikzpicture}

\begin{tikzpicture}
\begin{loglogaxis}[
    title=With Extra Ticks,
    xtickten={1,2},
    ytickten={-5,-6},
    extra x ticks={20,40},
    extra y ticks={5e-6,2.5e-6}]
\addplot coordinates
    {(10,1e-5) (20,5e-6) (40,2.5e-6)};
\end{loglogaxis}
\end{tikzpicture}

\begin{tikzpicture}
\begin{loglogaxis}[
    title=With Extra Ticks; $10^e$ format,
    extra tick style={log identify minor tick positions=false},
    xtickten={1,2},
    ytickten={-5,-6},
    extra x ticks={20,40},
    extra y ticks={5e-6,2.5e-6}]
\addplot coordinates
    {(10,1e-5) (20,5e-6) (40,2.5e-6)};
\end{loglogaxis}
\end{tikzpicture}
```

Remarks:

- Use `extra x ticks` to highlight special tick positions. The use of `extra x ticks` does not affect minor tick/grid line generation, so you can place extra ticks at positions $j \cdot 10^i$ in log–plots.

- Extra ticks are always typeset as major ticks.

  They are affected by `major tick length` or options like `grid`=`major`.

- Use the style `every extra x tick` (`every extra y tick`) to configure the appearance.

- You can also use '`extra x tick style`={$\langle...\rangle$}' which has the same effect.

/pgfplots/**xtickten**={$\langle$*exponent base 10 list*$\rangle$}
/pgfplots/**ytickten**={$\langle$*exponent base 10 list*$\rangle$}
/pgfplots/**ztickten**={$\langle$*exponent base 10 list*$\rangle$}

These options allow to place ticks at selected positions $10^k, k \in \{\langle$*exponent base 10 list*$\rangle\}$. They are only used for logplots. The syntax for {$\langle$*exponent base 10 list*$\rangle$} is the same as above for `xtick`={$\langle$*list*$\rangle$} or `ytick`={$\langle$*list*$\rangle$}.

Using '`xtickten`={1,2,3,4}' is equivalent to '`xtick`={1e1,1e2,1e3,1e4}', but it requires fewer computational time and it allows to use the short syntax '`xtickten`={1,...,4}'.
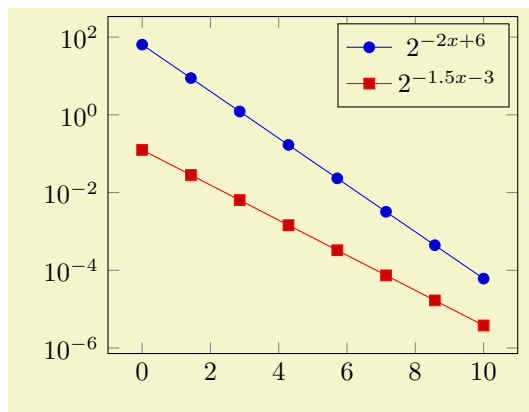
```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
\begin{semilogyaxis}[
    samples=8,
    ytickten={-6,-4,...,4},
    domain=0:10]

\addplot {2^(-2*x + 6)};
\addlegendentry{$2^{-2x + 6}$}

% or invoke gnuplot to generate coordinates:
\addplot gnuplot[id=pow2]
    {2**(-1.5*x -3)};
\addlegendentry{$2^{-1.5x -3}$}
\end{semilogyaxis}
\end{tikzpicture}
```

In case log basis x$\neq$ 10, the meaning of xtickten changes. In such a case, xtickten will still assign the exponent, but for the chosen log basis x instead of base 10.

/pgfplots/xticklabels={⟨*label list*⟩}
/pgfplots/yticklabels={⟨*label list*⟩}
/pgfplots/zticklabels={⟨*label list*⟩}

Assigns a *list* of tick *labels* to each tick position. Tick *positions* are assigned using the xtick and ytick-options.

This is one of two options to assign tick labels directly. The other option is xticklabel={⟨*command*⟩} (or yticklabel={⟨*command*⟩}). The option 'xticklabel' offers higher flexibility while 'xticklabels' is easier to use. See also the variant xticklabels from table.

The argument ⟨*label list*⟩ has the same format as for ticks, that means

```
xticklabels={$\frac{1}{2}$,$e$}
```

denotes the two–element–list $\{\frac{1}{2}, e\}$. The list indices match the indices of the tick positions. If you need commas inside of list elements, use

```
xticklabels={{0,5}, $e$}.
```
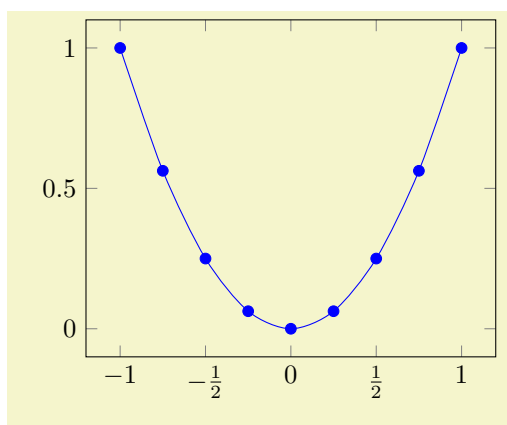


```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
\begin{axis}[
    xtick={-1.5,-1,...,1.5},
    xticklabels={%
        $-1\frac 12$,
        $-1$,
        $-\frac 12$,
        $0$,
        $\frac 12$,
        $1$},
    % note: \frac can be done automatically:
    % xticklabel style={/pgf/number format/frac},
]
\addplot[smooth,blue,mark=*]
coordinates {
    (-1,    1)
    (-0.75, 0.5625)
    (-0.5,  0.25)
    (-0.25, 0.0625)
    (0,     0)
    (0.25,  0.0625)
    (0.5,   0.25)
    (0.75,  0.5625)
    (1,     1)
};
\end{axis}
\end{tikzpicture}
```
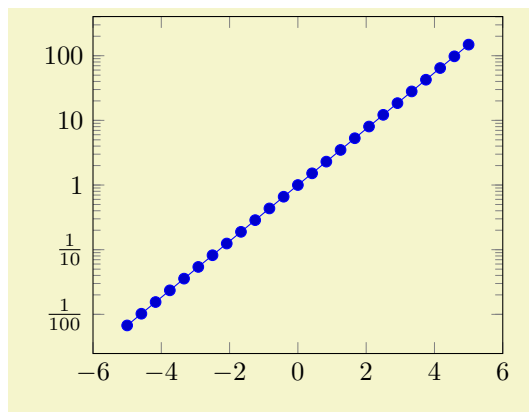
```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
\begin{semilogyaxis}[
    ytickten={-2,-1,0,1,2},
    yticklabels={$\frac{1}{100}$,%
        $\frac{1}{10}$,%
      1,10,100},
]
    \addplot {exp(x)};
\end{semilogyaxis}
\end{tikzpicture}
```

Note that it is also possible to terminate list entries with two backslashes, \\. In that case, the last entry needs to be terminated by \\ as well (it is the same alternative syntax which is also accepted for \legend and cycle list).

Please keep in mind that the arguments *always* refer the a list of tick positions, although it does not alter or define the list of positions. Consequently, you should also provide the list of positions. Note that a list of positions might be longer than what is actually displayed (in case the axis limits clip some of the value away), but the index mapping into ⟨*label list*⟩ still includes the clipped values.

/pgfplots/xticklabel={⟨*command*⟩}
/pgfplots/yticklabel={⟨*command*⟩}
/pgfplots/zticklabel={⟨*command*⟩}

These keys change the TEX-command which creates the tick *labels* assigned to each tick position (see options xtick and ytick).

This is one of the two options to assign tick labels directly. The other option is 'xticklabels={⟨*label list*⟩}' (or yticklabels={⟨*label list*⟩}). The option 'xticklabel' offers higher flexibility while 'xticklabels' is easier to use.

The argument ⟨*command*⟩ can be any TEX-text. The following commands are valid inside of ⟨*command*⟩:

\tick The current element of option xtick (or ytick).

\ticknum The current tick number, starting with 0 (it is a macro containing a number).

\nexttick This command is only valid if the x tick label as interval option is set (or the corresponding variable for y). It will contain the position of the next tick position, that means the right boundary of the tick interval.

The default argument is

- \axisdefaultticklabel for normal plots:

  ```
  \def\axisdefaultticklabel{$\pgfmathprintnumber{\tick}$}
  ```

- \axisdefaultticklabellog for logplots:

  ```
  \def\axisdefaultticklabellog{%
      \pgfkeysgetvalue{/pgfplots/log number format code/.@cmd}\pgfplots@log@label@style
      \expandafter\pgfplots@log@label@style\tick\pgfeov
  }
  ```

That means you can configure the appearance of linear axis with the number formatting options described in Section 4.13 and logarithmic axis with log number format code, see below.

The key yticklabel is a code fragment which is supposed to handle any incoming \tick value. Consequently, it can be used to append custom suffixes or even units:
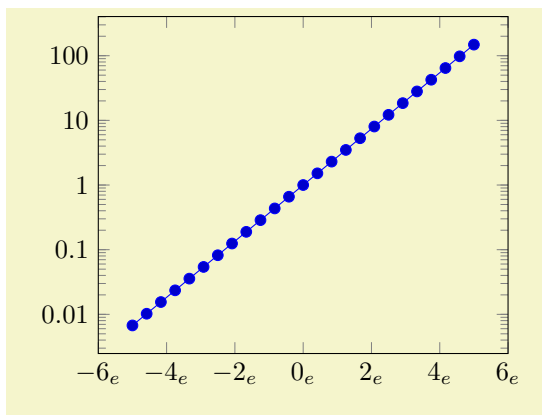
```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
    \begin{semilogyaxis}[
        log ticks with fixed point,
        xticklabel={$\pgfmathprintnumber{\tick}_e$},
    ]
        \addplot {exp(x)};
    \end{semilogyaxis}
\end{tikzpicture}
```

The following example uses explicitly formatted x tick labels and a small TEX script to format y tick labels as fractions in the form $\langle sign\rangle\langle number\rangle$/10 (note that the /pgf/number format/frac style can do similar things automatically, see PGFPLOTSTABLE and the documentation therein).
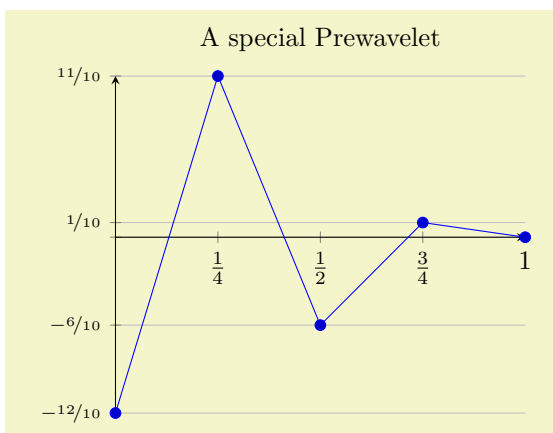
```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
% \usepackage{nicefrace}% required
\begin{tikzpicture}
\begin{axis}[
    % x ticks explicitly formatted:
    xtick={0,1,0.5,0.25,0.75},
    xticklabels={$0$,$1$,$\frac12$,$\frac14$,$\frac34$},
    % y ticks automatically by some code fragment:
    ytick=data,
    yticklabel={%
        \scriptsize
        \ifdim\tick pt<0pt % a TeX \if -- see TeX Book
            \pgfmathparse{-10*\tick}%
            $-\nicefrac{\pgfmathprintnumber{\pgfmathresult}}{10}$%
        \else
            \ifdim\tick pt=0pt
            \else
                \pgfmathparse{10*\tick}%
                $\nicefrac{\pgfmathprintnumber{\pgfmathresult}}{10}$%
            \fi
        \fi
    },
    % NOTE: this here does the same:
    % yticklabel style={/pgf/number format/.cd,frac,
    %     frac TeX=\nicefrac,frac whole=false,frac denom=10},
    ymajorgrids,
    title=A special Prewavelet,
    axis x line=center,
    axis y line=left,
    ]
    \addplot coordinates {(0,-1.2) (0.25,1.1)
        (0.5,-0.6) (0.75,0.1) (1,0)};
\end{axis}
\end{tikzpicture}
```

The TeX script takes the `\tick` macro as input and applies some logic. The `\ifdim\tick pt<0pt` means "if dimension `\tick` pt $<$ 0pt". The `\ifdim` is TeX's only way to compare real fixed point numbers and the author did not want to invoke `\pgfmath` for this simple task. Since `\ifdim` expects a dimension, we have to use the `pt` suffix which is compatible with `\pgfmath`. The result is that negative numbers, zero and positive numbers are typeset differently.

You can change the appearance of tick labels with

```
\pgfplotsset{tick label style={
    font=\tiny,
    /pgf/number format/sci}}% this modifies the 'every tick label' style
```

and/or

```
\pgfplotsset{x tick label style={
    above,
    /pgf/number format/fixed zerofill}}% this modifies the 'every x tick label' style
```

and

```
\pgfplotsset{y tick label style={font=\bfseries}}% modifies 'every y tick label'
```

/pgfplots/xticklabels from table={⟨\table or filename⟩}{⟨colname⟩}
/pgfplots/yticklabels from table={⟨\table or filename⟩}{⟨colname⟩}
/pgfplots/zticklabels from table={⟨\table or filename⟩}{⟨colname⟩}

A variant of `xticklabels`={⟨list⟩} which uses each entry in the column named ⟨colname⟩ from a table as tick labels.

The first argument ⟨\table or filename⟩ can be either a loaded table macro (i.e. the result of `\pgfplotstableread{`⟨file name⟩`}{`⟨\table⟩`}`) or just a file name.

The second argument can be a column name, a column alias or a `create on use` specification (see PGFPLOTSTABLE for the latter two). Furthermore, it can be `[index]`⟨integer⟩ in which case ⟨integer⟩ is a column index.

The behavior of `xticklabels from table` is the same as if the column ⟨colname⟩ would have been provided as comma separated list to `xticklabels`. This means the column can contain text, TeX macros or even math mode.

If you have white spaces in your cells, enclose the complete cell in curly braces, `{example cell}`. The detailed input format for tables is discussed in `\addplot table` and in the documentation for PGFPLOTSTABLE.

/pgfplots/extra x tick label={⟨TeX code⟩}
/pgfplots/extra y tick label={⟨TeX code⟩}
/pgfplots/extra z tick label={⟨TeX code⟩}

As `xticklabel` provides code to generate tick labels for each `xtick`, the key `extra x tick label` provides code to generate tick labels for every element in `extra x ticks`.

/pgfplots/extra x tick labels={⟨label list⟩}
/pgfplots/extra y tick labels={⟨label list⟩}
/pgfplots/extra z tick labels={⟨label list⟩}

As `xticklabels` provides explicit tick labels for each `xtick`, the key `extra x tick labels` provides explicit tick labels for every element in `extra x ticks`.

/pgfplots/x tick label as interval=true|false   (initially `false`)
/pgfplots/y tick label as interval=true|false   (initially `false`)
/pgfplots/z tick label as interval=true|false   (initially `false`)

Allows to treat tick labels as intervals; that means the tick positions denote the interval boundaries. If there are n positions, $(n-1)$ tick labels will be generated, one for each interval.
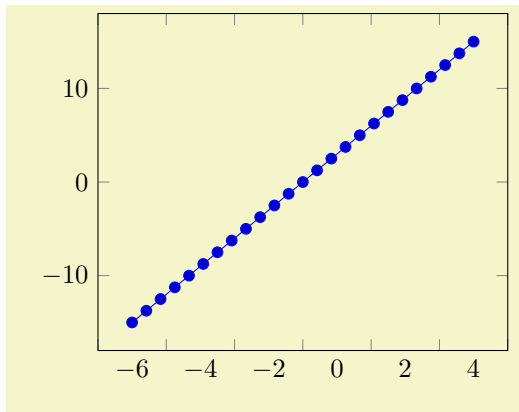
```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
\begin{axis}[x tick label as interval]
    \addplot {3*x};
\end{axis}
\end{tikzpicture}
```

This mode enables the use of `\nexttick` inside of `xticklabel` (or `yticklabel`). A common application might be a bar plot.
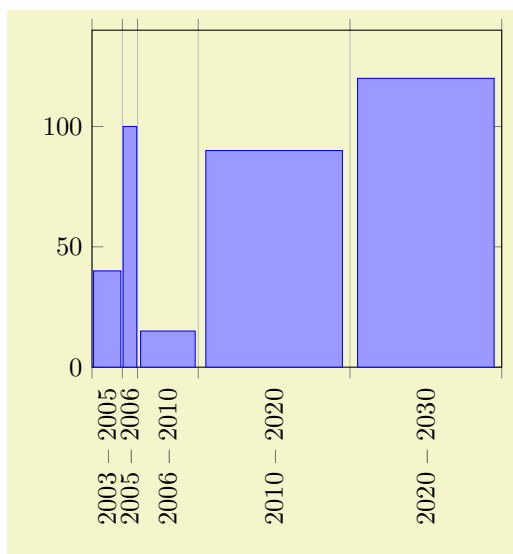
```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
\begin{axis}[
    ybar interval=0.9,
    x tick label as interval,
    xmin=2003,xmax=2030,
    ymin=0,ymax=140,
    xticklabel={
        $\pgfmathprintnumber{\tick}$
        -- $\pgfmathprintnumber{\nexttick}$},
    xtick=data,
    x tick label style={
        rotate=90,anchor=east,
        /pgf/number format/1000 sep=}
]

    \addplot[draw=blue,fill=blue!40!white]
        coordinates
        {(2003,40) (2005,100) (2006,15)
          (2010,90) (2020,120) (2030,3)};
\end{axis}
\end{tikzpicture}
```

/pgfplots/**xminorticks**=true|false	(initially **true**)
/pgfplots/**yminorticks**=true|false	(initially **true**)
/pgfplots/**zminorticks**=true|false	(initially **true**)
/pgfplots/**xmajorticks**=true|false	(initially **true**)
/pgfplots/**ymajorticks**=true|false	(initially **true**)
/pgfplots/**zmajorticks**=true|false	(initially **true**)
/pgfplots/**ticks**=minor|major|both|none	(initially **both**)

Enables/disables the small tick lines either for single axis or for all of them. Major ticks are those placed at the tick positions and minor ticks are between tick positions. Please note that minor ticks are automatically disabled if `xtick` is not a uniform range[57].

The key `minor tick length`={⟨*dimen*⟩} configures the tick length for minor ticks while the `major` variant applies to major ticks. You can configure the appearance using the following styles:

```
\pgfplotsset{every tick/.append style={color=black}} % applies to major and minor ticks,
\pgfplotsset{every minor tick/.append style={thin}}  % applies only to minor ticks,
\pgfplotsset{every major tick/.append style={thick}} % applies only to major ticks.
```

There is also the style "`every tick`" which applies to both, major and minor ticks.

/pgfplots/**xtickmin**={⟨*coord*⟩}
/pgfplots/**ytickmin**={⟨*coord*⟩}
/pgfplots/**ztickmin**={⟨*coord*⟩}

---

[57] A uniform list means the difference between all elements is the same for linear axis or, for logarithmic axes, log(10).

/pgfplots/**xtickmax**={⟨*coord*⟩}
/pgfplots/**ytickmax**={⟨*coord*⟩}
/pgfplots/**ztickmax**={⟨*coord*⟩}

These keys can be used to modify minimum/maximum values before ticks are drawn. Because this applies to axis discontinuities, it is described on page 274 in Section 4.9.12, "Axis Discontinuities"'.

4.15.2 Tick Alignment: Positions and Shifts

/pgfplots/**xtick pos**=left|right|both   (initially `both`)
/pgfplots/**ytick pos**=left|right|both   (initially `both`)
/pgfplots/**ztick pos**=left|right|both   (initially `both`)
/pgfplots/**tick pos**=left|right|both

Allows to choose where to place the small tick lines. In the default configuration, this does also affect tick *labels*, see below. The `tick pos` style sets all of them to the same value (aliased by `tickpos`). This option is only useful for boxed axes.

For x, the additional choices `bottom` and `top` can be used which are equivalent to `left` and `right`, respectively. Both are accepted for y.

Changing `tick pos` will also affect the placement of tick labels.

Note that it can also affect the `axis lines` key, although not all combinations make sense. Make sure the settings are consistent.

/pgfplots/**xticklabel pos**=left|right|default   (initially `default`)
/pgfplots/**yticklabel pos**=left|right|default   (initially `default`)
/pgfplots/**zticklabel pos**=left|right|default   (initially `default`)
/pgfplots/**ticklabel pos**=left|right|default   (initially `default`)

Allows to choose where to place tick *labels*. The choices `left` and `right` place tick labels either at the left or at the right side of the complete axis. The choice `default` uses the same setting as `xtick pos` (or `ytick pos`). This option is only useful for boxed axes – keep it to `default` for non-boxed figures. The `ticklabel pos` style sets all three of them to the same value.

For x, the additional choices `bottom` and `top` can be used which are equivalent to `left` and `right`, respectively. Both are accepted for x.

/pgfplots/**xtick align**=inside|center|outside   (initially `inside`)
/pgfplots/**ytick align**=inside|center|outside   (initially `inside`)
/pgfplots/**ztick align**=inside|center|outside   (initially `inside`)
/pgfplots/**tick align**=inside|center|outside   (initially `inside`)

Allows to change the location of the ticks relative to the axis lines. The `tick align` sets all of them to the same value. Default is "`inside`".
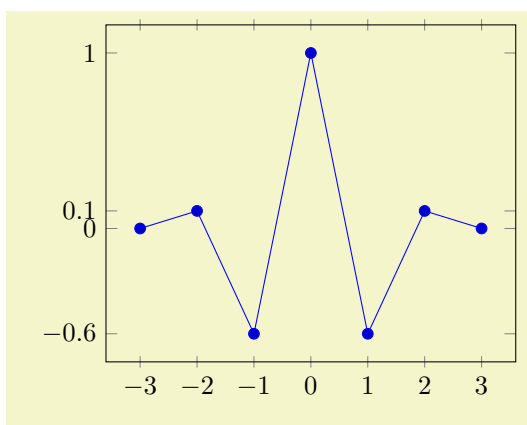

```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
\begin{axis}[
    xtick=data,ytick=data,
    xtick align=center]
\addplot coordinates
    {(-3,0) (-2,0.1) (-1,-0.6)
      (0,1)
      (1,-0.6) (2,0.1) (3,0)};
\end{axis}
\end{tikzpicture}
```
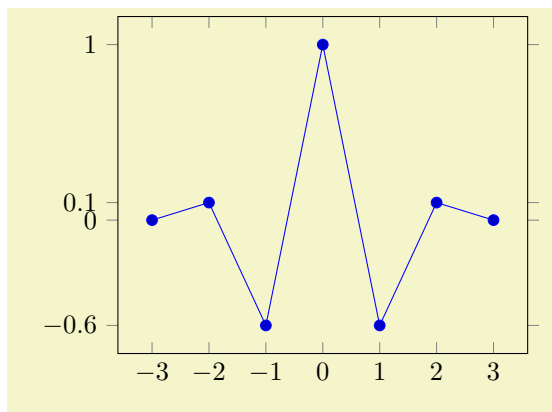
```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
\begin{axis}[
    xtick=data,ytick=data,
    ytick align=outside]
\addplot coordinates
    {(-3,0) (-2,0.1) (-1,-0.6)
      (0,1)
      (1,-0.6) (2,0.1) (3,0)};
\end{axis}
\end{tikzpicture}
```

These tick alignment options are set automatically by the `axis x line` and `axis y line` methods (unless one appends an asterisk '*'):
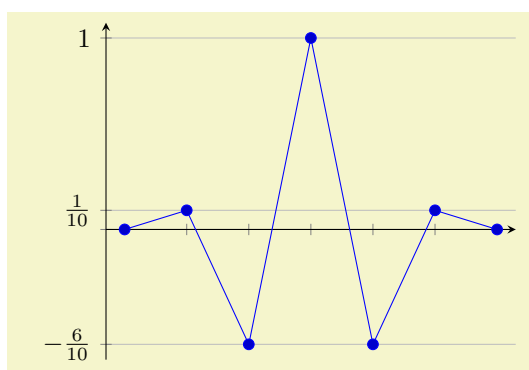

```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
\begin{axis}[
    xtick=data,
    axis x line=center,
    xticklabels={,,},
    ytick={-0.6,0,0.1,1},
    yticklabels={
        $-\frac{6}{10}$,,
        $\frac{1}{10}$,$1$},
    ymajorgrids,
    axis y line=left,
    enlargelimits=0.05]
\addplot coordinates
    {(-3,0) (-2,0.1) (-1,-0.6)
      (0,1)
      (1,-0.6) (2,0.1) (3,0)};
\end{axis}
\end{tikzpicture}
```

/pgfplots/**xticklabel shift**={⟨*dimension*⟩}   (initially `empty`)
/pgfplots/**yticklabel shift**={⟨*dimension*⟩}   (initially `empty`)
/pgfplots/**zticklabel shift**={⟨*dimension*⟩}   (initially `empty`)
/pgfplots/**ticklabel shift**={⟨*dimension*⟩}   (initially `empty`)

Shifts tick labels in direction of the outer unit normal of the axis by an amount of ⟨*dimension*⟩. The `ticklabel shift` sets the same value for all axes.

This is usually unnecessary as the `anchor` of a tick label already yields enough spacing in most cases.

See also `axis line shift`.

/pgfplots/**typeset ticklabels with strut**   (no value)
/pgfplots/**default typeset ticklabel**   (no value)

Typically, PGFPLOTS typesets ticks "as–is". This works good in almost all cases, especially if you just have numbers as tick labels.

But it needs adoptions if one ticklabel has text below the baseline and one does not. It is purpose of `typeset ticklabels with strut` to align them.
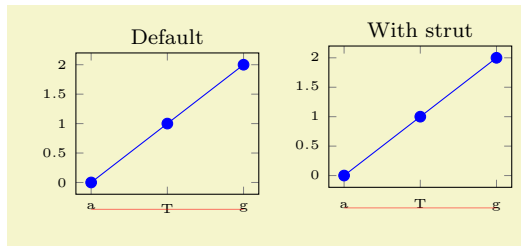
```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
    \begin{axis}[
        title=Default,
        tiny,
        symbolic x coords={a,T,g},
        xticklabel style={name=tick no \ticknum},
        xtick=data]
    \addplot coordinates {(a,0) (T,1) (g,2)};
    \end{axis}
    \draw[red,opacity=0.5] (tick no 0.base)
        -- (tick no 2.base);
\end{tikzpicture}
%
\begin{tikzpicture}
    \begin{axis}[
        title=With strut,
        tiny,
        symbolic x coords={a,T,g},
        xtick=data,
        xticklabel style={name=tick no \ticknum},
        typeset ticklabels with strut]
    \addplot coordinates {(a,0) (T,1) (g,2)};
    \end{axis}
    \draw[red,opacity=0.5] (tick no 0.base)
        -- (tick no 2.base);
\end{tikzpicture}
```

In order to make the normalize the tick labels, PGFPLOTS automatically inserts `\strut`. A `\strut` is a
TEX macro which inserts an empty box of "full height", including anything above or below the text's
baseline.

For standard axes, this key is basically equivalent to xticklabel=\strut\pgfmathprintnumber{\tick}.

Note that `\strut` is off by default as enlarges the bounding box unnecessarily for pure numeric nodes.
This is particularly unexpected for polaraxis, but also for normal plots.

4.15.3   Tick Scaling - Common Factors In Ticks

/pgfplots/scaled ticks=true|false|base 10:⟨e⟩|real:⟨num⟩|manual:{⟨label⟩}{⟨code⟩} (initially true)
/pgfplots/scaled x ticks=⟨one of the values⟩   (initially true)
/pgfplots/scaled y ticks=⟨one of the values⟩   (initially true)
/pgfplots/scaled z ticks=⟨one of the values⟩   (initially true)

Allows to factor out common exponents in tick labels for *linear axes*. For example, if you have tick
labels $20000, 40000$ and 60000, you may want to save some space and write $2, 4, 6$ with a separate factor
'$\cdot 10^4$'. Use 'scaled ticks=true' to enable this feature. In case of true, tick scaling will be triggered
if the data range is either too large or too small (see below).
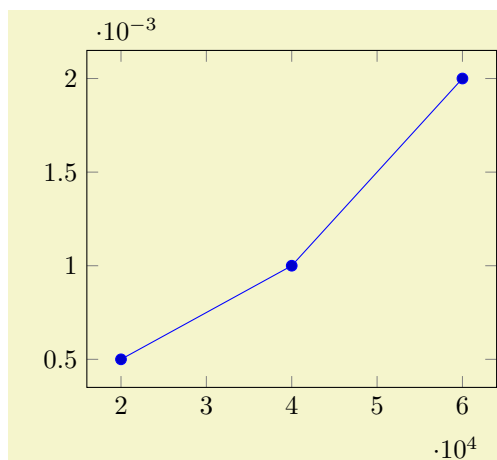
```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
\begin{axis}[scaled ticks=true]
    \addplot coordinates {
        (20000,0.0005)
        (40000,0.0010)
        (60000,0.0020)
    };
\end{axis}
\end{tikzpicture}%
```
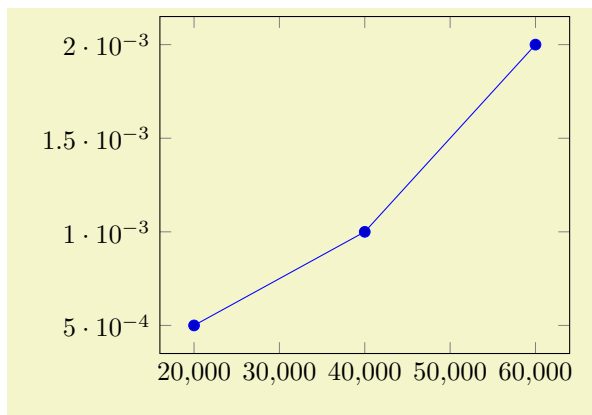
```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
\begin{axis}[scaled ticks=false]
    \addplot coordinates {
        (20000,0.0005)
        (40000,0.0010)
        (60000,0.0020)
    };
\end{axis}
\end{tikzpicture}
```

The `scaled ticks` key is a style which simply sets scaled ticks for both, x and y.

The value `base 10:`$\langle e \rangle$ allows to adjust the algorithm manually. For example, `base 10:3` will divide every tick label by 10^3:
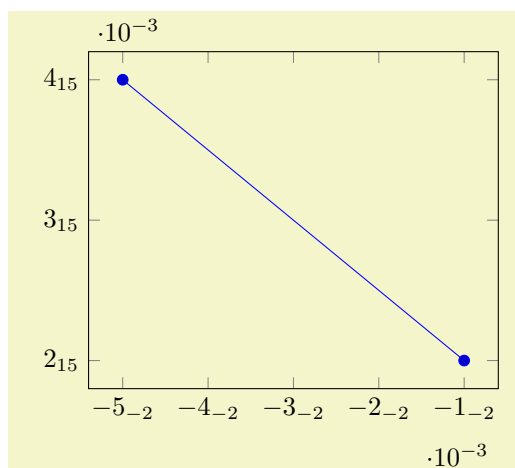

```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
    \begin{axis}[scaled ticks=base 10:3,
        /pgf/number format/sci subscript]
    \addplot coordinates
        {(-0.00001,2e12) (-0.00005,4e12) };
    \end{axis}
\end{tikzpicture}
```

Here, the `sci subscript` option simply saves space. In general, `base 10:`e will divide every tick by 10^e. The effect is not limited by the "too large or too small" decisions mentioned above.

The value `real:`$\langle num \rangle$ allows to divide every tick by a fixed $\langle num \rangle$. For example, the following plot is physically ranged from 0 to 2π, but the tick scaling algorithm is configured to divide every tick label by π.
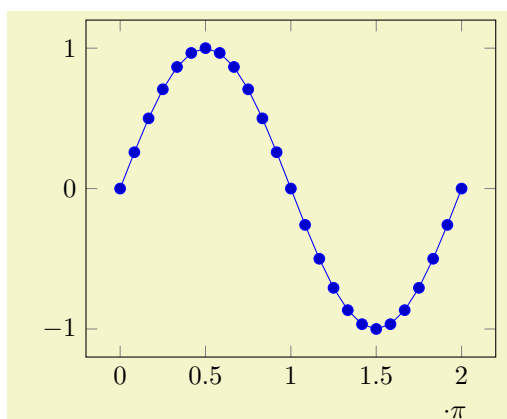

```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
    \begin{axis}[
        xtick={0,1.5708,...,10},
        domain=0:2*pi,
        scaled x ticks={real:3.1415},
        xtick scale label code/.code={$\cdot \pi$}]
    \addplot {sin(deg(x))};
    \end{axis}
\end{tikzpicture}
```

Setting `scaled ticks`=`real:`$\langle num \rangle$ also changes the `tick scale label code` to

```
\pgfkeys{/pgfplots/xtick scale label code/.code=
    {$\pgfkeysvalueof{/pgfplots/tick scale binop} \pgfmathprintnumber{#1}$}}.
```

The key `tick scale binop` is described below, it is set initially to `\cdot`.

A further – not very useful – example is shown below. Every x tick label has been divided by 2, every y tick label by 3.
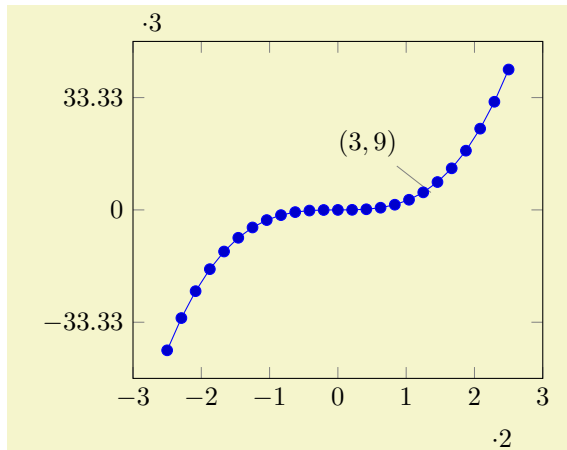
```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
    \begin{axis}[
        scaled x ticks=real:2,
        scaled y ticks=real:3]
    \addplot {x^3};
    \node[pin=135:{$(3,9)$}] at (3,9) {};
    \end{axis}
\end{tikzpicture}
```

The last option, `scaled ticks`=manual:{⟨*label*⟩}{⟨*code*⟩} allows even more customization. It allows *full control* over the displayed scaling label *and* the scaling code: ⟨*label*⟩ is used as-is inside of the tick scaling label while ⟨*code*⟩ is supposed to be a one-argument-macro which scales each tick. Example:
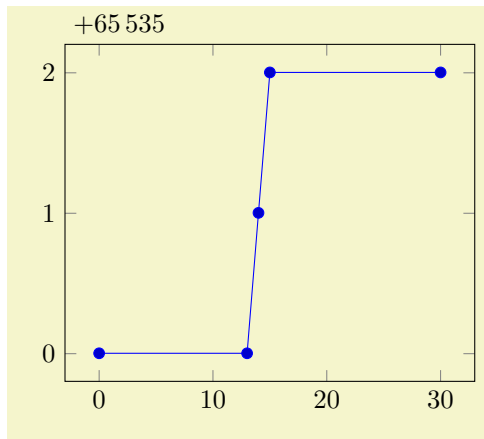
```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
\begin{axis}[
    % warning: the '%' signs are necessary (?)
    scaled y ticks=manual:{$+65\,535$}{%
        \pgfmathparse{#1-65535}%
    },
    yticklabel style={
        /pgf/number format/fixed,
        /pgf/number format/precision=1},
]
\addplot coordinates {
    (0, 65535)
    (13, 65535)
    (14, 65536)
    (15, 65537)
    (30, 65537)
};
\end{axis}
\end{tikzpicture}
```

The example uses `$+65\,535$` as tick scale label content. Furthermore, it defines the customized tick label formula $y - (+6.5535 \cdot 10^4) = y - 65535$ to generate y tick labels.

The ⟨*label*⟩ can be arbitrary. It is completely in user control. The second argument, ⟨*code*⟩ is supposed to be a one-argument-macro in which `#1` is the current tick position in floating point representation. The macro is expected to assign `\pgfmathresult` (as a number). The PGF manual [7] contains detailed documentation about its math engine.

This feature may also be used do transform coordinates in case they can't be processed with PGFPLOTS: transform them and supply a proper tick scaling method such that tick labels represent the original range.

If ⟨*label*⟩ is empty, the tick scale label won't be drawn (and no space will be occupied).

Tick scaling does *not* work for logarithmic axes.

/pgfplots/xtick scale label code/.code={⟨...⟩}
/pgfplots/ytick scale label code/.code={⟨...⟩}
/pgfplots/ztick scale label code/.code={⟨...⟩}

Allows to change the default code for scaled tick labels. The default is

```
\pgfplotsset{
    xtick scale label code/.code={$\cdot 10^{#1}$}
}
```

More precisely, it is

```
\pgfplotsset{
    xtick scale label code/.code={$\pgfkeysvalueof{/pgfplots/tick scale binop} 10^{#1}$}
}
```

and the initial value of `tick scale binop` is `\cdot`, but it can be changed to `\times` if desired.

If the code is empty, no tick scale label will be drawn (and no space is consumed).

/pgfplots/**tick scale label code**/.code={⟨...⟩}

A style which sets `xtick scale label code` and those for y and z.

/pgfplots/**tick scale binop**={⟨*T$_E$X math operator*⟩}   (initially `\cdot`)

Sets the binary operator used to display tick scale labels.
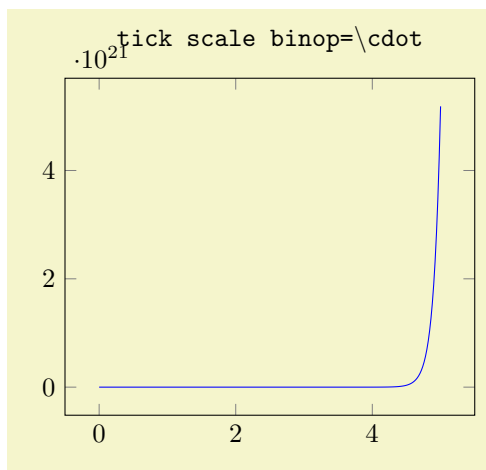

```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
\begin{axis}[
    title=\texttt{tick scale
        binop=\textbackslash cdot}]
\addplot
    [mark=none,blue,samples=250,
     domain=0:5]
    {exp(10*x)};
\end{axis}
\end{tikzpicture}
```
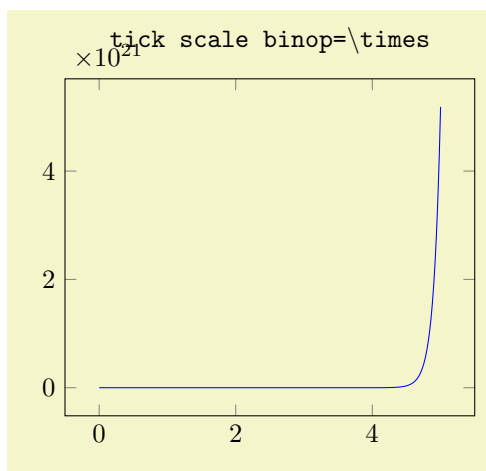


```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
\begin{axis}[
    title=\texttt{tick scale
        binop=\textbackslash times},
    tick scale binop=\times]
\addplot
    [mark=none,blue,samples=250,
     domain=0:5]
    {exp(10*x)};
\end{axis}
\end{tikzpicture}
```

/pgfplots/**scale ticks below exponent**={⟨*exponent*⟩}   (initially `-1`)

Allows fine tuning of the '`scaled ticks`' algorithm: if the axis limits are of magnitude 10^e and $e < ⟨exponent⟩$, the common prefactor 10^e will be factored out. The default is

/pgfplots/**scale ticks above exponent**={⟨*exponent*⟩}   (initially `3`)

Allows fine tuning of the '`scaled ticks`' algorithm: if the axis limits are of magnitude 10^e and $e > ⟨exponent⟩$, the common prefactor 10^e will be factored out.

4.15.4   Tick Fine-Tuning

The tick placement algorithm depends on a number of parameters which can be tuned to get better results.

/pgfplots/**max space between ticks**={⟨*number*⟩}   (initially 35)

    Configures the maximum space between adjacent ticks in full points. The suffix "pt" has to be omitted and fractional numbers are not supported.

/pgfplots/**try min ticks**={⟨*number*⟩}   (initially 4)

    Configures a loose lower bound on the number of ticks. It should be considered as a suggestion, not a tight limit. This number will increase the number of ticks if 'max space between ticks' produces too few of them.

    The total number of ticks may still vary because not all fractional numbers in the axis' range are valid tick positions.

/pgfplots/**try min ticks log**={⟨*number*⟩}   (initially 3)

    The same as try min ticks, but for logarithmic axis.

/pgfplots/**tickwidth**={⟨*dimension*⟩}   (initially 0.15cm)
/pgfplots/**major tick length**={⟨*dimension*⟩}   (initially 0.15cm)

    Sets the length of major tick lines.

    It can be accessed using \pgfkeysvalueof{/pgfplots/major tick length}.

/pgfplots/**subtickwidth**={⟨*dimension*⟩}   (initially 0.1cm)
/pgfplots/**minor tick length**={⟨*dimension*⟩}   (initially 0.1cm)

    Sets the length of minor tick lines.

    It can be accessed using \pgfkeysvalueof{/pgfplots/minor tick length}.

/pgfplots/**xtick placement tolerance**   (initially 0.05pt)
/pgfplots/**ytick placement tolerance**   (initially 0.05pt)
/pgfplots/**ztick placement tolerance**   (initially 0.05pt)

    Tick lines and labels will be placed if they are no more than this tolerance beyond the axis limits. This threshold should be chosen such that it does not produce visible differences while still providing fault tolerance.

    The threshold is given in paper units of the final figure.

/pgfplots/**log basis x**={⟨*number*⟩}   (initially empty)
/pgfplots/**log basis y**={⟨*number*⟩}   (initially empty)
/pgfplots/**log basis z**={⟨*number*⟩}   (initially empty)

    Allows to change the logarithms used for logarithmic axes.

    Changing to a different log basis is nothing but a scale. However, it also changes the way tick labels are displayed: they will also be shown in the new basis.
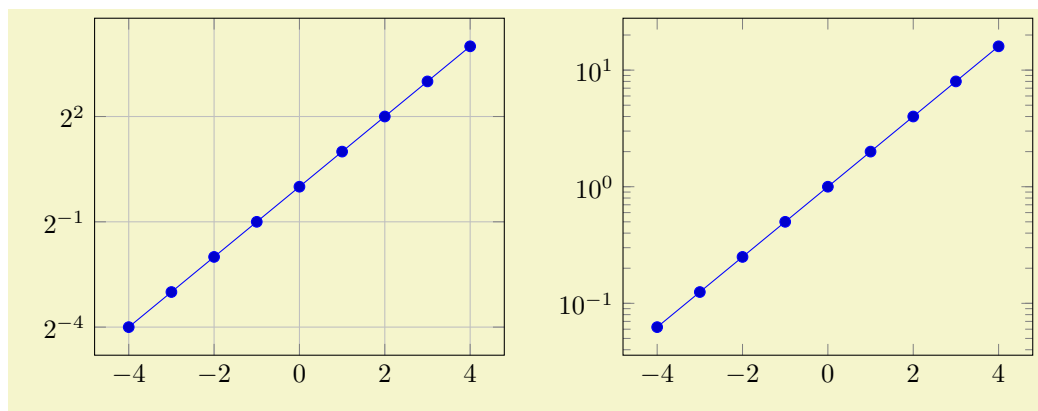
```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
    \begin{semilogyaxis}[log basis y=2,grid=major,samples at={-4,...,4}]
        \addplot {2^x};
    \end{semilogyaxis}
\end{tikzpicture}
~
\begin{tikzpicture}
    \begin{semilogyaxis}[log basis y=10,samples at={-4,...,4}]
        \addplot {2^x};
    \end{semilogyaxis}
\end{tikzpicture}
```

The initial setting is '`log basis x`=' which defaults to: the natural logarithm for any coordinates (basis $\exp(1)$), and the logarithm base 10 for the display of tick labels.

If the log basis is changed to something different than the empty string, the chosen logarithm will be applied to any input coordinate (if the axis scale is log as well) and tick labels will be displayed in this basis.

In other words: usually, you see log axes base 10 and that's it. It is only interesting for coordinate filters: the initial setting (with empty ⟨*number*⟩) uses coordinate lists basis *e* although the display will use basis 10 (i.e. it is rescaled). Any non-empty value ⟨*number*⟩ causes both, coordinate lists *and* display to use ⟨*number*⟩ as basis for the logarithm. The javascript code of the `clickable` library will always use the *display* basis (which is usally 10) when it computes slopes.

Technical remarks. When `log basis x` is used, the style `log basis ticks={`⟨*axis char*⟩`}` will be installed (in this case `log basis ticks=x`). This style in turn will change `log number format code`.

Please note that `xtickten` will be used differently now: it will provide the desired ticks in the new basis! Despite the misleading name "`ten`", `xtickten`=`{1,2,3,4}` will yield ticks at $2^1, 2^2, 2^3, 2^4$ if `log basis x`=2 has been set.

/pgfplots/**hide obscured x ticks**=true|false	(initially `true`)
/pgfplots/**hide obscured y ticks**=true|false	(initially `true`)
/pgfplots/**hide obscured z ticks**=true|false	(initially `true`)

Allows to configure whether PGFPLOTS should hide ticks and their labels if it assumes that they are obscured by other axis lines.
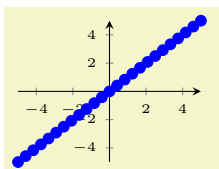
```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
    \begin{axis}[
        tiny,
        axis x line=center,
        axis y line=center,
        %hide obscured x ticks=false,
        %hide obscured y ticks=false,
    ]
    \addplot {x};
    \end{axis}
\end{tikzpicture}
```

```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
    \begin{axis}[
        tiny,
        axis x line=center,
        axis y line=center,
        hide obscured x ticks=false,
        hide obscured y ticks=false,
    ]
    \addplot {x};
    \end{axis}
\end{tikzpicture}
```
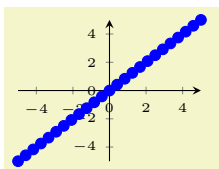
Note that this key applies if only and only if one of `axis x line`, `axis y line`, or `axis z line` is *not* `box`.

4.16 Grid Options

/pgfplots/xminorgrids=true|false	(initially `false`)
/pgfplots/yminorgrids=true|false	(initially `false`)
/pgfplots/zminorgrids=true|false	(initially `false`)
/pgfplots/xmajorgrids=true|false	(initially `false`)
/pgfplots/ymajorgrids=true|false	(initially `false`)
/pgfplots/zmajorgrids=true|false	(initially `false`)
/pgfplots/grid=minor|major|both|none	(initially `false`)

Enables/disables different grid lines. Major grid lines are placed at the normal tick positions (see xmajorticks) while minor grid lines are placed at minor ticks (see xminorticks).

This example employs the coordinates defined on page 189.
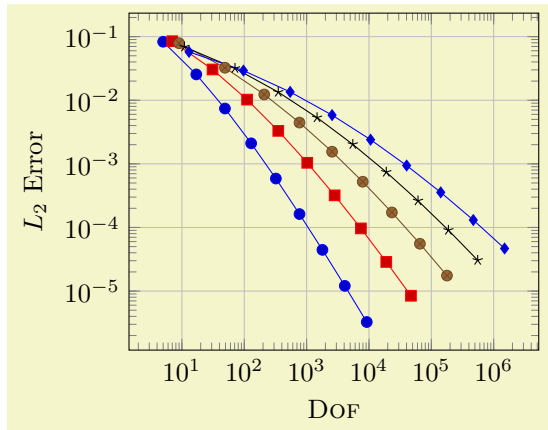

```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
\begin{loglogaxis}[
    xlabel={\textsc{Dof}},
    ylabel={$L_2$ Error},
    grid=major
]
% see above for this macro:
\plotcoords
\end{loglogaxis}
\end{tikzpicture}
```
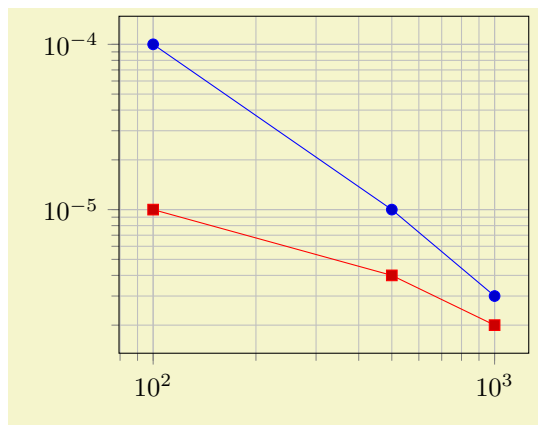


```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
\begin{loglogaxis}[
    grid=both,
    tick align=outside,
    tickpos=left]
\addplot coordinates
    {(100,1e-4) (500,1e-5) (1000,3e-6)};
\addplot coordinates
    {(100,1e-5) (500,4e-6) (1000,2e-6)};
\end{loglogaxis}
\end{tikzpicture}
```

Grid lines will be drawn before tick lines are processed, so ticks will be drawn on top of grid lines. You can configure the appearance of grid lines with the styles

```
\pgfplotsset{grid style={help lines}} % modifies the style 'every axis grid'
\pgfplotsset{minor grid style={color=blue}} % modifies the style 'every minor grid'
\pgfplotsset{major grid style={thick}} %modifies the style 'every major grid'
```

4.17 Custom Annotations

Often, one may want to add custom drawing elements or descriptive texts to an axis. These graphical elements should be associated to some logical coordinate, grid point, or perhaps they should just be placed somewhere into the axis.

PGFPLOTS assists with the following ways when it comes to annotations:

1. You can explicitly provide any TikZ instruction like `\draw ... ;` into the axis. Here, the axis cs allows to provide coordinates of PGFPLOTS.

   Furthermore, rel axis cs allows to position TikZ elements relatively (like "50% of the axis' width").

2. PGFPLOTS can automatically generate nodes at every coordinate using its `nodes near coords` feature.

3. PGFPLOTS allows you to place nodes on a plot, using the `\addplot ... node[pos=`⟨*fraction*⟩`] {};` feature.

This section explains all of the approaches, except for the `nodes near coords` feature which is documented in its own section.

4.17.1   Accessing Axis Coordinates in Graphical Elements

Coordinate system `axis cs`

PGFPLOTS provides a new coordinate system for use inside of an axis, the "axis coordinate system", `axis cs`.

Note that this coordinate system is actually the default one whenever one writes graphical elements in an axis. There is just one place where you really need to provide this coordinate system explicitly: if you have `symbolic x coords`.

Consequently, you can refer to this documentation as reference only; most standard use-cases work directly (as of `compat=1.11`).

It can be used to draw any TikZ-graphics at axis coordinates. It is used like

```
\draw
   (axis cs:18943,2.873391e-05)
|- (axis cs:47103,8.437499e-06);
```
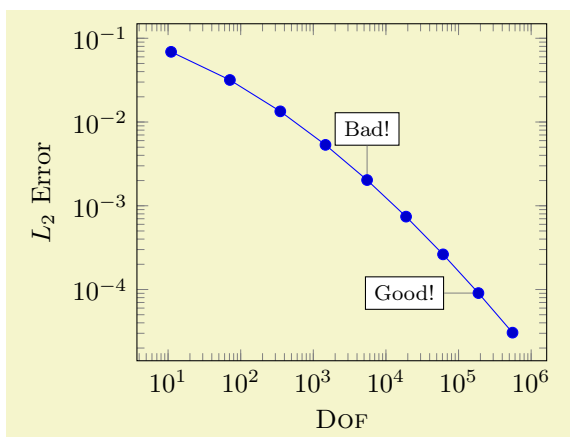


```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\tikzstyle{every pin}=[fill=white,
    draw=black,
    font=\footnotesize]
\begin{tikzpicture}
    \begin{loglogaxis}[
        xlabel={\textsc{Dof}},
        ylabel={$L_2$ Error}]

    \addplot coordinates {
        (11,       6.887e-02)
        (71,       3.177e-02)
        (351,      1.341e-02)
        (1471,     5.334e-03)
        (5503,     2.027e-03)
        (18943,    7.415e-04)
        (61183,    2.628e-04)
        (187903, 9.063e-05)
        (553983, 3.053e-05)
    };

    \node[coordinate,pin=above:{Bad!}]
        at (axis cs:5503,2.027e-03) {};
    \node[coordinate,pin=left:{Good!}]
        at (axis cs:187903,9.063e-05)    {};
    \end{loglogaxis}
\end{tikzpicture}
```

However, since `axis cs` is the default coordinate system of PGFPLOTS, you can simply omit the prefix `axis cs:` in coordinate descriptions[58].

---

[58]As of PGFPLOTS version 1.11 and `compat=1.11`. All older versions explicitly require the prefix; coordinates without the prefix will be placed at the wrong position.
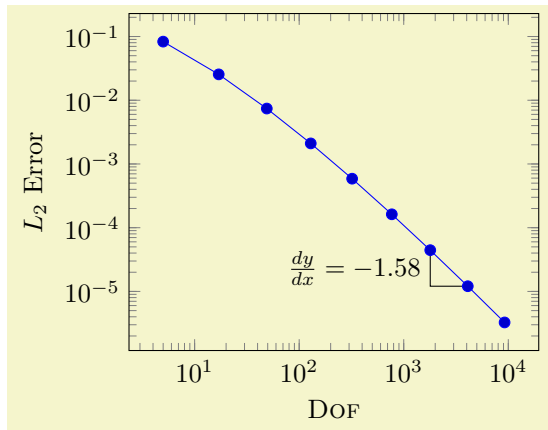
```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
\begin{loglogaxis}[
    xlabel=\textsc{Dof},
    ylabel=$L_2$ Error
]
\draw
        (1793,4.442e-05)
    |-  (4097,1.207e-05)
    node[near start,left]
    {$\frac{dy}{dx} = -1.58$};

\addplot coordinates {
    (5,      8.312e-02)
    (17,    2.547e-02)
    (49,    7.407e-03)
    (129,   2.102e-03)
    (321,   5.874e-04)
    (769,   1.623e-04)
    (1793, 4.442e-05)
    (4097, 1.207e-05)
    (9217, 3.261e-06)
};
\end{loglogaxis}
\end{tikzpicture}
```

The effect of `axis cs` is to apply any custom transformations (including `symbolic x coords`), logarithms, data scaling transformations or whatever PGFPLOTS usually does and provides a low level PGF coordinate as result.

In case you need only one component (say, the y component) of such a vector, you can use the `\pgfplotstransformcoordinatey` command, see Section 8.4 for details about basic level access.

The result of `axis cs` is always an absoute position inside of an axis. This means, in particular, that *adding* two points has unexpected effects: the expression `(0,0) ++ (1,0)` is not necessarily the same as `(1,0)`. The background for such unexpected effects is that PGFPLOTS applies a *shifted* linear transformation which moves the origin in order to support its high accuracy and high data range (compare the documentation of `disabledatascaling`).

In order to express *relative* positions (or lengths), you need to use `axis direction cs`.

Coordinate system `axis direction cs`

While `axis cs` allows to supply *absolute positions*, `axis direction cs` supplies *directions*. It allows to express *relative* positions, includings lengths and dimensions, by means of axis coordinates.

As noted in the documentation for `axis cs`, adding two coordinates by means of the Ti*k*Z `++` operator may have unexpected effects. The correct way for `++` operations is `axis direction cs`:
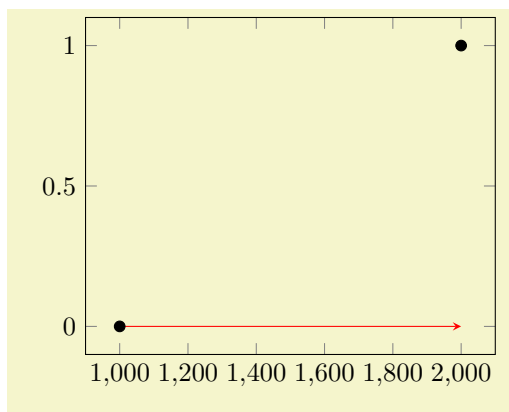
```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
\begin{axis}
    \draw[red,-stealth]
        (1000,0)
        -- % = line-to
         ++ % = calculate a vector sum
        (axis direction cs:1000,0);

    \addplot [only marks,mark=*]
        coordinates { (1000,0) (2000,1) };
\end{axis}
\end{tikzpicture}
```

Here, the target of the red arrow is the position `(2000,0)` as expected.

Using relative positions is mainly useful for linear axes. Applying this command to log-axes might still work, but it requires more care.

One use-case is to supply lengths – for example in order to support `circle` or `ellipse` paths. The correct way to draw an ellipse in PGFPLOTS would be to specify the two involved radii by means of

two (axis direction cs:$\langle x,y \rangle$) expressions. In general, this is possible if you use the basic level macros \pgfpathellipse and \pgfplotspointaxisdirectionxy. Please refer to the documentation of \pgfplotspointaxisdirectionxy for two examples of drawing arbitrary ellipses by means of this method.

Since drawing circles and ellipses inside of an axis is a common use-case, PGFPLOTS automatically communicates its coordinate system transformations to TikZ: whenever you write \draw ellipse[x radius=$\langle x \rangle$,y radius=$\langle y \rangle$], the arguments $\langle x \rangle$ and $\langle y \rangle$ are considered to be PGFPLOTS direction vectors and are handed over to axis direction cs. Consequently, ellipses with axis parallel radii are straight-forward and use the normal TikZ syntax:
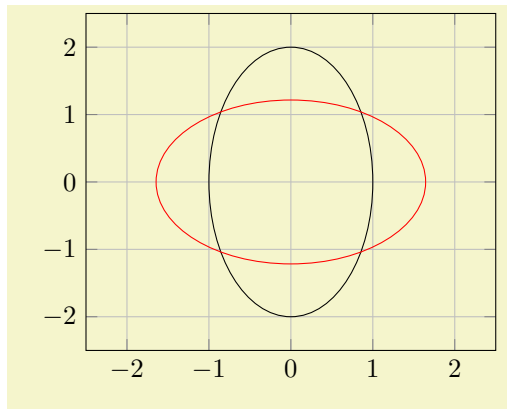

```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
% requires \pgfplotsset{compat=1.5.1} !
\begin{tikzpicture}
\begin{axis}[
    xmin=-2.5,   xmax=2.5,
    ymin=-2.5,   ymax=2.5,
    xtick={-2,-1,0,1,2},
    ytick={-2,-1,0,1,2},
    grid=major,
]
    % standard tikz syntax:
    \draw[black] (0,0)
        ellipse [
            x radius=1, y radius=2];

    \draw[red]    (0,0)
        ellipse [rotate=90,
            x radius=1, y radius=2];
    % see \pgfplotspointaxisdirectionxy
    % for arbitrary ellipses
\end{axis}
\end{tikzpicture}
```

Here, the two ellipses are specified as usual in TikZ. PGFPLOTS ensures that all necessary transformations are applied to the two radii. Note that PGFPLOTS usually has different axis scales for x and y. As a consequence, the rotated red ellipse does not fit into the axis lines; we would need to use axis equal to allow properly rotated ellipses.

Attention: this modification to circles and ellipses requires \pgfplotsset{compat=1.5.1}.

The same applies to circles: in the standard view, a circle with radius=r will appear as an ellipse due to the different axis scales. Supplying axis equal results in true circles:
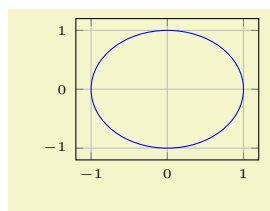

```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
% requires \pgfplotsset{compat=1.5.1} !
\begin{tikzpicture}
\begin{axis}[tiny,enlargelimits,
    xmin=-1,xmax=1,
    ymin=-1,ymax=1,
    xtick={-1,0,1},
    ytick={-1,0,1},
    grid=major,
]
    \draw[blue] (0,0) circle[radius=1];
\end{axis}
\end{tikzpicture}
```
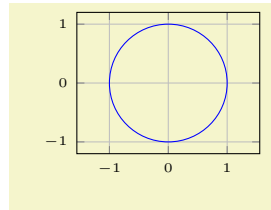
```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
\begin{axis}[tiny,enlargelimits,
    axis equal,
    xmin=-1,xmax=1,
    ymin=-1,ymax=1,
    xtick={-1,0,1},
    ytick={-1,0,1},
    grid=major,
]
    \draw[blue] (0,0) circle[radius=1];
\end{axis}
\end{tikzpicture}
```

In case you need access to `axis direction cs` inside of math expressions, you can employ the additional math function `transformdirectionx`. It does the same as `axis direction cs`, but only in x direction. The result of `transformdirectionx` is a dimensionless unit which can be interpreted relative to the current PGF x unit vector e_x (see the documentation of `\pgfplotstransformdirectionx` for details). There are the math commands `transformdirectionx`, `transformdirectiony`, and (if the axis is three–dimensional) `transformdirectionz`. Each of them defines `\pgfmathresult` to contain the result of `\pgfplotstransformdirectionx` (or its variants for y and z, respectively).

Coordinate system `rel axis cs`

The "relative axis coordinate system", `rel axis cs`, uses the complete axis vectors as units. That means '$x = 0$' denotes the point on the lower x axis range and '$x = 1$' the point on the upper x axis range (see the remark below for `x dir`=`reverse`).
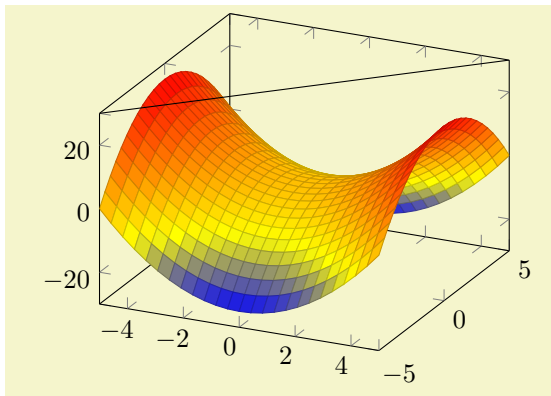
```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
\begin{axis}

    \addplot3[surf] {x^2 - y^2};
    \draw  (rel axis cs:0,0,1)
        -- (rel axis cs:1,1,1);
\end{axis}
\end{tikzpicture}
```
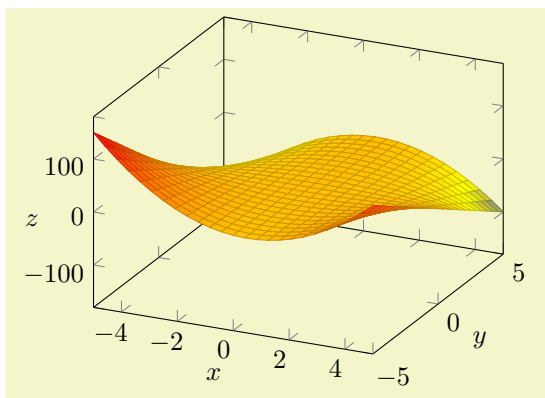
```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
\begin{axis}[
    xlabel=$x$,
    ylabel=$y$,
    zlabel=$z$,
    every axis x label/.style={
        at={(rel axis cs:0.5,-0.15,-0.15)}},
    every axis y label/.style={
        at={(rel axis cs:1.15,0.5,-0.15)}},
    every axis z label/.style={
        at={(rel axis cs:-0.15,-0.15,0.5)}},
]

    \addplot3[surf] {x*(1-x)*y};
\end{axis}
\end{tikzpicture}
```

Points identified by `rel axis cs` use the syntax

(`rel axis cs:`$\langle x \rangle$,$\langle y \rangle$) or

(`rel axis cs:`$\langle x \rangle$,$\langle y \rangle$,$\langle z \rangle$)

where $\langle x \rangle$, $\langle y \rangle$ and $\langle z \rangle$ are coordinates or constant mathematical expressions. The second syntax is only available in three dimensional axes.

There is one specialty: if you reverse an axis (with `x dir`=reverse), points provided by `rel axis cs` will be *unaffected* by the axis reversal. This is intended to provide consistent placement even for reversed axes. Use `allow reversal of rel axis cs`=false to disable this feature.

There is also a low–level interface to access the transformations and coordinates, see Section 8 on page 535.

Predefined node `current plot begin`

This coordinate will be defined for every plot and can be used is ⟨*trailing path commands*⟩ or after a plot. It is the first coordinate of the current plot.

Predefined node `current plot end`

This coordinate will be defined for every plot. It is the last coordinate of the current plot.

`/pgfplots/`**allow reversal of rel axis cs**=true|false   (initially `true`)

A fine-tuning key which specifies how to deal with `x dir`=reverse and `rel axis cs` and `ticklabel cs`.

The initial configuration `true` means that points placed with `rel axis cs` and/or `ticklabel cs` will be at the same position inside of the axes even if its ordering has been reversed. The choice `false` will disable the special treatment of `x dir`=reverse.

4.17.2 Placing Nodes on Coordinates of a Plot

The `\addplot` command is not only used for PGFPLOTS, it can also carry additional drawing instructions which are handed over to TikZ after the plot's path is complete. Among others, this can be used to add further nodes on the path.

`/tikz/`**pos**={⟨*fraction*⟩}

The ⟨*fraction*⟩ identifies a part of the recently completed plot if it is used before the trailing semicolon:
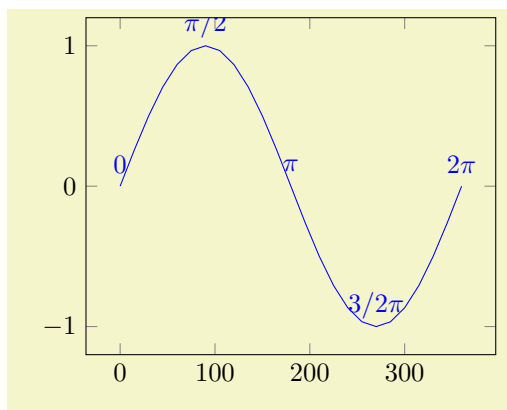
```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
    \begin{axis}
    \addplot[blue,domain=0:360] {sin(x)}
    [yshift=8pt]
        node[pos=0] {$0$}
        node[pos=0.25] {$\pi/2$}
        node[pos=0.5] {$\pi$}
        node[pos=0.75] {$3/2\pi$}
        node[pos=1] {$2\pi$}
    ;
    \end{axis}
\end{tikzpicture}
```

Here, the `[yshift=8pt]` tells TikZ to shift all following nodes upwards. The `node[pos=0] {$0$}` instruction tells TikZ to add a text node at 0% of the recently completed plot. The relative position 0% (`pos`=0) refers to the first coordinate which has been seen by PGFPLOTS, and 100% (`pos`=1) refers to the last coordinate. Any value between 0 and 1 is interpolated in-between. Note that all these nodes belong to the plot's visualization (which is terminated by the semicolon). Consequently, all these nodes inherit the same graphic settings (like color choices).

The position on the plot is computed by PGFPLOTS using *logical* coordinates. That means: it computes the overall length of the curve before the curve is projected to screen coordinates and identifies the desired position[59]. Afterwards, it projects the final position to screen coordinates. Thus, the position identifies a location on the plot which is always the same, even in case of a rotated three-dimensional axis. PGFPLOTS will linearly interpolate the fraction between successive coordinates.

Valid choices for ⟨*fraction*⟩ are any numbers in the range [0, 1].

Note that the precise meaning of `pos` depends on the current plot handler: for most plot handlers, it defaults to linear interpolation (as in the examples above). For `only marks`, `scatter`, `ybar`, `xbar`, `ybar`

---

[59]This can be a time-consuming process. Consider using the external library if you have lots of such figures.

`interval`, and `xbar interval`, it snaps to the nearest encountered coordinate. In this context, "snap to nearest" means that `pos`=p refers to the coordinate with index $i = \text{round}(p \cdot N)$ where N is the total number of points:
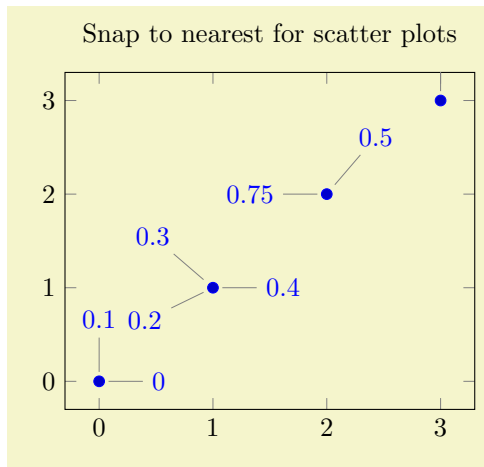

```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
\begin{axis}[title=Snap to nearest for scatter plots]
\addplot+[only marks]
    coordinates {(0,0) (1,1) (2,2) (3,3)}
    node[pos=0,   pin=0  :0   ] {}
    node[pos=0.1, pin=90 :0.1 ] {}
    node[pos=0.2, pin=200:0.2 ] {}
    node[pos=0.3, pin=135:0.3 ] {}
    node[pos=0.4, pin=0  :0.4 ] {}
    node[pos=0.5, pin=60 :0.5 ] {}
    node[pos=0.75,pin=180:0.75] {}
    node[pos=1,   pin=90 :1   ] {}
;
\end{axis}
\end{tikzpicture}
```

the previous example shows that `pos`=p maps to one of the four available coordinates, namely the one whose index is closest to $p \cdot N$. Note that in such a case, the distance between coordinates is irrelevant – only the coordinate index counts.

Note that the fact that PGFPLOTS uses *logical* coordinates to compute the target positions can produce unexpected effects if x and y axis operate on a different scales. Suppose, for example, that x is always of order 10^3 whereas y is of order 10^{-3}. In such a scenario, the y coordinate have no significant contribution to the curve's length – although the rescaled axes clearly show "significant" y dynamics. Consider using `axis equal` together with `pos` to produce comparable effects.

`/tikz/sloped`   (initially `false`)

Providing the TikZ key `sloped` to a node identified by `pos` causes it to be rotated such that it adapts to the plot's gradient.
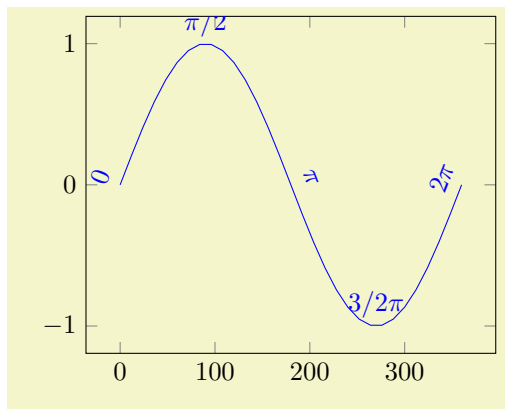

```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
    \begin{axis}
    \addplot[blue,domain=0:360,samples=31] {sin(x)}
    [every node/.style={yshift=8pt},sloped]
        node[pos=0] {$0$}
        node[pos=0.25] {$\pi/2$}
        node[pos=0.5] {$\pi$}
        node[pos=0.75] {$3/2\pi$}
        node[pos=1] {$2\pi$}
    ;
    \end{axis}
\end{tikzpicture}
```

Note that the sequence in which `sloped` and shift transformations are applied is important: if shifts are applied first (as would be the case without the `every node/.style` construction), the shifts do not respect the rotation. If `sloped` is applied first, any subsequent shifts will be applied in the *rotated* coordinates. Thus, the case `every node/.style={yshift=8pt}` shifts every node by `8pt` in direction of its normal vector.

The `sloped` transformation is based on the gradient between two points (the two points adjacent to `pos`). Consequently, it inherits any sampling weaknesses. To see this, consider the example above with a different number of samples:
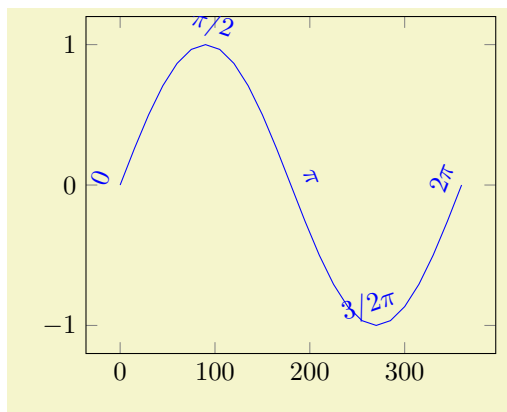
```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
% same as above with different number of samples
\begin{tikzpicture}
    \begin{axis}
    \addplot[blue,domain=0:360,samples=25] {sin(x)}
    [every node/.style={yshift=8pt},sloped]
        node[pos=0] {$0$}
        node[pos=0.25] {$\pi/2$}
        node[pos=0.5] {$\pi$}
        node[pos=0.75] {$3/2\pi$}
        node[pos=1] {$2\pi$}
    ;
    \end{axis}
\end{tikzpicture}
```

Here, the two extreme points have small slopes due to the sampling. While this does not seriously affect the quality of the plot, it has a huge impact on the transformation matrizes. Keep this in mind when you work with sloped (perhaps it even helps to add a further rotate argument).

/tikz/allow upside down=true|false   (initially false)

If /tikz/sloped is enabled and one has some difficult line plot, the transformation may cause nodes to be drawn upside down. The default configuration allow upside down=false will switch the rotation matrix, whereas allow upside down allows this case.

/tikz/pos segment={⟨segment index⟩}   (initially empty)

Occasionally, one has a single plot which consists of multiple segments (like those generated by empty line=jump or contour prepared). The individual segments will typically have different lengths, so it is tedious to identify a position on one of these segments.

If pos segment=⟨segment index⟩ is non-empty, the key pos=⟨fraction⟩ is interpreted relatively to the provided segment rather than the whole plot. The argument ⟨segment index⟩ is an integer, where 0 denotes the first segment.
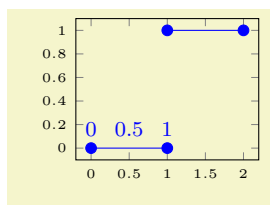

```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
\begin{axis}[tiny]
\addplot coordinates {
    (0,0) (1,0)

    (1,1) (2,1)}
    [pos segment=0,yshift=7pt,font=\footnotesize]
    node[pos=0] {0}
    node[pos=0.5] {0.5}
    node[pos=1] {1};
\end{axis}
\end{tikzpicture}
```

Here, the plot has two segments. However, all three annotation nodes are placed with pos segment=0.
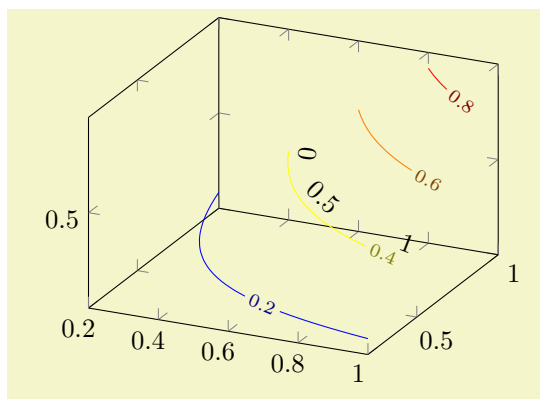

```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
\begin{axis}
\addplot3[contour gnuplot,domain=0:1] {x*y}
    [sloped,
     allow upside down,
     pos segment=2,
     every node/.style={yshift=7pt}]
    node[pos=0] {0}
    node[pos=0.5] {0.5}
    node[pos=1] {1}
    ;
\end{axis}
\end{tikzpicture}
```

This plot has four segments (which are generated automatically by the plot handler). The annotation nodes are placed on the third segment, where sloped causes them to be rotated, allow upside down

improves the rendering of the '0', and `every node/.style` install a shift in direction of the normal vector (see the documentation of `sloped` for details).

Occasionally, one wants to place a node using `pos` *and* one wants to typeset the coordinates of that point inside of the node. This can be accomplished using `\pgfplotspointplotattime`:

`\pgfplotspointplotattime`
`\pgfplotspointplotattime{⟨fraction⟩}`

This command is part of the `pos={⟨fraction⟩}` implementation: it defines the current point of PGF to ⟨fraction⟩ of the current plot. Without an argument in curly braces, `\pgfplotspointplotattime` will take the current argument of the `pos` key.

Thus, the command computes the basic PGF coordinates – but it also returns the *logical* coordinates of the resulting point into the following keys:

`/data point/x`   (no value)
`/data point/y`   (no value)
`/data point/z`   (no value)

After `\pgfplotspointplotattime` returns, these macros contain the x, y, and z coordinates of the resulting point. They can be used by means of `\pgfkeysvalueof{/data point/x}`, for example.
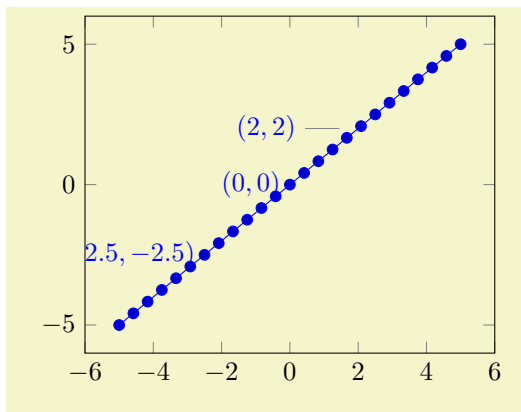
```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
    \begin{axis}
\addplot {x}
    [left,/pgf/number format/relative=0]
node[pos=0.5] {%
  \pgfplotspointplotattime
  $(\pgfmathprintnumber
        {\pgfkeysvalueof{/data point/x}},
    \pgfmathprintnumber
        {\pgfkeysvalueof{/data point/y}})$
}
node[pos=0.25] {%
  \pgfplotspointplotattime
  $(\pgfmathprintnumber
        {\pgfkeysvalueof{/data point/x}},
    \pgfmathprintnumber
        {\pgfkeysvalueof{/data point/y}})$
}
node[pos=0.7,pin=180:{%
  \pgfplotspointplotattime{0.7}
  $(\pgfmathprintnumber
        {\pgfkeysvalueof{/data point/x}},
    \pgfmathprintnumber
        {\pgfkeysvalueof{/data point/y}})$
}] {}
    ;
    \end{axis}
\end{tikzpicture}
```

In the example above, three nodes have been placed using different `pos=` arguments. Invoking `\pgfplotspointplotattime` inside of the associated node's body checks if `pos` already has a value and uses that value. The third node displays the coordinates inside of a `pin`. Due to internals of TikZ, the `pin` knows nothing about the `pos=0.7` argument of its enclosing `node`, so we need to replicate the '0.7' argument for `\pgfplotspointplotattime{0.7}`. The `/pgf/number format/relative=0` style causes the number printer to round relative to 10^0 (compare against the same example without this style).

In case you have `symbolic x coords` (or any other `x coord inv tafo` which produces non-numeric results), the output stored in `/data point/x` will be the symbolic expression:
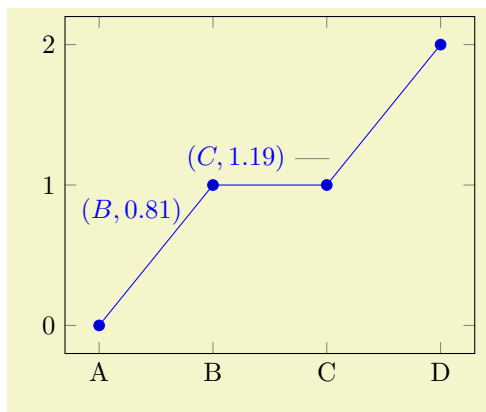
```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
    \begin{axis}[symbolic x coords={A,B,C,D}]
\addplot coordinates {(A,0) (B,1) (C,1) (D,2)}
    [left]
node[pos=0.3] {%
  \pgfplotspointplotattime
  $(\pgfkeysvalueof{/data point/x},
    \pgfmathprintnumber
        {\pgfkeysvalueof{/data point/y}})$
}
node[pos=0.7,pin=180:{%
  \pgfplotspointplotattime{0.7}
  $(\pgfkeysvalueof{/data point/x},
    \pgfmathprintnumber
        {\pgfkeysvalueof{/data point/y}})$
}] {}
    ;
    \end{axis}
\end{tikzpicture}
```

In that specific case, you have to avoid `\pgfmathprintnumber` since the argument is *no* number. Note that `symbolic x coords` cannot return fractions between, say, A and B as you would expect. However, the point will still be placed at the fractional position (unless you have a `scatter` or `bar` plot).

The computation of coordinates for the `pos` feature is computationally expensive for plots with many points. To reduce time, PGFPLOTS will cache computed values: invoking the command `\pgfplotspointplotattime` multiple times with the same argument will reuse the computed value.

4.17.3 Placing Decorations on Top of a Plot

Ti*k*Z comes with the powerful `decorations` library (or better: set of libraries). Decorations allow to replace or extend an existing path by means of fancy additional graphics. An introduction into the decorations functionality of Ti*k*Z is beyond the scope of this manual and the interested reader should read the associated section in [7].

This section shows how to use decorations to enhance plots in PGFPLOTS. Suppose you have some graphics for which you would like to add "direction pointers":
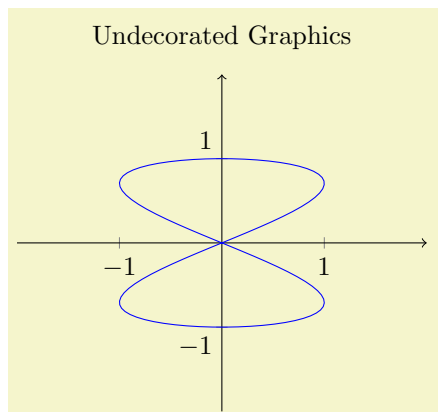
```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}[]
% An undecorated graphics with a lot of
% pretty-printing styles:
\begin{axis}[
    axis lines=middle,
    title=Undecorated Graphics,
    xmin=-2, xmax=2, ymin=-2, ymax=2,
    xtick={-1,1}, ytick={-1,1},
    % this disables the standard
    % tick label *text* (but not the line)
    yticklabel=\ ,
    extra description/.code={
        % this generates custom y labels to implement
        % individual styles for every tick:
        \node[below left] at (axis cs:0,-1) {$-1$};
        \node[above left] at (axis cs:0,1) {$1$};
    },
    axis line style={->},
  ]
  \addplot[blue,samples=100,domain=0:2*pi]
    ({sin(deg(2*x))}, {sin(deg(x))});
\end{axis}
\end{tikzpicture}
```

Our aim is to add short pointers indicating the direction of the parameterization.

The solution is to use `\usetikzlibrary{decorations.markings}` and a decoration inside of `\addplot`:

Decorated Graphics
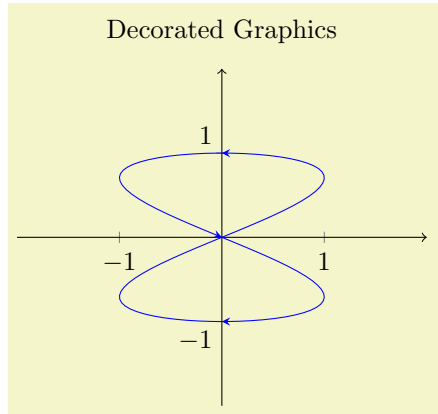
```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
% requires \usetikzlibrary{decorations.markings}
\begin{tikzpicture}[]
% Same as in previous example, but with decorations:
\begin{axis}[axis lines=middle,
    title=Decorated Graphics,
    xmin=-2, xmax=2, ymin=-2, ymax=2,
    xtick={-1,1}, ytick={-1,1},
    % this disables the standard
    % tick label *text* (but not the line)
    yticklabel=\ ,
    extra description/.code={
        % this generates custom y labels to implement
        % individual styles for every tick:
        \node[below left] at (axis cs:0,-1) {$-1$};
        \node[above left] at (axis cs:0,1) {$1$};
    },
    axis line style={->},
  ]
  \addplot[blue,samples=100,domain=0:2*pi,
    postaction={decorate},% ------
    decoration={markings, % ------
        mark=at position 0.25 with {\arrow{stealth}},
        mark=at position 0.5  with {\arrow{stealth}},
        mark=at position 0.75 with {\arrow{stealth}}}
    ]
    ({sin(deg(2*x))}, {sin(deg(x))});
\end{axis}
\end{tikzpicture}
```

The only changes are in the option list for `\addplot`: it contains a `postaction`=`{decorate}` which activates the decoration (without replacing the original path) and some specification `decoration` containing details about how to decorate the path.

A discussion of details of the `decorations` libraries is beyond the scope of this manual (see [7] for details), but the main point is to add the required decorations to `\addplot` and its option list.

4.18 Style Options

4.18.1 All Supported Styles

PGFPLOTS provides many styles to customize its appearance and behavior. They can be defined and changed in any place where keys are allowed. Furthermore, own styles are defined easily.

Key handler ⟨*key*⟩/`.style`={⟨*key-value-list*⟩}

Defines or redefines a style ⟨*key*⟩. A style is a normal key which will set all options in ⟨*key-value-list*⟩ when it is set.

Use `\pgfplotsset`{⟨*key*⟩/`.style`={⟨*key-value-list*⟩}} to (re)define a style ⟨*key*⟩ in the namespace `/pgfplots`.

Key handler ⟨*key*⟩/`.append style`={⟨*key-value-list*⟩}

Appends ⟨*key-value-list*⟩ to an already existing style ⟨*key*⟩. This is the preferred method to change the predefined styles: if you only append, you maintain compatibility with future versions.

Use `\pgfplotsset`{⟨*key*⟩/`.append style`={⟨*key-value-list*⟩}} to append ⟨*key-value-list*⟩ to the style ⟨*key*⟩. This will assume the prefix `/pgfplots`.

Styles installed for linear/logarithmic axis

`/pgfplots/every axis`   (style, initially `empty`)

Installed at the beginning of every axis. TikZ options inside of it will be used for anything inside of the axis rectangle and any axis descriptions.

`/pgfplots/every axis post`   (style, initially `empty`)

A style which is applied right *after* arguments provided to an axis are processed.

In the following example, such a style is used to override the `xmin` and `xmax` options provided as arguments to \begin{axis}[...]:

```
\begin{tikzpicture}
    \pgfplotsset{
        every axis post/.style={
            xmin=0,xmax=1,
        },
    }
    \begin{axis}[
        xmin=-1,xmax=2,
        ymin=0,ymax=1]
        ...
    \end{axis}
\end{tikzpicture}
```

It is processed right after the arguments of \begin{axis}, but before styles like `yticklabel style` etc. are evaluated.

/pgfplots/**every semilogx axis**   (style, initially `empty`)

Installed at the beginning of every plot with linear x axis and logarithmic y axis, but after 'every axis'.

/pgfplots/**every semilogy axis**   (style, initially `empty`)

Likewise, but with interchanged roles for x and y.

/pgfplots/**every loglog axis**   (style, initially `empty`)

Installed at the beginning of every log–log plot.

/pgfplots/**every linear axis**   (style, initially `empty`)

Installed at the beginning of every plot with normal axis scaling.

Styles installed for single plots

/pgfplots/**every axis plot**   (style, initially `empty`)

Installed for each plot. This style may contain options like samples, gnuplot parameters, error bars and it may contain options which affect the final drawing commands.

/pgfplots/**every axis plot post**   (style, initially `empty`)

This style is similar to `every axis plot` in that is applies to any drawing command in \addplot. However, it is set *after* any user defined styles or `cycle list` options.


```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
\pgfplotsset{
    every axis plot post/.append style=
        {mark=none}}

\begin{axis}[
    legend style={
        at={(0.03,0.97)},anchor=north west},
    domain=0:1]
    \addplot {x^2};
    \addplot {exp(x)};
    \legend{$x^2$,$e^x$}
\end{axis}
\end{tikzpicture}
```
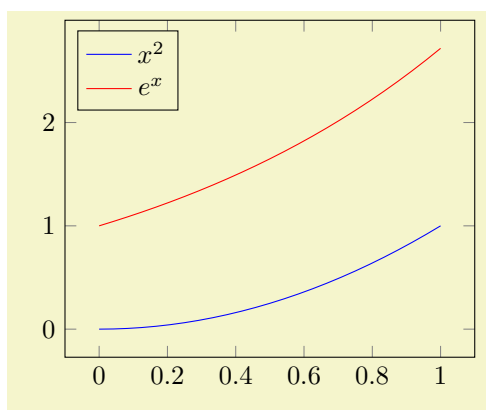
/pgfplots/**every axis plot no #**   (style, initially `empty`)

Used for every #th plot where $\# = 0, 1, 2, 3, 4, \ldots$.

/pgfplots/**every forget plot**   (style, initially `empty`)

Used for every plot which has `forget plot` activated.

/pgfplots/**forget plot style**={⟨*key-value-list*⟩}

An abbreviation for **every forget plot**/.append style={⟨*key-value-list*⟩}.

It appends options to the already existing style **every forget plot**.

Styles for axis descriptions

/pgfplots/**every axis label** (style, initially **empty**)

Used for all axis label (like **xlabel** and **ylabel**).

/pgfplots/**label style**={⟨*key-value-list*⟩}

An abbreviation for **every axis label**/.append style={⟨*key-value-list*⟩}.

It appends options to the already existing style **every axis label**.

/pgfplots/**every axis x label** (style, no value)
/pgfplots/**every axis y label** (style, no value)
/pgfplots/**every axis z label** (style, no value)

Used only for x, y, or z labels, respectively and installed after '**every axis label**'.

The initial settings are set by **xlabel absolute** and its variants (if the initial configuration **compat**=pre 1.3 is active) or **xlabel near ticks** which provides the better spacing as it incorporates the tick label sizes to compute the position.

Attention: These styles will be overwritten by **axis x line** and/or **axis y line**. Please remember to place your modifications after the axis line variations.

/pgfplots/**x label style**={⟨*key-value-list*⟩}
/pgfplots/**y label style**={⟨*key-value-list*⟩}
/pgfplots/**z label style**={⟨*key-value-list*⟩}
/pgfplots/**xlabel style**={⟨*key-value-list*⟩}
/pgfplots/**ylabel style**={⟨*key-value-list*⟩}
/pgfplots/**zlabel style**={⟨*key-value-list*⟩}

Different abbreviations for **every axis x label**/.append style={⟨*key-value-list*⟩} (or the respective styles for y, **every axis y label**/.append style={⟨*key-value-list*⟩}, and z, **every axis z label**/.append style={⟨*key-value-list*⟩}).

/pgfplots/**every axis title** (style, no value)

Used for any axis title. The **at**=(⟨*x,y*⟩) syntax will place the title using **axis description cs**.

The initial setting is

```
\pgfplotsset{every axis title/.style={at={(0.5,1)},above,yshift=6pt}}
```

To be more precise, the **yshift** doesn't use the hardcoded **6pt**: it uses the value of

/pgfplots/**every axis title shift**={⟨*default shift*⟩} (initially **6pt**)

which can be reset if needed.

/pgfplots/**title style**={⟨*key-value-list*⟩}

An abbreviation for **every axis title**/.append style={⟨*key-value-list*⟩}.

It appends options to the already existing style **every axis title**.

/pgfplots/**every axis legend** (style, no value)

Installed for each legend. As described for **axis description cs**, the legend's position can be placed using coordinates between 0 and 1 (it employs **axis description cs** automatically).

The initial setting is

```
\pgfplotsset{every axis legend/.style={
        cells={anchor=center},
        inner xsep=3pt,inner ysep=2pt,nodes={inner sep=2pt,text depth=0.15em},
        anchor=north east,
        shape=rectangle,
        fill=white,draw=black,
        at={(0.98,0.98)}}}
```

/pgfplots/legend style={⟨*key-value-list*⟩}

An abbreviation for every axis legend/.append style={⟨*key-value-list*⟩}.

It appends options to the already existing style every axis legend.

/pgfplots/every legend image post   (style, no value)

Allows to change the appearance of the small legend images *after* the options of the plot style have been applied. Thus, legend formatting can be changed independently of the plot style using every legend image post.

This key is also documented on page 256.

/pgfplots/legend image post style={⟨*key-value-list*⟩}

An abbreviation for every legend image post/.append style={⟨*key-value-list*⟩}.

It appends options to the already existing style every legend image post.

/pgfplots/every legend to name picture   (style, no value)

A style for use with legend to image, see the documentation therein.

/pgfplots/every colorbar   (style, no value)

A style to change the colorbar. See page 280 for the reference documentation of every colorbar.

/pgfplots/colorbar style={⟨*key-value-list*⟩}

An abbreviation for every colorbar/.append style={⟨*key-value-list*⟩}.

It appends options to the already existing style every colorbar.

Styles for axis lines

/pgfplots/every outer x axis line   (style, initially empty)
/pgfplots/every outer y axis line   (style, initially empty)
/pgfplots/every outer z axis line   (style, initially empty)

Installed for every axis line which lies on the outer box.

If you want arrow heads, you may also need to check the separate axis lines boolean key.

/pgfplots/every inner x axis line   (style, initially empty)
/pgfplots/every inner y axis line   (style, initially empty)
/pgfplots/every inner z axis line   (style, initially empty)

Installed for every axis line which is drawn using the center or middle options.

/pgfplots/axis line style={⟨*key-value-list*⟩}
/pgfplots/inner axis line style={⟨*key-value-list*⟩}
/pgfplots/outer axis line style={⟨*key-value-list*⟩}
/pgfplots/x axis line style={⟨*key-value-list*⟩}
/pgfplots/y axis line style={⟨*key-value-list*⟩}
/pgfplots/z axis line style={⟨*key-value-list*⟩}

These options modify parts of the axis line styles. They append options to every inner x axis line and every outer x axis line and the respective y/z variants.

Please refer to Section 4.9.9 on page 268 for details about styles for axis lines.

/pgfplots/every 3d box foreground   (style, no value)

Installed for the parts drawn by 3d box=complete. This affects axis lines, tick lines and grid lines drawn in the *foreground*. The background drawing operations have already been done when this style is evaluated.

/pgfplots/3d box foreground style={⟨*key-value-list*⟩}

An abbreviation for every 3d box foreground/.append style={⟨*key-value-list*⟩}.

It appends options to the already existing style every 3d box foreground.

/pgfplots/**every colorbar sampled line**   (style, no value)

    To be used in conjunction with `colorbar sampled line`, see the documentation therein.

/pgfplots/**colorbar sampled line style**={⟨*key-value-list*⟩}

    An abbreviation for `every colorbar sampled line`/`.append style`={⟨*key-value-list*⟩}.

    It appends options to the already existing style `every colorbar sampled line`.

Styles for ticks

/pgfplots/**every tick**   (style, initially `very thin,gray`)

    Installed for each of the small tick *lines.*

/pgfplots/**tick style**={⟨*key-value-list*⟩}

    An abbreviation for `every tick`/`.append style`={⟨*key-value-list*⟩}.

    It appends options to the already existing style `every tick`.

/pgfplots/**every minor tick**   (style, initially `empty`)

    Used for each minor tick line, installed after '`every tick`'.

/pgfplots/**minor tick style**={⟨*key-value-list*⟩}

    An abbreviation for `every minor tick`/`.append style`={⟨*key-value-list*⟩}.

    It appends options to the already existing style `every minor tick`.

/pgfplots/**every major tick**   (style, initially `empty`)

    Used for each major tick line, installed after '`every tick`'.

/pgfplots/**major tick style**={⟨*key-value-list*⟩}

    An abbreviation for `every major tick`/`.append style`={⟨*key-value-list*⟩}.

    It appends options to the already existing style `every major tick`.

/pgfplots/**every tick label**   (style, initially `empty`)

    Used for each x and y tick labels.

/pgfplots/**tick label style**={⟨*key-value-list*⟩}
/pgfplots/**ticklabel style**={⟨*key-value-list*⟩}

    Different abbreviations for `every tick label`/`.append style`={⟨*key-value-list*⟩} (or the respective styles for y, `every tick label`/`.append style`={⟨*key-value-list*⟩}, and z, `every tick label`/`.append style`={⟨*key-value-list*⟩}).

/pgfplots/**every x tick label**   (style, initially `empty`)
/pgfplots/**every y tick label**   (style, initially `empty`)
/pgfplots/**every z tick label**   (style, initially `empty`)

    Used for each x (or y or z, respectively) tick label, installed after '`every tick label`'.

/pgfplots/**x tick label style**={⟨*key-value-list*⟩}
/pgfplots/**y tick label style**={⟨*key-value-list*⟩}
/pgfplots/**z tick label style**={⟨*key-value-list*⟩}
/pgfplots/**xticklabel style**={⟨*key-value-list*⟩}
/pgfplots/**yticklabel style**={⟨*key-value-list*⟩}
/pgfplots/**zticklabel style**={⟨*key-value-list*⟩}

    Different abbreviations for `every x tick label`/`.append style`={⟨*key-value-list*⟩} (or the respective styles for y, `every y tick label`/`.append style`={⟨*key-value-list*⟩}, and z, `every z tick label`/`.append style`={⟨*key-value-list*⟩}).

/pgfplots/**every x tick scale label**   (style, no value)
/pgfplots/**every y tick scale label**   (style, no value)

/pgfplots/**every z tick scale label**   (style, no value)

Configures placement and display of the nodes containing the order of magnitude of tick labels, see Section 4.15.3 for more information about scaled ticks.

The initial settings with compat=1.8 or higher are

```
\pgfplotsset{
    every x tick scale label/.style={
        at={(xticklabel cs:0.9,5pt)},
        anchor=near xticklabel,
        inner sep=0pt},
    every y tick scale label/.style={
        at={
            (yticklabel* cs:1.03,-0.3em)},
            /pgfplots/near ticklabel align=outside,
            anchor=near yticklabel opposite,
            inner sep=0pt},
    every z tick scale label/.style={
        at={(zticklabel* cs:1.2,-0.3em)},
        anchor=near zticklabel,
        inner sep=0pt},
```

/pgfplots/**x tick scale label style**={⟨*key-value-list*⟩}
/pgfplots/**y tick scale label style**={⟨*key-value-list*⟩}
/pgfplots/**z tick scale label style**={⟨*key-value-list*⟩}

An abbreviation for every x tick scale label/.append style={⟨*key-value-list*⟩} (or the respective styles for *y*, every y tick scale label/.append style={⟨*key-value-list*⟩}, and the *z*–axis, every z tick scale label/.append style={⟨*key-value-list*⟩}).

It appends options to the already existing style every x tick scale label.

/pgfplots/**every x tick**   (style, initially empty)
/pgfplots/**every y tick**   (style, initially empty)
/pgfplots/**every z tick**   (style, initially empty)

Installed for tick *lines* on either *x* or *y* axis.

/pgfplots/**xtick style**={⟨*key-value-list*⟩}
/pgfplots/**ytick style**={⟨*key-value-list*⟩}
/pgfplots/**ztick style**={⟨*key-value-list*⟩}

An abbreviation for every x tick/.append style={⟨*key-value-list*⟩} (or the respective styles for *y*, every y tick/.append style={⟨*key-value-list*⟩}, and the *z*–axis, every z tick/.append style={⟨*key-value-list*⟩}).

It appends options to the already existing style every x tick.

/pgfplots/**every minor x tick**   (style, initially empty)
/pgfplots/**every minor y tick**   (style, initially empty)
/pgfplots/**every minor z tick**   (style, initially empty)

Installed for minor tick lines on either *x* or *y* axis.

/pgfplots/**minor x tick style**={⟨*key-value-list*⟩}
/pgfplots/**minor y tick style**={⟨*key-value-list*⟩}
/pgfplots/**minor z tick style**={⟨*key-value-list*⟩}

An abbreviation for every minor x tick/.append style={⟨*key-value-list*⟩} (or the respective styles for *y*, every minor y tick/.append style={⟨*key-value-list*⟩}, and the *z*–axis, every minor z tick/.append style={⟨*key-value-list*⟩}).

It appends options to the already existing style every minor x tick.

/pgfplots/**every major x tick**   (style, initially empty)
/pgfplots/**every major y tick**   (style, initially empty)
/pgfplots/**every major z tick**   (style, initially empty)

Installed for major tick lines on either *x* or *y* axis.

/pgfplots/**major x tick style**={⟨*key-value-list*⟩}
/pgfplots/**major y tick style**={⟨*key-value-list*⟩}
/pgfplots/**major z tick style**={⟨*key-value-list*⟩}

An abbreviation for `every major x tick`/`.append style`={⟨*key-value-list*⟩} (or the respective styles for *y*, `every major y tick`/`.append style`={⟨*key-value-list*⟩}, and the *z*–axis, `every major z tick`/`.append style`={⟨*key-value-list*⟩}).

It appends options to the already existing style `every major x tick`.

/pgfplots/**every extra x tick** (style, no value)
/pgfplots/**every extra y tick** (style, no value)
/pgfplots/**every extra z tick** (style, no value)

Allows to configure the appearance of '`extra x ticks`'. This style is installed before touching the first extra *x* tick. It is possible to set any option which affects tick or grid line generation.

The initial setting is

```
\pgfplotsset{
    every extra x tick/.style={/pgfplots/log identify minor tick positions=true},
    every extra y tick/.style={/pgfplots/log identify minor tick positions=true}}
```

Useful examples are shown below.

```
\pgfplotsset{every extra x tick/.append style={grid=major}}
\pgfplotsset{every extra x tick/.append style={major tick length=0pt}}
\pgfplotsset{every extra x tick/.append style={/pgf/number format=sci subscript}}
\pgfplotsset{extra x tick style={
        grid style={
            color=red,
        },
        tickwidth=3mm,
        % the initial 'every tick style' defines a 'line width'.
        % this here redefines it:
        tick style={
            line width=2mm,
        },
    }
}
```

/pgfplots/**extra x tick style**={⟨*key-value-list*⟩}
/pgfplots/**extra y tick style**={⟨*key-value-list*⟩}
/pgfplots/**extra z tick style**={⟨*key-value-list*⟩}

An abbreviation for `every extra x tick`/`.append style`={⟨*key-value-list*⟩} (or the respective styles for *y*, `every extra y tick`/`.append style`={⟨*key-value-list*⟩}, and the *z*–axis, `every extra z tick`/`.append style`={⟨*key-value-list*⟩}).

It appends options to the already existing style `every extra x tick`.

/pgfplots/**extra tick style**={⟨*key-value-list*⟩}

An abbreviation which appends ⟨*key-value-list*⟩ to `every extra x tick`, `every extra y tick` and `every extra z tick`.

Styles for grid lines

/pgfplots/**every axis grid** (style, initially `thin,black!25`)

Used for each grid line.

/pgfplots/**grid style**={⟨*key-value-list*⟩}

An abbreviation for `every axis grid`/`.append style`={⟨*key-value-list*⟩}.

It appends options to the already existing style `every axis grid`.

/pgfplots/**every minor grid** (style, initially `empty`)

Used for each minor grid line, installed after '`every axis grid`'.

/pgfplots/minor grid style={⟨*key-value-list*⟩}

An abbreviation for every minor grid/.append style={⟨*key-value-list*⟩}.

It appends options to the already existing style every minor grid.

/pgfplots/every major grid   (style, initially empty)

Likewise, for major grid lines.

/pgfplots/major grid style={⟨*key-value-list*⟩}

An abbreviation for every major grid/.append style={⟨*key-value-list*⟩}.

It appends options to the already existing style every major grid.

/pgfplots/every axis x grid   (style, initially empty)
/pgfplots/every axis y grid   (style, initially empty)
/pgfplots/every axis z grid   (style, initially empty)

Used for each grid line in either x or y direction.

/pgfplots/x grid style={⟨*key-value-list*⟩}
/pgfplots/y grid style={⟨*key-value-list*⟩}
/pgfplots/z grid style={⟨*key-value-list*⟩}

An abbreviation for every axis x grid/.append style={⟨*key-value-list*⟩} (or the respective styles for y, every axis y grid/.append style={⟨*key-value-list*⟩}, and the z–axis, every axis z grid/.append style={⟨*key-value-list*⟩}).

It appends options to the already existing style every axis x grid.

/pgfplots/every minor x grid   (style, initially empty)
/pgfplots/every minor y grid   (style, initially empty)
/pgfplots/every minor z grid   (style, initially empty)

Used for each minor grid line in either x or y direction.

/pgfplots/minor x grid style={⟨*key-value-list*⟩}
/pgfplots/minor y grid style={⟨*key-value-list*⟩}
/pgfplots/minor z grid style={⟨*key-value-list*⟩}

An abbreviation for every minor x grid/.append style={⟨*key-value-list*⟩} (or the respective styles for y, every minor y grid/.append style={⟨*key-value-list*⟩}, and the z–axis, every minor z grid/.append style={⟨*key-value-list*⟩}).

It appends options to the already existing style every minor x grid.

/pgfplots/every major x grid   (style, initially empty)
/pgfplots/every major y grid   (style, initially empty)
/pgfplots/every major z grid   (style, initially empty)

Used for each major grid line in either x or y direction.

/pgfplots/major x grid style={⟨*key-value-list*⟩}
/pgfplots/major y grid style={⟨*key-value-list*⟩}
/pgfplots/major z grid style={⟨*key-value-list*⟩}

An abbreviation for every major x grid/.append style={⟨*key-value-list*⟩} (or the respective styles for y, every major y grid/.append style={⟨*key-value-list*⟩}, and the z–axis, every major z grid/.append style={⟨*key-value-list*⟩}).

It appends options to the already existing style every major x grid.

Styles for error bars

/pgfplots/every error bar   (style, initially thin)

Installed for every error bar.

/pgfplots/error bars/error bar style={⟨*key-value-list*⟩}

An abbreviation for every error bar/.append style={⟨*key-value-list*⟩}.

It appends options to the already existing style every error bar.

4.18.2 (Re)Defining Own Styles

Use `\pgfplotsset{`⟨*style name*⟩`/.style={`⟨*key-value-list*⟩`}}` to create own styles. If ⟨*style name*⟩ exists already, it will be replaced. Please note that it is *not* possible to use the TikZ-command `\tikzstyle{`⟨*style name*⟩`}=[]` in this context[60].
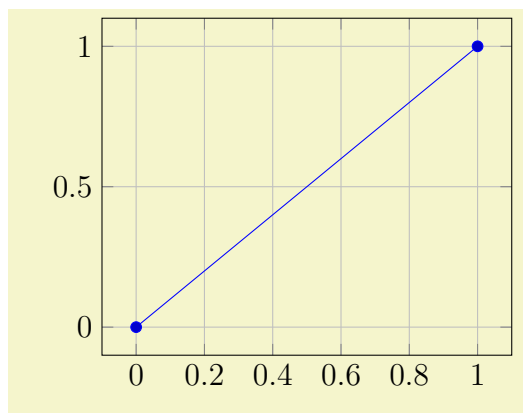
```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\pgfplotsset{my personal style/.style=
    {grid=major,font=\large}}

\begin{tikzpicture}
\begin{axis}[my personal style]
    \addplot coordinates {(0,0) (1,1)};
\end{axis}
\end{tikzpicture}
```

4.19 Alignment Options

4.19.1 Basic Alignment

Alignment works with two main methods: a coordinate where the axis shall be drawn and an "anchor" inside of the axis which shall be drawn at this particular coordinate. This methodology is common for each TikZ node – and an axis is nothing but a (special) TikZ node. The coordinate can be specified using the `at` key, while the anchor can be specified with the `anchor` key. In most cases, it is sufficient to provide only an anchor – unless one needs more than one axis in the same picture environment.

`/pgfplots/at=`{⟨*coordinate expression*⟩}

Assigns a position for the complete axis image. This option works similarly to the `at`-option of `\node[at={`⟨*coordinate expression*⟩`}]`, see [7]. The common syntax is `at={(`⟨*x,y*⟩`)}`.

The idea is to provide an ⟨*coordinate expression*⟩ where the axis will be placed. The axis' anchor will be placed at ⟨*coordinate expression*⟩.

`/pgfplots/anchor=`{⟨*name*⟩} (initially `south west`)

Chooses one of the different possible positions inside of an axis which is placed with `at`. The `at` key defines the position where to place the axis inside of the embedding picture, the `anchor` key defines which point of the axis shall be positioned by '`at`'. The initial configuration assumes `at={(0,0)}`. Thus, `anchor=center` will place the axis' center at the logical picture position $(0, 0)$. Similarly, `anchor=south west` will position the lower left corner of the axis at $(0, 0)$.

For users who are familiar with TikZ: an axis is actually a very special node, so anchors work as in [7].

Anchors are useful in conjunction with horizontal or vertical alignment of plots, see the examples below.

There are four sets of anchors available: anchors positioned on the axis bounding box, anchors on the outer bounding box and anchors which have one coordinate on the outer bounding box and the other one at a position of the axis rectangle. Finally, one can place anchors near the origin.

In more detail, we have anchors on the axis rectangle (the bounding box around the axis)[61],

---

[60]This was possible in a previous version and is still supported for backwards compatibility. But in some cases, it may not work as expected.

[61]Versions prior to PGFPLOTS v.1.3 did *not* use the bounding box of the axis, they used axis coordinates to orient these anchors. This has been fixed. If you *really* want to undo the bugfix, see `compat/anchors`.
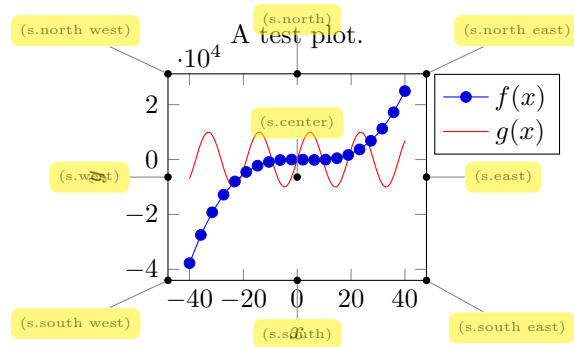
Anchors on the outer bounding box,
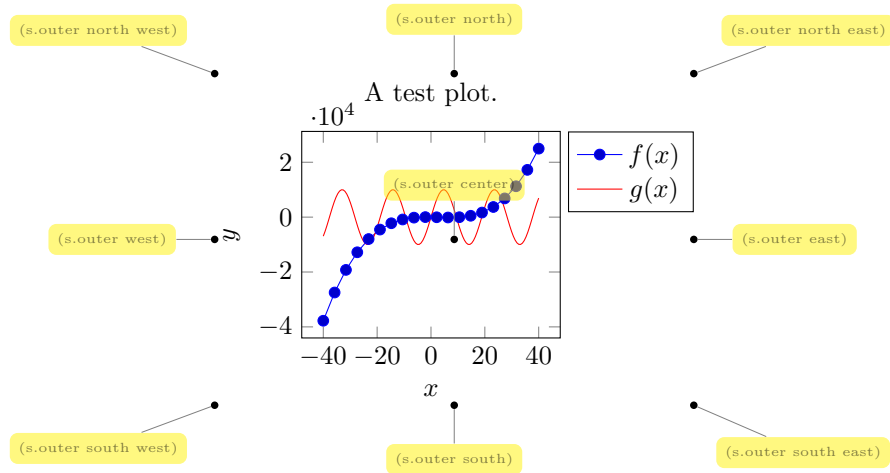
There are anchors which have one coordinate on the outer bounding box, and one on the axis rectangle,
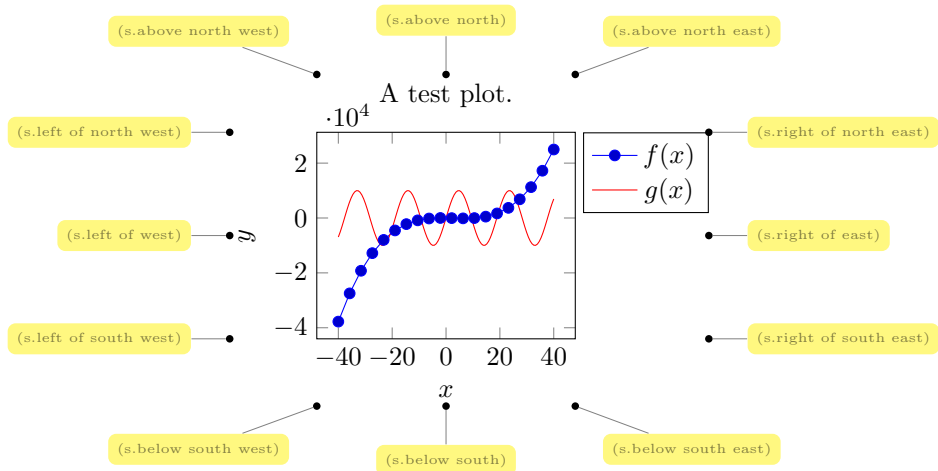
And finally, we have origin anchors which are especially useful when axis lines pass through the origin,
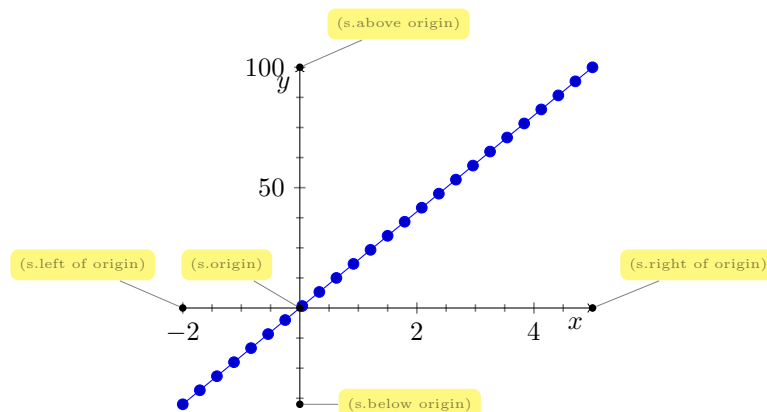
There is a fifth anchor which is not directly related to the axis: you can provide the anchor of *a named inner node*. Thus, you can define your own anchor, by writing `\node` (⟨*name*⟩) `at` (⟨*point coordinate*⟩) `{};` as follows (using the `baseline` option described below):
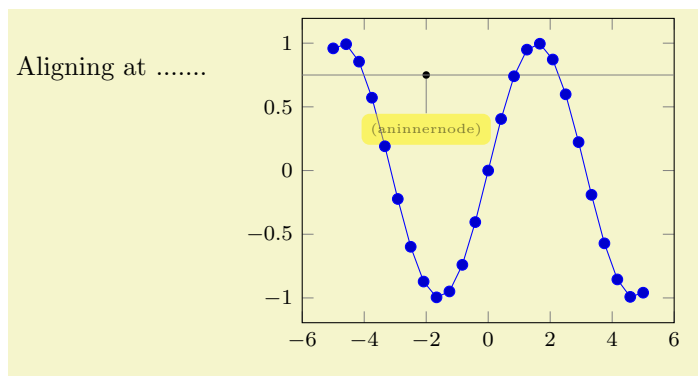

```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
Aligning at .......
\begin{tikzpicture}[baseline]
\begin{axis}[small,anchor=aninnernode.center]
    \addplot {sin(deg(x))};
    \node
        [pin=-90:(aninnernode),fill=black,circle,scale=0.3]
        (aninnernode) at (-2,0.75) {};
    \draw[help lines] (-6,0.75) -- (6,0.75);
\end{axis}
\end{tikzpicture}
```

What happens is that a node is placed at `(-2,0.75)`. Note that the options `[pin=...]` are merely to show the `\node` (the pin style has been defined by the PGFPLOTS manual). Since a name can also be assigned using `name=`⟨*node's name*⟩ and since any PGFPLOTS description is also a `\node`, you can align your plot at selected axis descriptions:
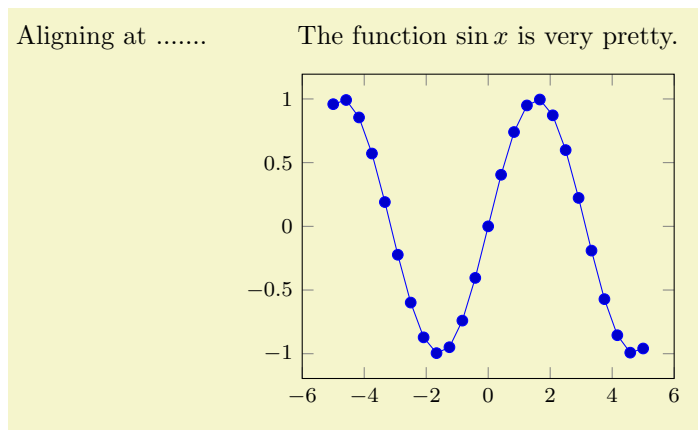

```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
Aligning at .......
\begin{tikzpicture}[baseline]
\begin{axis}[
    small,
    title={The function $\sin x$ is very pretty.},
    title style={name=MyTitleNode},
    anchor=MyTitleNode.base,
]
    \addplot {sin(deg(x))};
\end{axis}
\end{tikzpicture}
```

The default value is `anchor=south west`. You can use anchors in conjunction with the TikZ `baseline` option and/or \begin{pgfinterruptboundingbox} to perform alignment.

Remarks: Each of the anchors on the axis rectangle has an equivalent to a coordinate in the `axis description cs` described in Section 4.9.1. That means the first set of anchors actually lives on the

tight bounding box around the axis (without any ticks or descriptions). The `south west` anchor will always be the lower left corner of this bounding box, even in case of a rotated or skewed coordinate system[62]. Similar statements hold for the other anchors.

4.19.2   Vertical Alignment with `baseline`

/tikz/baseline   (no value)

The `baseline` option should be provided as argument to a `tikzpicture`. It configures TikZ to shift the picture position $y = 0$ to the embedding text's baseline:

This is ● a picture, here ● another one.

```
This is \tikz[baseline]\fill[red] (0,0) circle(3pt); a picture,
here \tikz[baseline]\fill[red] (0,10pt) circle(3pt); another one.
```

Consequently, the `baseline` option allows to align different `tikzpicture`s. An axis is, by default, placed with `at={(0,0)}`, and the `anchor` key specifies which part of the axis is placed at `(0,0)`. Consequently, the `baseline` option, together with `anchor`, allows to align different axes with the embedding text.

The default axis anchor is `south west`, which means that the picture coordinate $(0,0)$ is the lower left corner of the axis. As a consequence, the TikZ option "`baseline`" allows vertical alignment of adjacent plots:
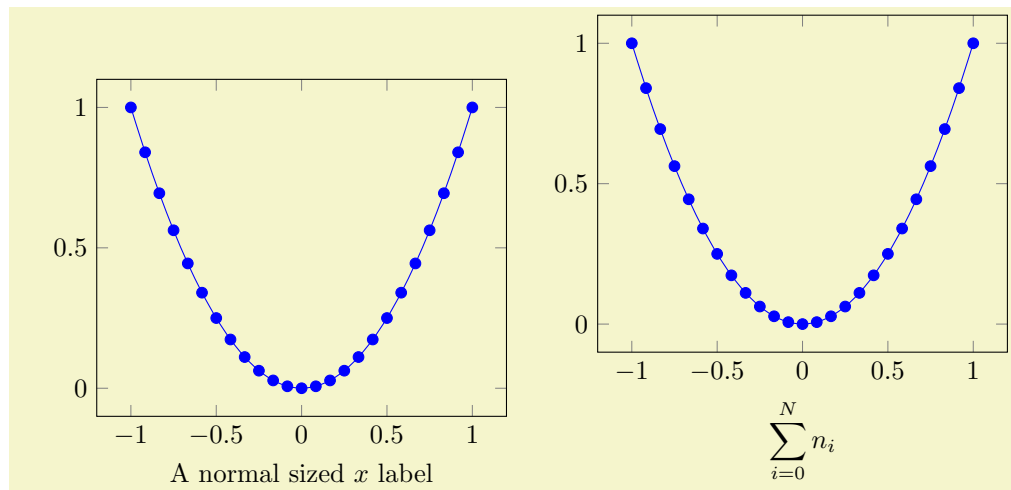

```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
% 1. Unaligned:
\pgfplotsset{domain=-1:1}
\begin{tikzpicture}
    \begin{axis}[xlabel=A normal sized $x$ label]
    \addplot[smooth,blue,mark=*] {x^2};
    \end{axis}
\end{tikzpicture}%
\hspace{0.15cm}
\begin{tikzpicture}
    \begin{axis}[xlabel={$\displaystyle \sum_{i=0}^N n_i $ }]
    \addplot[smooth,blue,mark=*] {x^2};
    \end{axis}
\end{tikzpicture}
```

---

[62]Note that this is only true for versions since 1.3.

```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
% 2. Aligned:
\pgfplotsset{domain=-1:1}
\begin{tikzpicture}[baseline]
    \begin{axis}[xlabel=A normal sized $x$ label]
    \addplot[smooth,blue,mark=*] {x^2};
    \end{axis}
\end{tikzpicture}%
\hspace{0.15cm}
\begin{tikzpicture}[baseline]
    \begin{axis}[xlabel={$\displaystyle \sum_{i=0}^N n_i $ }]
    \addplot[smooth,blue,mark=*] {x^2};
    \end{axis}
\end{tikzpicture}
```
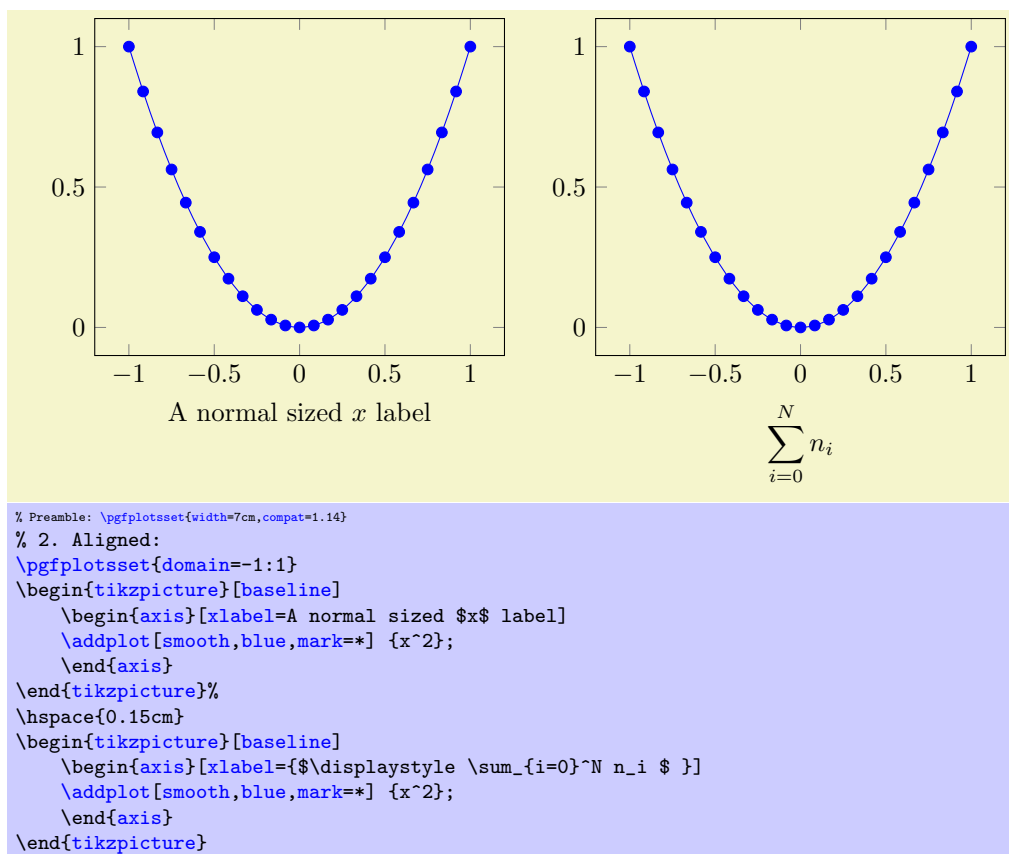
Note that it is also possible to write `baseline`=5cm in which case the image offset at $y =$5cm will be used as baseline.

The `baseline` key is related to `\begin{minipage}[`⟨*alignment*⟩`]` or `\begin{tabular}[`⟨*alignment*⟩`]`: the ⟨*alignment*⟩ tells LATEX which part of the `minipage` or `tabular` shall be positioned on the baseline. Thus, `baseline` does the same for pictures (with more freedom for ⟨*alignment*⟩).

4.19.3 Horizontal Alignment

Horizontal alignment can be done in two ways:

1. Using separate `tikzpicture` environments which have reduced bounding boxes or

2. A single `tikzpicture` environment in which the complete alignment is done.

The first approach requires the use of reduced bounding boxes and is discussed in Section 4.20.1.

The second approach, a single `tikzpicture` environment, employs the `at` and `anchor` keys to align parts of the images. For example, if you place multiple `axes` into a single `tikzpicture` and use the '`anchor`'-option, you can control horizontal alignment:
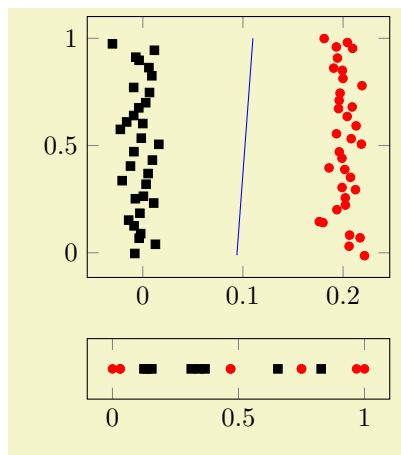
```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
\pgfplotsset{every axis/.append style={
cycle list={
    {red,only marks,mark options={
        fill=red,scale=0.8},mark=*},
    {black,only marks,mark options={
        fill=black,scale=0.8},mark=square*}}}}

\begin{axis}[width=4cm,scale only axis,
    name=main plot]
\addplot file
    {plotdata/pgfplots_scatterdata1.dat};
\addplot file
    {plotdata/pgfplots_scatterdata2.dat};
\addplot[blue] coordinates {
    (0.093947,    -0.011481)
    (0.101957,     0.494273)
    (0.109967,     1.000027)};
\end{axis}

\begin{axis}[
    at={(main plot.below south west)},yshift=-0.1cm,
    anchor=north west,
    width=4cm,scale only axis,height=0.8cm,
    ytick=\empty]

\addplot file
  {plotdata/pgfplots_scatterdata1_latent.dat};
\addplot file
  {plotdata/pgfplots_scatterdata2_latent.dat};
\end{axis}
\end{tikzpicture}
```

Here, the second axis uses `at`={(main plot.below south west)} to be placed below the first one. Furthermore, it has `yshift`=-0.1cm in order to leave additional space, and it uses `anchor`=north west to place the upper left corner at the specified position. Instead of the `at`={} construction, we could also have used `yshift` with larger negative shift.

4.19.4   Alignment In Array Form (Subplots)

Sometimes multiple alignment axes in array form are desired. PGFPLOTS supports this task in several ways which are described in the following. There are basically three related, yet different, approaches:

1. Simply place \begin{tikzpicture}...\end{tikzpicture} into a LATEX table. This is straight–forward; you would do the very same thing with \includegraphics.

   In addition to \includegraphics, the `baseline` feature allows simple yet effective vertical alignment. In addition, the `trim left` and `trim right` features allow simple yet effective horizontal alignment (see below).

2. Use a *single* picture which contains an array of axes, i.e. a pattern like

   \begin{tikzpicture} \matrix{ ⟨*multiple axes*⟩}; \end{tikzpicture}.

   This allows considerably simpler alignment! Alas, it needs special handling for `legend entries` due to a weakness of \matrix. If you use the `external` library (which is recommended), it takes more time since the picture gets larger.

3. Use the `groupplots` library shipped with PGFPLOTS. It is specialized on axes in array form with particular strength if the axes are closely related (for example if they share axis descriptions like `xlabel` or even tick labels). Note, however, that the other approaches are better when it comes to automatic handling of bounding boxes.

The `groupplots` library is discussed in all detail in Section 5.8. This section discusses the other two approaches.

Array Alignment using LATEX Tables   The idea is simple: use a LATEX table and provide one `tikzpicture` for every cell. You are probably familiar with this sort of alignment, perhaps together

with \includegraphics. It works in the very same way for PGFPLOTS. The approach is the simplest one since it doesn't need special knowledge. Its disadvantage, however, is more difficulty to control positions *inside* of the image (like differently sized axis descriptions).

Is is strongly recommended to employ the `baseline` option for each cell picture, which simplifies vertical alignment considerably. If you want a simple solution to place separate axes in array form, and you prefer to use one `tikzpicture` for every axis, the probably most simple and most effective way to get horizontal alignment are the `trim left` and `trim right` features – or styles based on them:

The `trim axis left` feature can be used to exclude axis descriptions on the left from the bounding box, and the `trim axis right` can exclude axis descriptions on the right from the bounding box. Thus, alignment is done using the vertical axis lines. Since both keys effectively modify the bounding box, they are documented in Section 4.20.1 "Bounding Box Restrictions". Here is just a small example for array alignment by means of `tabular`, `baseline` and the `trim left`/`trim right` features:
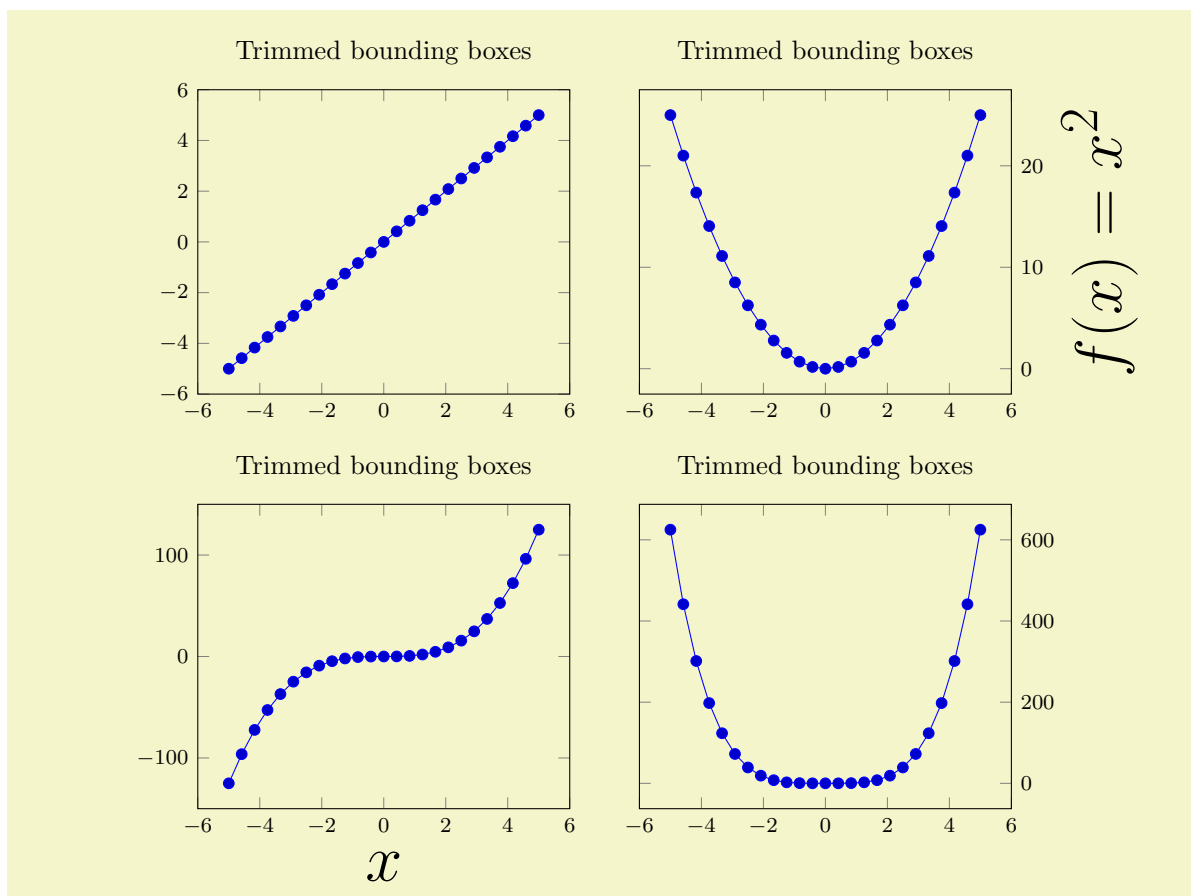
```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\pgfplotsset{
    small,
    title=Trimmed bounding boxes
}
\begin{center}
\begin{tabular}{rl}
    \begin{tikzpicture}[baseline,trim axis left]
        \begin{axis}
            \addplot {x};
        \end{axis}
    \end{tikzpicture}
    &
    \begin{tikzpicture}[baseline,trim axis right]
    \begin{axis}[
        ylabel={$f(x)=x^2$},
        yticklabel pos=right,
        ylabel style={font=\Huge}]
        \addplot {x^2};
    \end{axis}
    \end{tikzpicture}
    \\
    %
    \begin{tikzpicture}[baseline,trim axis left]
    \begin{axis}[xlabel=$x$,xlabel style={font=\Huge}]
        \addplot {x^3};
    \end{axis}
    \end{tikzpicture}%
    &
    \begin{tikzpicture}[baseline,trim axis right]
    \begin{axis}[yticklabel pos=right]
        \addplot {x^4};
    \end{axis}
    \end{tikzpicture}%
    \\
\end{tabular}%
\end{center}
```

The example has 2×2 axes. The `baseline` feature controls the vertical alignment: the lower axis lines are always on the same height. The `trim axis left` key is a style which tells TikZ to trim everything which is left of the left axis line. Similarly, the `trim axis right` key does not include picture parts right of the right axis line. Together with `\begin{center}` and the `yticklabel pos`=right key, we get correct horizontal and vertical alignment together with centering at the left- and right axis lines (without descriptions).

A strong advantage is that this type of alignment requires almost no changes to your pictures. Thus, you can copy–paste existing images (TeX code) relatively simple.

Note that the approach is fully compatible with the image `external`ization library: each picture is exported separately, and the bounding box restrictions (and the `baseline` offset) are stored in separate `.dpth` files. The `trim left`/`trim right` approach for horizontal alignment is the *only* supported way for reduced bounding boxes and image externalization.

Array Alignment using Ti*k*Z Matrices   While it is possible to use (for example) `tabular` combined with the vertical and horizontal alignment methods discussed above, it might be better to use a TikZ `matrix` since it automatically handles the size of axis descriptions.

A Ti*k*Z matrix is some sort of "graphical" table. It knows everything about picture alignment and it has more flexibility than `tabular` when it comes to graphics. The idea is to pack the complete array into a *single* picture.

The complete documentation of a Ti*k*Z matrix is beyond the scope of this manual, please refer to [7] for details. But we provide an example here:
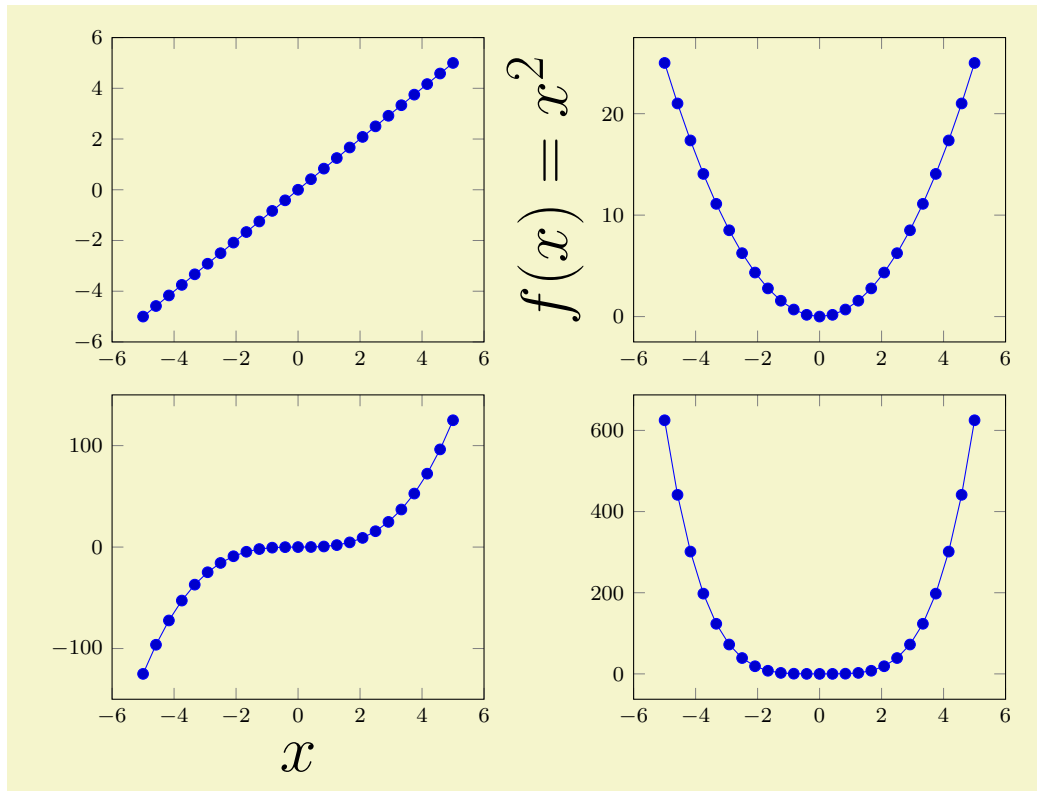
```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
    \pgfplotsset{small}
    \matrix {
        \begin{axis}
            \addplot {x};
        \end{axis}
        &
        % differently large labels are aligned automatically:
        \begin{axis}[ylabel={$f(x)=x^2$},ylabel style={font=\Huge}]
            \addplot {x^2};
        \end{axis}
        \\
        %
        \begin{axis}[xlabel=$x$,xlabel style={font=\Huge}]
            \addplot {x^3};
        \end{axis}
        &
        \begin{axis}
            \addplot {x^4};
        \end{axis}
        \\
    };
\end{tikzpicture}
```

So, a matrix is a picture element inside of `tikzpicture`. Its cells are separated by '`&`' as in tabular (or, if '`&`' causes problems, with `\pgfmatrixnextcell`). Its rows are separated by '`\\`'. Each cell is aligned using the cells' anchor. Since, by default, the anchor of an axis is placed at the lower left corner, the example above is completely aligned, without the need for any bounding box modifications – even the labels are aligned correctly. If another anchor shall be used, simply place

```
\pgfplotsset{anchor=....}
\matrix {
  ...
};
```

in front of the matrix. This will use the same configuration for every sub-plot.

Attention: Unfortunately, the array alignment with `\matrix` needs special *attention with legends*. A legend is also a `\matrix` and TikZ matrices can't be nested. You will need to use the `legend to name` feature (or to assemble a legend by means of `\label` and `\ref`) to overcome this weakness (see Section 4.9.6 for details).

4.19.5 Miscellaneous for Alignment

Predefined node `current axis`

A node which refers to the current axis or the last typeset axis.

You can use this node in axis descriptions, for example to place axis labels or titles.

Remark: If you use `current axis` inside of axis descriptions, the "current axis" is not yet finished. That means you *can't use any outer anchor* inside of axis descriptions.

It is also possible to use `current axis` in any drawing or plotting commands inside of an axis (but no outer anchor as these are not defined when drawing commands are processed). This usage is similar to the `axis description cs`.

4.20 The Picture's Size: Bounding Box and Clipping

This section explains how a picture receives its final dimensions. The picture's dimension is the bounding box. It is possible to restrict the bounding box, but display graphical elements outside of the bounding box. This is called subject of Section 4.20.1. Another use-case is to restrict both the bounding box and the clip the graphical elements to some outer path which is subject of Section 4.20.2.

4.20.1 Bounding Box Restrictions

Bounding box restrictions are a useful and often necessary tool if multiple pictures need to be aligned properly. Consequently, it is often applied together with the Alignments methods of Section 4.19.

Bounding box restrictions can be archieved with several methods of PGF:

1. The `overlay` option,
2. The `pgfinterruptboundingbox` environment,
3. The `\pgfresetboundingbox` command,
4. The `\useasboundingbox` path,
5. The `trim left` and `trim right` feature (which is the *only* supported way of restricted bounding boxes and image externalization; at least for PDF output).

An additional item is a specific use-case of PGFPLOTS:

6. The `hide axis` feature will exclude any axis–specific stuff from the bounding box. See the reference for `hide axis` for details.

Note that image externalization (the `external` library) is more or less incompatible with methods (1.)–(4.). The problem is that `pdflatex` crops everything outside of the bounding box away. There are only two safe ways to "restrict" bounding boxes of external `.pdf` images: the first is the mentioned `trim left`/`trim right` feature and the second is to use negative `\hspace` or `\vspace` commands (or options to `\includegraphics`).

`/tikz/overlay` (no value)

A special key of PGF which disables bounding box updates for (parts of) the image. The effect is that those parts are an "overlay" over the document.

For PGFPLOTS, `overlay` can be useful to position legends or other axis descriptions outside of the axis – without affecting its size (and without affecting alignment).

For example, one may want to include only certain parts of the axis into the final bounding box. This would allow horizontal alignment (centering):
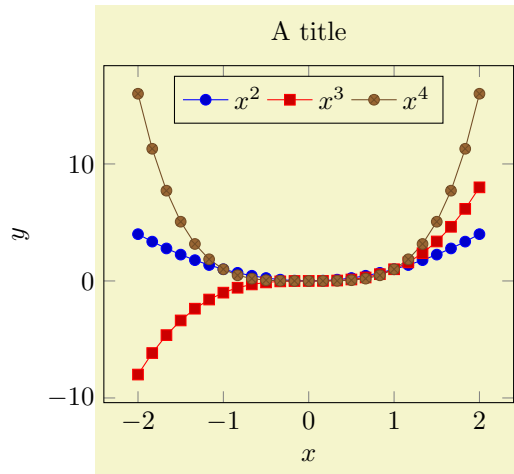
```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}%
    \begin{axis}[
        title=A title,
        ylabel style={overlay},
        yticklabel style={overlay},
        xlabel={$x$},
        ylabel={$y$},
        legend style={at={(0.5,0.97)},
            anchor=north,legend columns=-1},
        domain=-2:2
    ]
    \addplot {x^2};
    \addplot {x^3};
    \addplot {x^4};
    \legend{$x^2$,$x^3$,$x^4$}
    \end{axis}
\end{tikzpicture}%
```

Now, the left axis descriptions (y label and y ticks) stick out of the bounding box.

The following example places a legend somewhere without affecting the bounding box.
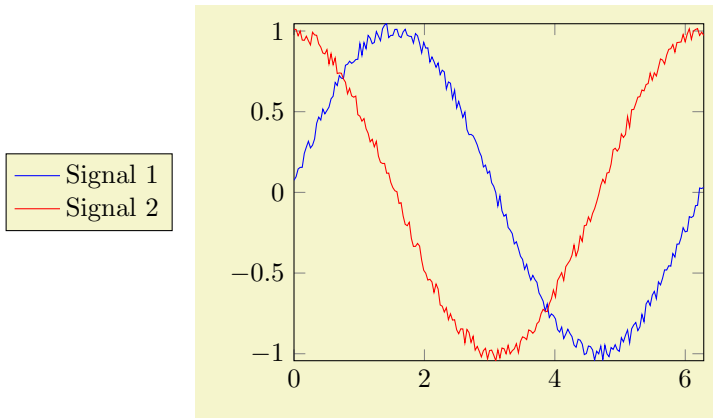

```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
    \begin{axis}[
        domain=0:6.2832,samples=200,
        legend style={
            overlay,
            at={(-0.5,0.5)},
            anchor=center},
        every axis plot post/.append style={mark=none},
        enlargelimits=false]

    \addplot {sin(deg(x)+3)+rand*0.05};
    \addplot {cos(deg(x)+2)+rand*0.05};
    \legend{Signal 1,Signal 2}
    \end{axis}
\end{tikzpicture}
```

More information about the `overlay` option can be found in the PGF manual [7].

\pgfresetboundingbox

This command of PGF resets the bounding box of the current picture. The computation starts from scratch afterwards, allowing to compute a user–defined bounding box.
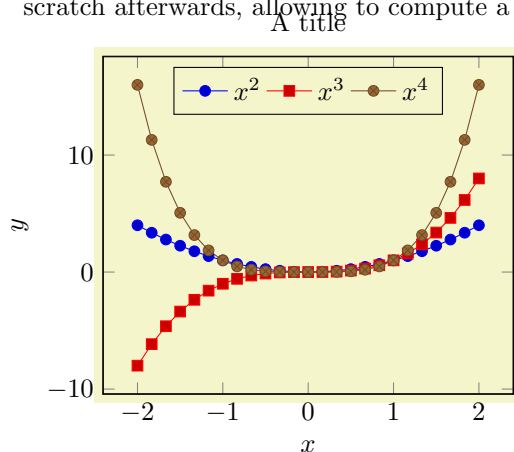

```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\setlength{\fboxsep}{0pt}%
\fbox{%
\begin{tikzpicture}%
    \begin{axis}[
        title=A title,
        xlabel={$x$},
        ylabel={$y$},
        legend style={at={(0.5,0.97)},
            anchor=north,legend columns=-1},
        domain=-2:2
    ]
    \addplot {x^2};
    \addplot {x^3};
    \addplot {x^4};
    \legend{$x^2$,$x^3$,$x^4$}
    \end{axis}

    \pgfresetboundingbox
    \path
            (current axis.south west)
    rectangle (current axis.north east);
\end{tikzpicture}%
}%
```

The example draws a normal picture, containing an axis. Afterwards, it throws the bounding box away and creates a new one based on the `current axis` node and its anchors.

`\begin{`pgfinterruptboundingbox`}`
⟨*environment contents*⟩
`\end{`pgfinterruptboundingbox`}`

Yet another approach with the same effect is shown below: the bounding box is interrupted manually, and resumed afterwards.
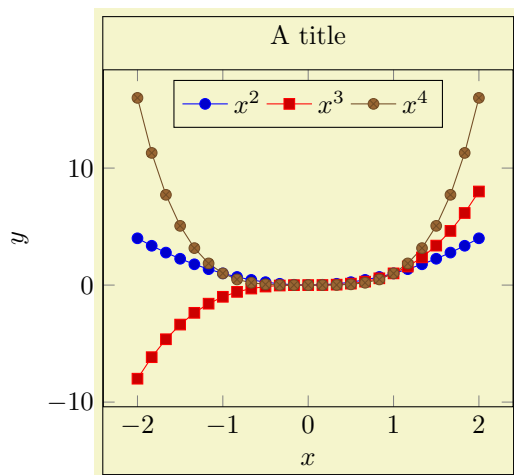

```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\setlength{\fboxsep}{0pt}%
\fbox{%
\begin{tikzpicture}%
    \begin{pgfinterruptboundingbox}
    \begin{axis}[
        title=A title,
        xlabel={$x$},
        ylabel={$y$},
        legend style={at={(0.5,0.97)},
            anchor=north,legend columns=-1},
        domain=-2:2
    ]
    \addplot {x^2};
    \addplot {x^3};
    \addplot {x^4};
    \legend{$x^2$,$x^3$,$x^4$}
    \end{axis}
    \end{pgfinterruptboundingbox}

    \useasboundingbox
            (current axis.below south west)
    rectangle (current axis.above north east);
\end{tikzpicture}%
}%
```

The `pgfinterruptboundingbox` environment does not include its content into the image's bounding box, and `\useasboundingbox` sets the pictures bounding box to the following argument (see [7]).

`/tikz/`**trim left**`={`⟨*x coordinate or point*⟩`}`   (default `0pt`)
`/tikz/`**trim right**`={`⟨*x coordinate or point*⟩`}`

These two keys allow to reduce the size of the bounding box.

The `trim left` key expects either a single x coordinate like `1cm` or a point like `(current axis.west)`. If a point is provided, is uses only the x coordinate of that point. Then, the left end of the bounding box is set to the resulting x coordinate and everything left of it is outside of the bounding box.

The `trim right` key has the same effect, only for the right end of the bounding box.

More detailed documentation can be found in the TikZ manual.

`/tikz/`**trim axis left**   (style, no value)

A style with value `trim left`=(current axis.south west).

The style needs to be provided as argument to `\begin{`tikzpicture`}`[trim axis left]. It expects (at least) one PGFPLOTS environment in the picture. The effect is to trim everything which is left of the last axis' anchor `south west` (i.e. everything left of the left axis boundary).

`/tikz/`**trim axis right**   (style, no value)

A style with value `trim right`=(current axis.south east).

It works similarly to `trim axis left`: the effect is that everything right of the right axis line of the last axis environment is truncated from the bounding box.

`/tikz/`**trim axis group left**   (style, no value)

A style which has the same effect as `trim axis left`, but is tailored for the `groupplots` library.

It has the value `trim left`=(group c1r1.south west).

The style needs to be provided as argument to \begin{`tikzpicture`}[trim axis group left]. It expects (at least) one `groupplot` environment in the picture. The effect is to trim everything which is left of the first group axis' anchor `south west` (i.e. everything left of the left axis boundary).

/tikz/**trim axis group right** (style, no value)

A style which has the same effect as `trim axis right`, but is tailored for the `groupplots` library.

It works similarly to `trim axis group left`: the effect is that everything right of the rightmost axis in a group plot (the last element of the `groupplot` environment) is truncated from the bounding box.

4.20.2 Clipping

Clipping influences both the picture size and the visible output in contrast to bounding box restrictions which reduce the picture's final size while keeping the same graphical output.

Typically, PGFPLOTS uses the path for a boxed axis as clip path. However, clipping has some special features and fine–tuning keys which are explained in this section.

/pgfplots/**clip**=true|false (initially `true`)

Controls whether any paths inside of an axis shall be clipped.

This is in effect even if `hide axis`=true.

Note that a clip path can contribute to the picture's bounding box. Starting with `compat`=1.8, PGF-PLOTS applies intelligence to separate the responsabilities clipping and bounding box control, see `clip bounding box` and its choices. As of `compat`=1.8, a clip path can be in effect although the bounding box is considerably smaller than the clip path. This is typically what one expects if the clip path is invisible.

The clip path is generated using \pgfplotspathaxisoutline, i.e. it is the path induced by boxed axis lines. For a three–dimensional plot, only the outer axis lines are used. A plot with centered axis lines uses the outer axis lines as well.

/pgfplots/**clip marker paths**=true|false (initially `false`)

The initial choice `clip marker paths`=false causes markers to be drawn *after* the clipped region. Only their positions will be clipped.

As a consequence, markers will be drawn completely, or not at all. The value `clip marker paths`=true is here for backwards compatibility: it does not introduce special marker treatment, so markers may be drawn partially if they are close to the clipping boundary[63].

This key has no effect if `clip`=false.

Note that clip marker paths also affects the sequence in which plots and their markers are drawn on top of each other. See also the related key `clip mode`.

/pgfplots/**clip bounding box**=default tikz|upper bound (initially `controlled by compat key`)

Controls how the path generated by `clip`=true contributes to the bounding box. This has a consequence for `axis lines`≠box, in particular, for `hide axis`: if the value is `default tikz`, hiding (parts of) the axis will not reduce the bounding box because the clip path is as large as before. The value `upper bound` allows to reduce the bounding box also in case of `hide axis`.

More precisely, the choice `default tikz` installs the clip path induced by the axis as ordinary TikZ path (see \pgfplotspathaxisoutline). That means its bounding box essentially contributes to the picture's bounding box, irrespective of the size of contained paths.

The choice `upper bound` allows to *reduce* the picture's bounding box to what is actually shown: if the picture only contains graphical elements which are completely within the bounding box of \pgfplotspathaxisoutline, the bounding box is made up of those contained elements. If the contained elements are actually larger than the bounding box of \pgfplotspathaxisoutline, they are clipped to the outline's path ("upper bound"). The latter case ensures that parts of the graphics which are excluded by `clip` are not counted for the bounding box.

Keep in mind that `hide axis` is independent of `clip`=true: the clip path might still be in effect even though the axis outline is invisible.

---

[63]Please note that clipped marker paths may be slightly faster during TEX compilation.

This key is irrelevant if `clip`=false. In addition, it has no effect for `axis lines`=box since the `box` path is made up from `\pgfplotspathaxisoutline`. It has an effect for `hide axis`=true or for choices of `axis lines` in which parts of the axis are empty.

This key is controlled by the `compat` level. Its default is `default tikz`. Since `compat`=1.8, it is set to `upper bound`.

The key has no effect if `clip`=false.

/pgfplots/clip mode=global|individual   (initially `global`)

This key controls how PGFPLOTS implements the `clip`=true feature (which is on by default). Its primary motivation is control where markers are placed: are markers on top of everything else (choice `global`) or are they overdrawn by following plots (choice `individual`)?

The choice `global` tells PGFPLOTS to install one single clip path for the complete picture[64]. In order to avoid clipped marker paths, any markers are processed after the clip path has been closed, i.e. on a separate layer (see `clip marker paths`). An unexpected side–effect is that marks are on top of plots, even if the plots have been added after the markers.

The choice `individual` instructs PGFPLOTS to install a separate clip path for *every* `\addplot` command. Consequently, the plot will be clipped. But most importantly, its markers will be drawn immediately after the clip path has been deactivated.

An unexpected side–effect of `clip mode`=individual is that

1. the resulting pdf will be slightly larger due to the repeated paths,
2. custom drawing instruction like `\node` or `\draw` need to be clipped *manually*: use
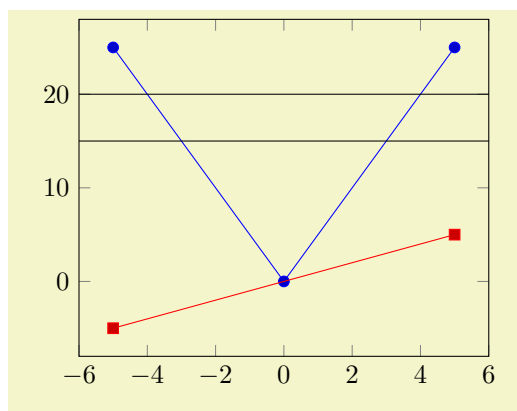

```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
    \begin{axis}[
        clip mode=individual,
    ]
    \addplot+[samples=3] {x^2};

    \begin{scope}
        \clip \pgfextra{\pgfplotspathaxisoutline};

        \draw (-20,15) -- (20,15);

        \draw (-20,20) -- (20,20);
    \end{scope}

    \addplot+[samples=2] {x};
    \end{axis}
\end{tikzpicture}
```

to install a custom clip path around your `\draw` instructions for such a use–case. Here, the path instruction `\pgfplotspathaxisoutline` results in a path of the axis outline, i.e. the path which is used for the background paths or for clipping. Since it is a basic level macro, it needs to be encapsulated by `\pgfextra`.

Note that `clip marker paths` can lead to the same result as `clip mode`=individual if the plot does not reach the boundaries.

4.21   Symbolic Coordinates and User Transformations

PGFPLOTS supports user transformations which can be applied to input and output coordinates. Suppose the plot shall display days versus account statements over time. Then, one wants to visualize date versus credit balance. But: dates need to be transformed to numbers before doing so! Furthermore, tick labels shall be displayed as dates as well. This, and more general transformations, can be implemented using the `x coord trafo` and `y coord trafo` keys.

---

[64]The choice `clip mode=global` was the only supported clipping mechanism up to and including version 1.5.

Remark: This section applies to users who want to have non-standard input *coordinates*. If you have normal numbers which don't need to be transformed and you like to have special symbols as tick labels, you should consider using the `xticklabels` (`yticklabels`) key described on page 334.

See also Section 4.23.1 for different types of transformations and their interaction.

```
/pgfplots/x coord trafo/.code={⟨...⟩}
/pgfplots/y coord trafo/.code={⟨...⟩}
/pgfplots/z coord trafo/.code={⟨...⟩}
/pgfplots/x coord inv trafo/.code={⟨...⟩}
/pgfplots/y coord inv trafo/.code={⟨...⟩}
/pgfplots/z coord inv trafo/.code={⟨...⟩}
```

These code keys allow arbitrary coordinate transformations which are applied to input coordinates and output tick labels.

The `x coord trafo` and `y coord trafo` command keys take one argument which is the input coordinate. They are expected to set `\pgfmathresult` to the final value.

At this level, the input coordinate is provided as it is found in the `\addplot` statement. For example, if x coordinates are actually of the form ⟨*year*⟩-⟨*month*⟩-⟨*day*⟩, for example 2008-01-05, then a useful coordinate transformation would transform this string into a number (see below for a predefined realization).

In short, *no* numerics has been applied to input coordinates when this transformation is applied[65].

The input coordinate transformation is applied to

- any input coordinates (specified with `\addplot` or `axis cs`),
- any user-specified `xtick` or `ytick` options,
- any user-specified `extra x ticks` and `extra y ticks` options,
- any user-specified axis limits like `xmin` and `xmax`.

The output coordinate transformation `x coord inv trafo` is applied to tick positions just before evaluating the `xticklabel` and `yticklabel` keys. The argument to `x coord inv trafo` is a fixed point number (which may have trailing zeros after the period). The tick label code may use additional macros defined by the inverse transformation.

Remark: PGFPLOTS will continue to produce tick positions as usual, no extra magic is applied. It may be necessary to provide tick positions explicitly if the default doesn't respect the coordinate space properly.

The initial value of these keys is

```
\pgfplotsset{
    x coord trafo/.code={},
    x coord inv trafo/.code={}}
```

which simply disables the transformation (the same for y, of course).

Remark: It might be necessary to set

```
\pgfplotsset{
    xticklabel={\tick},
    scaled x ticks=false,
    plot coordinates/math parser=false,
}
```

in order to avoid number formatting routines on `\tick` or numerics for tick scale methods. This is done automatically by the predefined symbolic coordinate styles (see below).

4.21.1 String Symbols as Input Coordinates

It is possible to provide a string dictionary to PGFPLOTS. An input coordinate can then use any symbol provided in that dictionary.

---

[65]Of course, if coordinates have been generated by gnuplot or PGF, this does no longer hold.

/pgfplots/**symbolic x coords**={⟨*dictionary*⟩}
/pgfplots/**symbolic y coords**={⟨*dictionary*⟩}
/pgfplots/**symbolic z coords**={⟨*dictionary*⟩}

A style which sets `x coord trafo` and `x coord inv trafo` (or the respective `y` or `z` variants) such that any element in ⟨*dictionary*⟩ is a valid input coordinate. The ⟨*dictionary*⟩ can be a comma separated list or a list terminated with '\\'. In both cases, white space is considered to be part of the names (use '%' at end of lines).

The dictionary will assign integer numbers to every element (starting with 0). These integers are used internally for arithmetics. Finally, the inverse transformation takes a fixed point number and maps it to the nearest integer, and that integer is mapped into the dictionary.
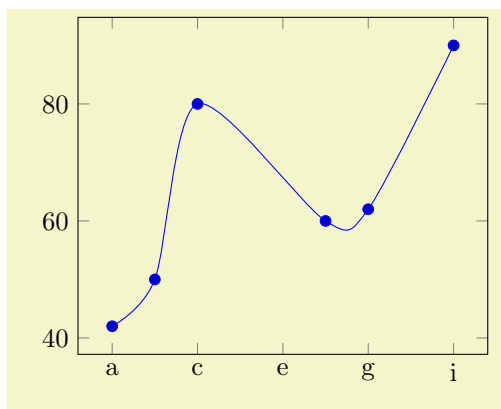

```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
\begin{axis}[symbolic x coords={a,b,c,d,e,f,g,h,i}]
    \addplot+[smooth] coordinates {
        (a,42)
        (b,50)
        (c,80)
        (f,60)
        (g,62)
        (i,90)};
\end{axis}
\end{tikzpicture}
```

The effect of the transformation is simply that input coordinates can be elements of the dictionary and tick labels will be chosen out of this dictionary as well.

Note that `symbolic x coords` is more-or-less equivalent to explicitly provided `xtick` positions and `xticklabels`:
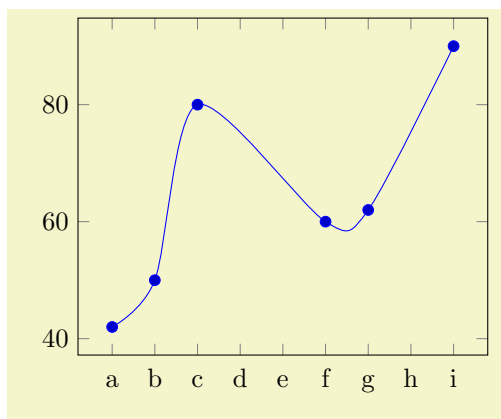

```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
\begin{axis}[
    xtick={0,1,2,...,20},
    xticklabels={a,b,c,d,e,f,g,h,i},
    xticklabel style={
        anchor=base,
        yshift=-\baselineskip
    },
    ]
    \addplot+[smooth] coordinates {
        (0,42)
        (1,50)
        (2,80)
        (5,60)
        (6,62)
        (8,90)};
\end{axis}
\end{tikzpicture}
```

The difference is that the approach with `symbolic x coords` is simpler to read whereas the `xtick` approach is simpler with respect to coordinate arithmetics (for example to increase limits using `enlargelimits`). The `xticklabel style` here is an attempt to align all tick labels at their base line (which would be useful for `symbolic x coords` as well as soon as labels have characters which exceed the baseline).

The key `symbolic x coords` and its variants accepts a comma–separated list of strings. These can be arbitrary and can even contain unexpandable material[66]:

---

[66]As of PGFPLOTS version 1.11.
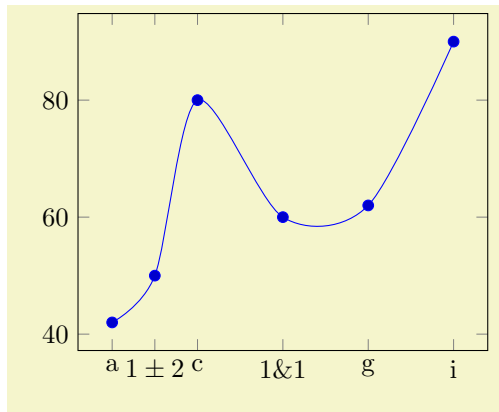
```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
\begin{axis}[
    symbolic x coords={a,$1 \pm 2$,c,d,1\&1,f,g,h,i},
    xtick=data,
]
    \addplot+[smooth] coordinates {
        (a,42)
        ($1 \pm 2$,50)
        (c,80)
        (1\&1,60)
        (g,62)
        (i,90)};
\end{axis}
\end{tikzpicture}
```

In any case, the arguments of ⟨*dictionary*⟩ must be met precisely, including any white spaces.

Symbolic coords are useful since they reduce the burden to map strings to indices and vice–versa. However, they have a caveat: what if you want to set xmin to something to the left of the first symbolic x coord? This is impossible since any input coordinate is expected to be contained in symbolic x coord. To allow such modifications nevertheless, PGFPLOTS checks for the magic prefix [normalized]:
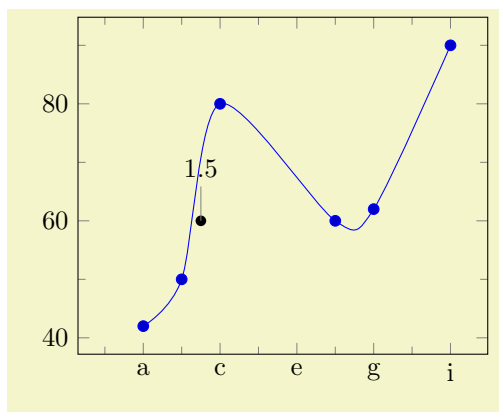

```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
\begin{axis}[
    symbolic x coords={a,b,c,d,e,f,g,h,i},
    xmin={[normalized]-1.7},
    minor tick num=1,
]
    \addplot+[smooth] coordinates {
        (a,42)
        (b,50)
        (c,80)
        (f,60)
        (g,62)
        (i,90)};

    \fill (axis cs:{[normalized]1.5},60)
        circle(2pt) coordinate[pin={$1.5$}];
\end{axis}
\end{tikzpicture}
```

Whenever PGFPLOTS finds a symbolic coordinate which starts with the precise string '[normalized]', it will interprete everything after the prefix to be a normalized number and *no* symbol. In our example, xmin will be set to −1.7, i.e. something to the left of *a* (which would be 0 according to the definition above). Furthermore, the custom \node is placed at (1.5, 60) despite the fact the 1.5 is no defined symbol – but we know that it is between b and c which are dictionary entry 1 and 2, respectively.

See also the option to add tick and/or grid lines at every encountered coordinate using xtick=data (or minor xtick=data).

4.21.2   Dates as Input Coordinates

The already mentioned application of using dates as input coordinates has been predefined, together with support for hours and minutes. It relies on the PGF calendar library which converts dates to numbers in the Julian calendar. Then, one coordinate unit is one day.

```
\usepgfplotslibrary{dateplot} % LaTeX and plain TeX
\usepgfplotslibrary[dateplot] % ConTeXt
\usetikzlibrary{pgfplots.dateplot} % LaTeX and plain TeX
\usetikzlibrary[pgfplots.dateplot] % ConTeXt
```

Loads the coordinate transformation code.

/pgfplots/date coordinates in=⟨*coordinate*⟩

Installs `x coord trafo` and `x coord inv trafo` (or the respective variant for ⟨*coordinate*⟩) such that ISO dates of the form ⟨*year*⟩-⟨*month*⟩-⟨*day*⟩ are accepted. Here, ⟨*coordinate*⟩ is usually one of `x`, `y`, or `z`, but it can also contain stuff like `hist/data`.

After installing this style, input values like `2006-02-28` will be converted to an "appropriate" integer using the Julian calender. Input coordinates may be of the form

⟨*year*⟩-⟨*month*⟩-⟨*day*⟩

or they may contain times as

⟨*year*⟩-⟨*month*⟩-⟨*day*⟩ ⟨*hour*⟩:⟨*minute*⟩.

The result of the transformation are numbers where one unit is one day and times are fractional numbers.

The transformation is implemented using the PGF-calendar module, see [7, Calendar Library]. This reference also contains more information about extended syntax options for dates.

The inverse transformation provides the following macros which are available during tick label evaluation (i.e. when used inside of `xticklabel` or `yticklabel`):

- `\year` expands to the year component,
- `\month` expands to the month component,
- `\day` expands to the day component,
- `\hour` expands to the hour component (using two digits),
- `\Hour` expands to the hour component (but omits leading zeros),
- `\minute` expands to the minute component (two digits),
- `\Minute` expands to the minute component (omits leadings zeros),
- `\lowlevel` expands to the low level number representing the tick,
- `\second` will always be `00`.

This allows to use `\day.\month.\year` or `\day.  \hour:\minute` inside of `xticklabel`, for example.

A complete example (with fictional data) is shown below.

date	account1	account2	account3
2008-01-03	60	1200	400
2008-02-06	120	1600	410
2008-03-15	-10	1600	410
2008-04-01	1800	500	410
2008-05-20	2300	500	410
2008-06-15	800	1920	410
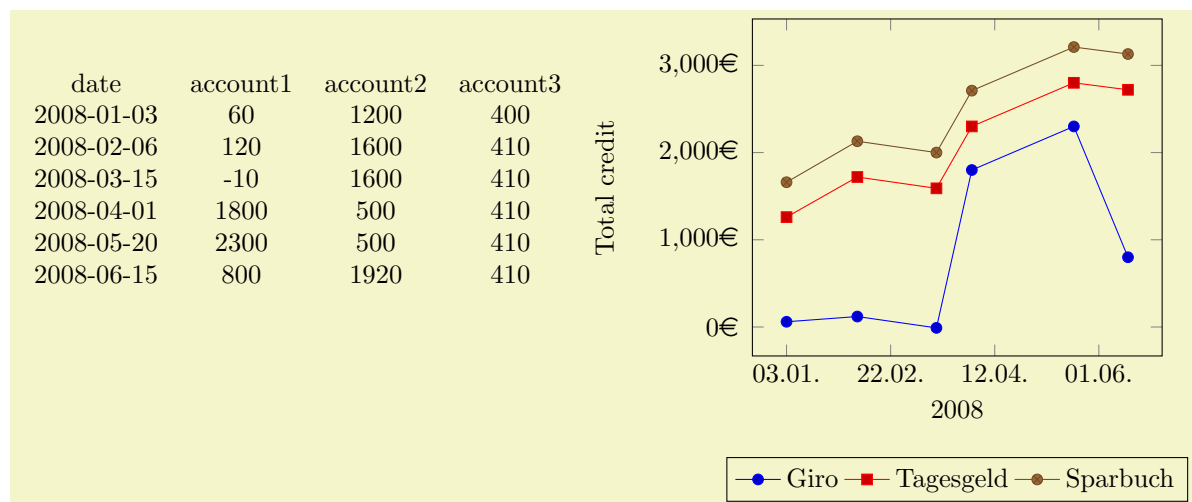
```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}\usepgfplotslibrary{dateplot}
% requires \usepgfplotslibrary{dateplot} !

\pgfplotstabletypeset[string type]{plotdata/accounts.dat}

\begin{tikzpicture}
    \begin{axis}[
        date coordinates in=x,
        xticklabel={\day.\month.},
        xlabel={2008},
        stack plots=y,
        yticklabel={\pgfmathprintnumber{\tick}\EUR{}}, % <- requires \usepackage{eurosym}
        ylabel=Total credit,
        ylabel style={yshift=10pt},
        legend style={
            at={(0.5,-0.3)},anchor=north,legend columns=-1}]

    \addplot table[x=date,y=account1] {plotdata/accounts.dat};
    \addplot table[x=date,y=account2] {plotdata/accounts.dat};
    \addplot table[x=date,y=account3] {plotdata/accounts.dat};
    \legend{Giro,Tagesgeld,Sparbuch}
    \end{axis}
\end{tikzpicture}
```
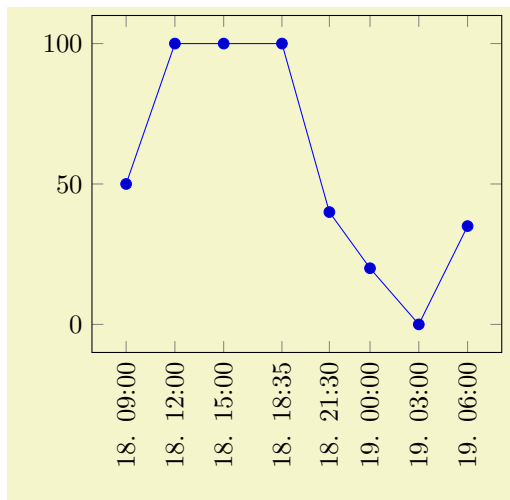


```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}\usepgfplotslibrary{dateplot}
% requires \usepgfplotslibrary{dateplot} !
\begin{tikzpicture}
  \begin{axis}[
    date coordinates in=x,
    xtick=data,
    xticklabel style=
        {rotate=90,anchor=near xticklabel},
    xticklabel=\day. \hour:\minute,
  ]
  \addplot coordinates {
    (2009-08-18 09:00,  050)
    (2009-08-18 12:00,  100)
    (2009-08-18 15:00,  100)
    (2009-08-18 18:35,  100)
    (2009-08-18 21:30,  040)
    (2009-08-19,        020)
    (2009-08-19 3:00,   000)
    (2009-08-19 6:0,    035)
  };
  \end{axis}
\end{tikzpicture}
```

/pgfplots/date ZERO=⟨*year*⟩-⟨*month*⟩-⟨*day*⟩

A technical key which defines the 0 coordinate of date coordinates in.

PGFPLOTS up to and including version 1.12 required this value. As of 1.13, the first encountered coordinate is used as date ZERO, i.e. it is assigned automatically without user intervention.

Users will never see the resulting numbers, so one probably never needs to change this value. This key allows to set the result as needed.

4.22 Skipping Or Changing Coordinates – Filters

PGFPLOTS offers filters. A filter expects a (numeric) input coordinate and is allowed to modify the coordinate or throw it away. Filters can either operate on individual coordinates or on all simultaneously. One main application is to skip coordinates, i.e. to install a filter which causes the coordinate to be skipped. This works by assigning special "this coordinate does not exist" values instead of the original values. Valid choices for "this coordinate does not exist" are defined using unbounded coords as described in Section 4.5.14 about Interrupted Plots, namely empty line or unbounded coords.

See also Section 4.23.1 for different types of transformations and their interaction.

/pgfplots/x filter/.expression={⟨*math expression*⟩}
/pgfplots/y filter/.expression={⟨*math expression*⟩}

/pgfplots/z filter/.expression={⟨*math expression*⟩}

Installs a coordinate filter which allows to modify the current value of a *single* coordinate.

The argument *math expression* is a math expression which contains x, y, or z.
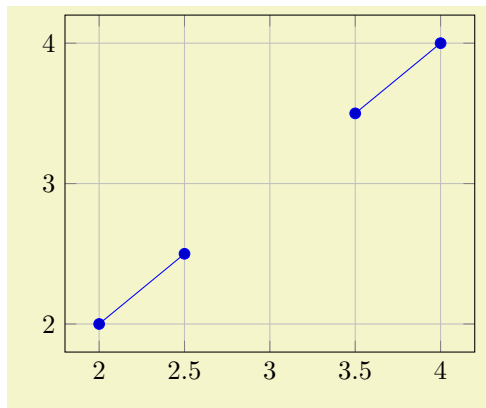

```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
    \begin{axis}[grid=major]
    \addplot+[
        unbounded coords=jump,
        x filter/.expression={x+1},
        y filter/.expression={y==3 ? nan : y},
    ]
    table {
    x y
    1 2
    1.5 2.5
    2 3
    2.5 3.5
    3 4
    };
    \end{axis}
\end{tikzpicture}
```

The x filter is evaluated first. It can depend on x, y, and z whose values are the "prepared" coordinates: values which have been found after applying x coord trafo and any logarithms (for logarithmic axes).

The y filter is evaluated as next. It can depend on x which is the result of x filter. It can also depend on y and z which have the same value as discussed in the previous paragraph.

The z filter is evaluated as last. It can depend on x and y which are result of their respective filters. It can also depend on z which is the plain z coordinate (as discussed for x filter).

Defining filters by math expression is actually a special case of x filter, see below.

/pgfplots/x filter/.code={⟨...⟩}
/pgfplots/y filter/.code={⟨...⟩}
/pgfplots/z filter/.code={⟨...⟩}
/pgfplots/filter point/.code={⟨...⟩}

The code keys x filter and y filter allow coordinate filtering which are based on a *single* coordinate. A coordinate filter gets an input coordinate as #1 (on input, the same value is stored in \pgfmathresult), applies some operation and writes the result into the macro \pgfmathresult. If \pgfmathresult is empty afterwards, the coordinate is discarded. You can also set \pgfmathresult to nan or inf in which case the coordinate can be either discarded (if unbounded coords=discard is set) or the plot can be interrupted (the case unbounded coords=jump).

The filter point/.code filter allows filtering depending on all components forming a complete point (x, y and z); it is described below.

It is allowed that filters do not change \pgfmathresult. In this case, the unfiltered coordinate will be used.

Coordinate filters are useful in automatic processing system, where PGFPLOTS is used to display automatically generated plots. You may not want to filter your coordinates by hand, so these options provide a tool to do this automatically.

The following filter adds 0.5 to every x coordinate.
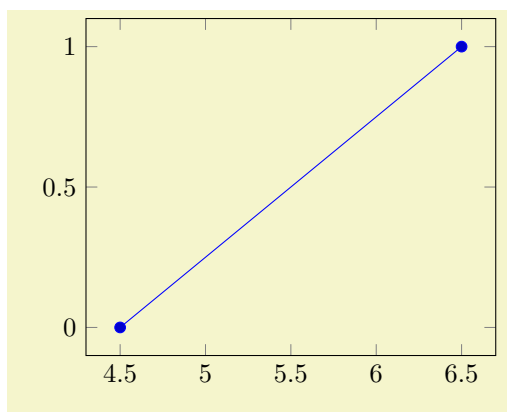
```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
% equivalent to 'x filter/.expression={x+0.5}':
\begin{axis}[x filter/.code=
    {\pgfmathadd{#1}{0.5}}]
\addplot coordinates {
    (4,0)
    (6,1)
};
\end{axis}
\end{tikzpicture}
```

Please refer to [7, pgfmath manual] for details about the math engine of PGF. Please keep in mind that the math engine works with limited TeX precision.

During evaluation of the filter, the macro `\coordindex` contains the number of the current coordinate (starting with 0). Thus, the following filter discards all coordinates after the 5th and before the 10th.
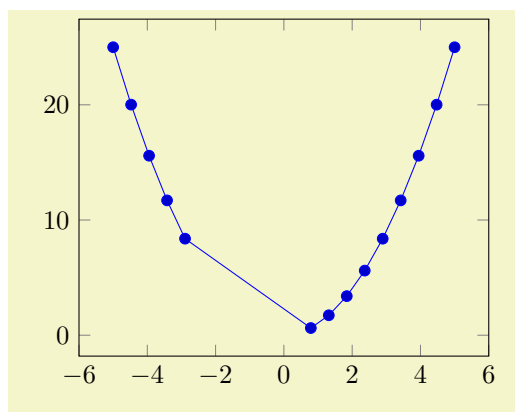
```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
\begin{axis}[
    samples=20,
    x filter/.code={
        \ifnum\coordindex>4
            \ifnum\coordindex<11
                \def\pgfmathresult{}
            \fi
        \fi
    }]
\addplot {x^2};
\end{axis}
\end{tikzpicture}
```

There is also a style key which simplifies selection by index, see below.

PGFPLOTS invokes the filter with argument `#1` set to the input coordinate. For x-filters, this is the x-coordinate as it is specified to `\addplot`, for y-filters it is the y-coordinate.

If the corresponding axis is logarithmic, `#1` is the *logarithm* (see `log basis x` and its variants) of the coordinate as a real number, for example `#1=4.2341`. In case the logarithm was undefined, the argument will be empty.

The arguments to coordinate filters are minimally preprocessed: first, for logarithmic axes, the *log* of the argument is supplied. Second, any high level coordinate maps like `x coord trafo` (which may be used to map dates to numbers or string to numbers or so) are applied. In consequence, the `#1` argument is supposed to be a number. No further transformation has been applied.

Occasionally, it might be handy to get the "raw", completely unprocessed input coordinate as it has been reported by the coordinate input routine. This unprocessed data is available in the three math parser constants `rawx`, `rawy` and `rawz`. All these values are ready for use in filters (and some other methods influence plots as well). Note that `rawy` is to be used like a function without arguments, i.e. filters can employ it where math parsing is done.

An application could be to filter log values based on the normal scale:
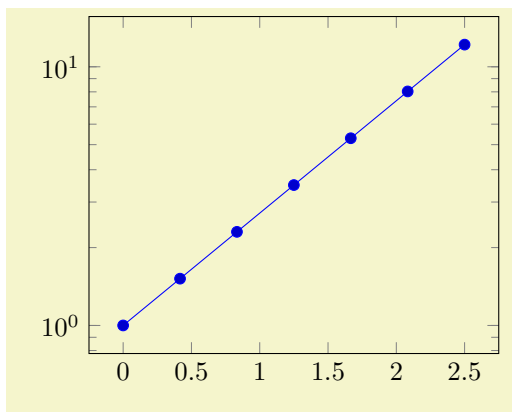
```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
\begin{semilogyaxis}
    \addplot+[
        restrict expr to domain={rawy}{1e0:1.5e1},
    ]{exp(x)};
\end{semilogyaxis}
\end{tikzpicture}
```

The preceding example uses `rawy` to throw all samples outside of the range $[1, 15]$ away.

If key filters are invoked for `plot table`, access to the current row's data can be achieved using `\thisrow{`⟨*column name*⟩`}` (and its variants). This includes all columns of the table.

The `filter point` key is more technical. It doesn't take an argument: its arguments are given in terms of the pgfkeys variables `/data point x`, `/data point y` and `/data point z`. It may change its coordinates using `\pgfkeyssetvalue{/data point x}{`⟨*new value*⟩`}`; access to variables can be accessed with `\pgfkeysvalueof{/data point/x}` or, if the argument shall be written into a macro, with `\pgfkeysgetvalue`. This filter is evaluated after the other ones.

Note that you can provide different `x filter`/`y filter` arguments to each `\addplot` command. It seems there are only problems with the '`#1`' argument, and I haven't yet found out why. Please use `\pgfmathresult` in place of `#1` if you provide `\addplot[x filter/.code={...}]`.

Note that coordinate filtering is also available for `mesh`, `surf`, and `patch` plots. In this context, a `patch type` is drawn if and only if all its vertices have bounded coordinates. In other words: if one vertex of, say, a rectangle has been filtered away, the entire rectangle will be omitted. Coordinate filtering for `mesh` and `surf`ace plots has a further special requirement: the default for such plots is `mesh input`=`lattice`. If a coordinate filter silently discards a coordinate, the lattice will break and PGFPLOTS will become confused. Consequently, coordinate filtering for `mesh` and `surf`ace plots always needs `unbounded coords`=`jump`, and any point which is filtered away should receive the value `nan` instead of an empty string (since empty strings will *always* be discarded even in presence of `unbounded coords`=`jump`). Please see the reference documentation of `unbounded coords` and the example therein on page 118 for details about coordinate filtering and three dimensional plots.

/pgfplots/`pre filter`/`.code`={⟨. . .⟩}

Applied before `x filter`, `y filter`, and `z filter`.

/pgfplots/`skip coords between index`={⟨*begin*⟩}{⟨*end*⟩}

A style which appends an `x filter` which discards selected coordinates. The selection is done by index where indexing starts with 0, see `\coordindex`. Every coordinate with index ⟨*begin*⟩ $\leq i <$ ⟨*end*⟩ will be skipped.
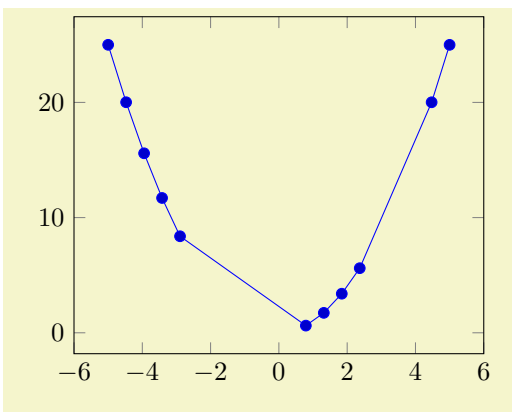

```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
\begin{axis}[
    samples=20,
    skip coords between index={5}{11},
    skip coords between index={15}{18}]

\addplot {x^2};
\end{axis}
\end{tikzpicture}
```

Technical note : this style usually applies to x coordinates (i.e. it counts x coordinates). In case you want to apply it to something like `hist/data` or `quiver/u`, you can

1. append an asterisk '`*`' to the style's name and
2. provide the target coordinate's name as first argument.

For example, `skip coords between index*={hist/data}{2}` applies to `hist/data`.

/pgfplots/**each nth point**=\{⟨*integer*⟩\}

A style which appends an `x filter` which discards all but each nth input coordinate.

This downsampling works fairly well. It can be used to reduce a huge amount of coordinates from an input file. In this case, you should also set `filter discard warning`=false to avoid repeated notifications about skipped coordinates and `unbounded coords`=discard such that PGFPLOTS should silently forget any discarded points (rather than generated interrupted plots).

Note that there is also a `mark repeat` style which applies the same operation to plot marks only.

Technical note : this style usually applies to x coordinates (i.e. it counts x coordinates). In case you want to apply it to something like `hist/data` or `quiver/u`, you can

1. append an asterisk '`*`' to the style's name and
2. provide the target coordinate's name as first argument.

For example, `each nth point*={hist/data}{2}` applies to `hist/data`.

/pgfplots/**restrict x to domain**=⟨*min*⟩:⟨*max*⟩
/pgfplots/**restrict y to domain**=⟨*min*⟩:⟨*max*⟩
/pgfplots/**restrict z to domain**=⟨*min*⟩:⟨*max*⟩
/pgfplots/**restrict x to domain***=⟨*min*⟩:⟨*max*⟩
/pgfplots/**restrict y to domain***=⟨*min*⟩:⟨*max*⟩
/pgfplots/**restrict z to domain***=⟨*min*⟩:⟨*max*⟩

These keys append x (or y or z) coordinate filters to restrict the respective coordinate to a domain.

The versions without star (like `restrict x to domain`) will assign the value `-inf` if the coordinate is below ⟨*min*⟩ and `+inf` if the coordinate is above ⟨*max*⟩. The starred versions (like `restrict x to domain*`) will truncate coordinates to [⟨*min*⟩, ⟨*max*⟩], i.e. they assign the value ⟨*min*⟩ if the coordinate falls outside of the lower limit and ⟨*max*⟩ if the value falls outside of the upper limit.

For logarithmic axes, ⟨*min*⟩ and ⟨*max*⟩ are *logs* of the respective values. A variant which uses the non-logarithmic number might be to use `restrict expr to domain={\pgfmathrawx}{`⟨*min*⟩`}{`⟨*max*⟩`}`.

The non-starred versions also set `unbounded coords`=jump which leads to interrupted plots.
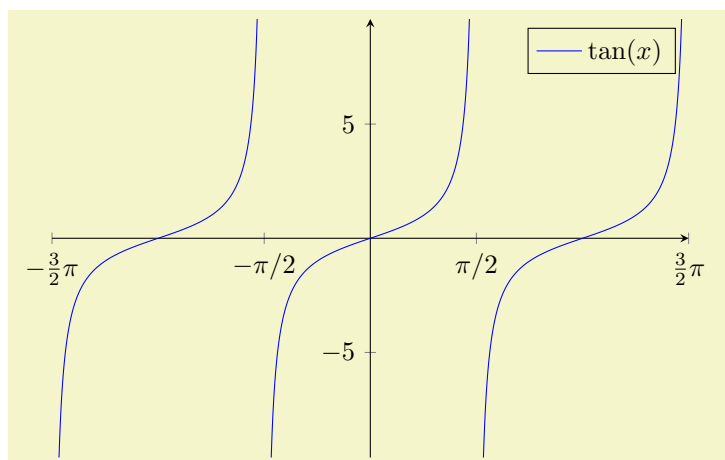
```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
\begin{axis}[
    restrict y to domain=-10:10,
    samples=1000,
    % some fine-tuning for the display:
    width=10cm, height=210pt,
    xmin=-4.7124, xmax=4.7124,
    xtick={-4.7124,-1.5708,...,10},
    xticklabels={$-\frac32 \pi$,$-\pi/2$,$\pi/2$,$\frac32 \pi$},
    axis x line=center,
    axis y line=center]

\addplot[blue] gnuplot[id=tangens,domain=-1.5*pi:1.5*pi] {tan(x)};
\legend{$\tan(x)$}
\end{axis}
\end{tikzpicture}
```

/pgfplots/**restrict expr to domain**={⟨*expression*⟩}{⟨⟨*min*⟩:⟨*max*⟩⟩}
/pgfplots/**restrict expr to domain***={⟨*expression*⟩}{⟨⟨*min*⟩:⟨*max*⟩⟩}

Appends an x coordinate filter which sets the x coordinate to `-inf` if the ⟨*expression*⟩ evaluates to something less than ⟨*min*⟩ and to `inf` if ⟨*expression*⟩ evaluates to something larger than ⟨*max*⟩.

The starred variant, `restrict to domain*` assigns ⟨*min*⟩ if ⟨*expression*⟩ is less then the lower limit and ⟨*max*⟩ if it is larger than the upper limit.

The non-starred version also sets `unbounded coords`=`jump` which leads to interrupted plots.

In contrast to `restrict x to domain`, ⟨*expression*⟩ can depend on anything which is valid during `\addplot`, in particular `\coordindex` or table columns (`\thisrow`{⟨*column name*⟩} and friends). The expression doesn't need to depend on x at all.

/pgfplots/**@restrict to domain**={⟨*filter name*⟩}{⟨*expression*⟩}{⟨⟨*min*⟩:⟨*max*⟩⟩}0|1

A low–level (technical) key which allows to apply the `restrict * to ...` features also to something like `hist/data`.

For example, `@restrict to domain`={hist/data}{}{0:1}{0} applies the domain-restriction to the histogram-input `hist/data`. The final '0' means that it works in a similar way as the key `restrict x to domain`=0:1, i.e. it skips everything which is outside of $[0, 1]$. In a similar way, `@restrict to domain`={hist/data}{}{0:1}{1} applies the functionality of `restrict x to domain*`=0:1 to `hist/data`: it truncates values outside of $[0, 1]$ to the domain's end-points.

The ⟨*filter name*⟩ is expected to be a coordinate name like `x`, `y`, `z` (or `hist/data`).

The ⟨*expression*⟩ configures an expression which will be used rather than the value of ⟨*filter name*⟩. It can be empty.

The ⟨*min*⟩:⟨*max*⟩ are as described above.

If the last argument is `1`, any coordinate outside of the allowed domain will take the domain boundary as value. If it is `0`, such a coordinate will get either `inf` or `-inf`.

/pgfplots/**filter discard warning**=true|false   (initially `true`)

Issues a notification in your logfile whenever coordinate filters discard coordinates.

You can find somewhat more on coordinate filtering in Section 4.5.14: "Interrupted Plots".

4.23   Transforming Coordinate Systems

Usually, PGFPLOTS works with cartesian coordinates. However, one may want to provide coordinates in a different coordinate system.

In this case, the `data cs` key can be used to identify the input coordinate system:

/pgfplots/**data cs**=cart|polar|polarrad   (initially `cart`)

Defines the coordinate system ('cs') of the input coordinates. PGFPLOTS will apply transformations if the argument does not match the expected coordinate system.

Use `data cs` if your input has a different coordinate system than the axis. More precisely, every axis type has its own coordinate system. For example, a normal `axis` has the `cart` coordinate system, whereas a `polaraxis` has a `polar` coordinate system. The use of `data cs` with a different argument than the default of your axis instructs PGFPLOTS to apply transformations.

At the time of this writing, PGFPLOTS supports the following values for `data cs`:

The `data cs=cart` denotes the cartesian coordinate system. It is the coordinate system of the usual `axis` (or its logarithmic variants). It can have three components, x, y, and z. Specifying it is only necessary if you have a non-cartesian axis:
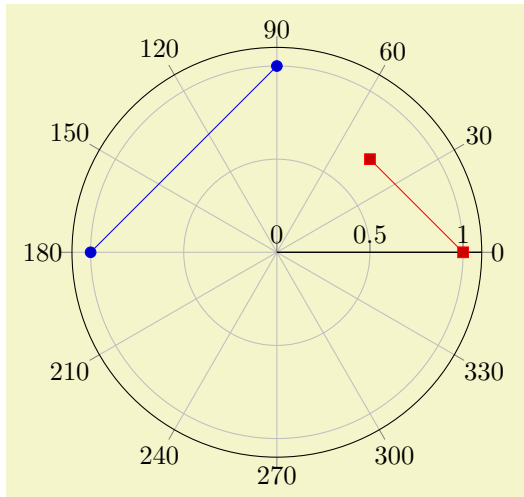

```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
% requires \usepgfplotslibrary{polar}
\begin{tikzpicture}
    \begin{polaraxis}
    \addplot coordinates {(90,1) (180,1)};
    \addplot+[data cs=cart]
        coordinates {(1,0) (0.5,0.5)};
    \end{polaraxis}
\end{tikzpicture}
```

The `data cs=polar` is the (two–dimensional) coordinate system with (angle, radius), i.e. the first component "x" is the angle and the second component "y" is the radius. The angle is a number in the periodic range $[0, 360)$; the radius is any number. If a `polar` coordinate has a z component, it is taken as-is (the transformations ignore it).
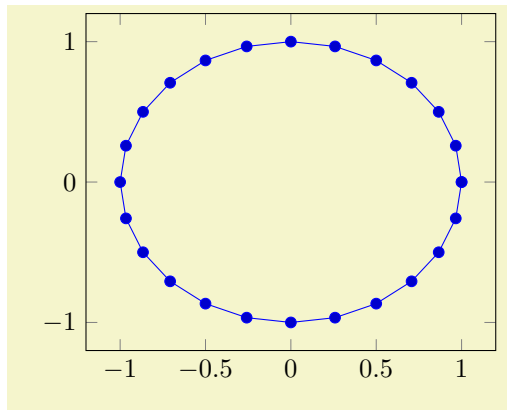

```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
    \begin{axis}
    \addplot+[data cs=polar,domain=0:360] (\x,1);
    \end{axis}
\end{tikzpicture}
```

The `data cs=polarrad` is similar to `polar`, but it expects the angle in radians, i.e. in the periodic range $[0, 2\pi)$.

```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
    \begin{axis}
    \addplot+[data cs=polarrad,domain=0:2*pi] (\x,1);
    \end{axis}
\end{tikzpicture}
```

Note that the math function `deg(⟨rad⟩)` transforms ⟨rad⟩ into degrees and `rad(⟨degree⟩)` transforms ⟨degree⟩ into radians. Consequently, `polar` and `polarrad` are more-or-less equivalent for plot expression.
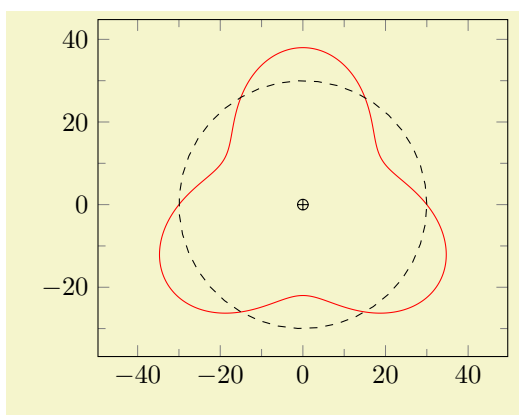
```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
 \begin{axis}[
    axis equal,
    minor tick num=1,
]
\def\FREQUENCY{3}
\addplot[red,domain=0:360,samples=200,
    smooth,data cs=polar]
    (x,{30-8*sin(\FREQUENCY*x)});

\addplot[samples=40,domain=0:2*pi,dashed,
    data cs=polar] (deg(x),30);

\addplot[mark=oplus,only marks] coordinates {(0,0)};
 \end{axis}
\end{tikzpicture}
```

At the point of this writing, the `data cs` method will work for most plot handlers. But for complicated plot handlers, further logic may be needed which is not yet available (for example, the `quiver` plot handler might not be able to convert its direction vectors correctly)[67].

\pgfplotsaxistransformmcs{⟨fromname⟩}{⟨toname⟩}

Expects the current point in a set of keys, provided in the coordinate system ⟨fromname⟩ and replaces them by the same coordinates represented in ⟨toname⟩.

On input, the coordinates are stored in /data point/x, /data point/y, and /data point/z (the latter may be empty). The macro will test if there is a declared coordinate transformation from ⟨fromname⟩ to ⟨toname⟩ and invoke it. If there is none, it will attempt to convert to `cart` first and then from `cart` to ⟨toname⟩. If that does not exist either, the operation fails.

\pgfplotsdefinecstransform{⟨fromname⟩}{⟨toname⟩}{⟨code⟩}

Defines a new coordinate system transformation. The ⟨code⟩ is expected to get input and write output as described for \pgfplotsaxistransformmcs.

Implementing a new coordinate system immediately raises the question in which math mode the operations shall be applied. PGFPLOTS supports different so–called "coordinate math systems" for generic operations, and for each individual coordinate as well. These coordinate math systems can either use basic PGF math arithmetics, the `fpu`, or perhaps there will come a LuaTeX library.

The documentation of this system is beyond the scope of this manual[68]. Please consider reading the source-code comments and the source of existing transformations if you intend to write own transformations.

---

[67]In case you run into problems, consider writing a bug report or ask others in TeX online discussion forums.
[68]Which is quite comprehensive even without API documentation, as you will certainly agree...

4.23.1   Interaction of Transformations

There are a couple of coordinate mappings in PGFPLOTS. For each encountered coordinate in a coordinate stream (`\addplot`), it applies the following steps:

1. Remember the "raw" coordinates in math constants `rawx`, `rawy`, `rawz`,

2. Apply `pre filter`,

3. Apply `x coord trafo`, logarithm if necessary, and `x filter` (in this order),

4. Apply `y coord trafo`, logarithm if necessary, and `y filter`,

5. Apply `z coord trafo`, logarithm if necessary, and `z filter`,

6. Apply `filter point`,

7. Transfrom from `data cs` to the coordinate system of `axis type`,

8. Handle coordinate stacking (`stack plots`=x and/or `stack plots`=y).

Here, `pre filter` takes no arguments; it simply prepares the following filters. Consequently, the first item which actually accepts the input argument is `x coord trafo`. This method is part of the parsing; it accepts the "raw" coordinate which may be in symbolic form. The output of `x coord trafo` and its variants is a number. This number can be filtered or transformed by means of `x filter` and its variants. Note that `x filter` simply takes one argument: the result of `x coord trafo`.

The intented meaning of `x coord trafo` is to define how the "raw" string form as provided by the user makes its way into PGFPLOTS. It is also the only transformation which has an inverse, the key `x coord inv trafo`. The inverse can be used to transform back from internal numeric form to some string for the end user. The key `x coord trafo` can only be defined as option to an axis, i.e. it it cannot be provided to `\addplot`.

The meaning of `x filter` and its variants is to transform numbers or to conditionally throw away numbers (and thus the entire coordinate). Each `\addplot` can receive its own (set of) filters.

The key `filter point` accepts *all* arguments (more precisely: the result of the preceding steps). It can rely on x, y, and z, and it can change any of them. The way it accepts the coordinates is by means of keys `/data point/x` and its variants for y and z. In principle, `filter point` is the most general filter. However, you can define both `x filter` and `filter point`, and both will be applied. Each `\addplot` can receive its own `filter point`.

The implementation for the key `data cs` is similar to `filter point` in that it accepts the result of all previous mapping steps. However, it maps from a well–defined input coordinate system to some well–defined internal coordinate system (which is inherent to the axis). Each `\addplot` can receive its own `data cs`.

Finally, `stack plots` takes measures to add/subtract the results. Stacking of plots is a property of the axis; it is not intented to be provided as argument to `\addplot`[69].

4.24   Fitting Lines – Regression

This section documents the attempts of PGFPLOTS to fit lines to input coordinates. PGFPLOTS currently supports `create col/linear regression` applied to columns of input tables. The feature relies on PGF-PLOTSTABLE, it is actually implemented as a table postprocessing method.

`/pgfplots/table`**`/create col/linear regression`**`={`⟨*key-value-config*⟩`}`

A style for use in `\addplot table` which computes a linear (least squares) regression $y(x) = a \cdot x + b$ using the sample data (x_i, y_i) which has to be specified inside of ⟨*key-value-config*⟩ (see below).

It creates a new column on-the-fly which contains the values $y(x_i) = a \cdot x_i + b$. The values a and b will be stored (globally) into `\pgfplotstableregressiona` and `\pgfplotstableregressionb`.

---

[69]Also it appears to do something which is not entirely useless.
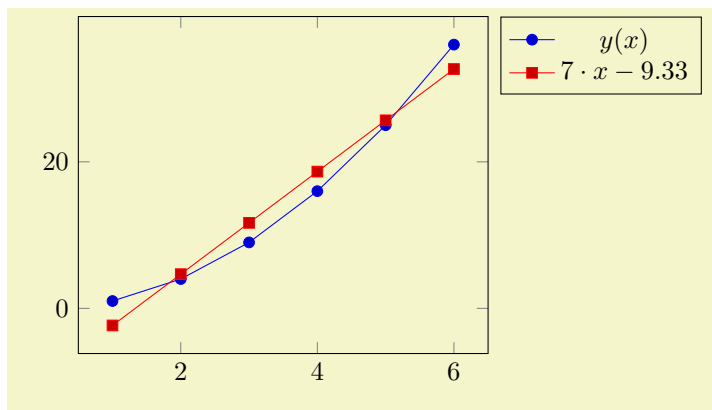
```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
    \begin{axis}[legend pos=outer north east]
    \addplot table {% plot X versus Y. This is original data.
        X Y
        1 1
        2 4
        3 9
        4 16
        5 25
        6 36
    };
    \addplot table[
        y={create col/linear regression={y=Y}}] % compute a linear regression from the input table
    {
        X Y
        1 1
        2 4
        3 9
        4 16
        5 25
        6 36
    };
    %\xdef\slope{\pgfplotstableregressiona} %<-- might be handy occasionally
    \addlegendentry{$y(x)$}
    \addlegendentry{%
        $\pgfmathprintnumber{\pgfplotstableregressiona} \cdot x
        \pgfmathprintnumber[print sign]{\pgfplotstableregressionb}$}
    \end{axis}
\end{tikzpicture}
```

The example above has two plots: one showing the data and one containing the `linear regression` line. We use `y={create col/linear regression={}}` here, which means to create a new column[70] containing the regression values automatically. As arguments, we need to provide the y column name explicitly[71]. The x value is determined from context: `linear regression` is evaluated inside of `\addplot table`, so it uses the same x as `\addplot table` (i.e. if you write `\addplot table[x={⟨col name⟩}]`, the regression will also use ⟨col name⟩ as its `x` input). Furthermore, it shows the line parameters a and b in the legend.

Note that the uncommented line with `\xdef\slope{\pgfplotstableregressiona}` is useful if you have *more than one* regression line: it copies the value of `\pgfplotstableregressiona` (in this case) into a new global variable called '`\slope`'. This allows to use '`\slope`' instead of `\pgfplotstableregressiona` – even after `\pgfplotstableregressiona` has been overwritten.

The following ⟨key-value-config⟩ keys are accepted as comma–separated list:

/pgfplots/table/create col/linear regression/**table**={⟨\macro or *file name*⟩} (initially `empty`)

> Provides the table from where to load the `x` and `y` columns. It defaults to the currently processed one, i.e. to the value of `\pgfplotstablename`.

---

[70]The `y={create col/` feature is available for any other PGFPLOTSTABLE postprocessing style, see the `create on use` documentation in the PGFPLOTSTABLE manual.

[71]In fact, PGFPLOTS sees that there are only two columns and uses the second by default. But you need to provide it if there are at least 3 columns.

/pgfplots/table/create col/linear regression/x={⟨*column*⟩} (initially `empty`)
/pgfplots/table/create col/linear regression/y={⟨*column*⟩} (initially `empty`)

Provides the source of x_i and y_i data, respectively. The argument ⟨*column*⟩ is usually a column name of the input table, yet it can also contain [`index`]⟨*integer*⟩ to designate column indices (starting with 0), `create on use` specifications or `alias`es (see the PGFPLOTSTABLE manual for details on `create on use` and `alias`).

The initial configuration (an empty value) checks the context where the `linear regression` is evaluated. If it is evaluated inside of `\pgfplotstabletypeset`, it uses the first and second table columns. If it is evaluated inside of `\addplot table`, it uses the same x input as the `\addplot table` statement. The `y` key needs to be provided explicitly (unless the table has only two columns).

/pgfplots/table/create col/linear regression/xmode=auto|linear|log (initially `auto`)
/pgfplots/table/create col/linear regression/ymode=auto|linear|log (initially `auto`)

Enables or disables processing of logarithmic coordinates. Logarithmic processing means to apply ln before computing the regression line and exp afterwards.

The choice `auto` checks if the column is evaluated inside of a PGFPLOTS axis. If so, it uses the axis scaling of the embedding axis. Otherwise, it uses `linear`.

In case of logarithmic coordinates, the `log basis x` and `log basis y` keys determine the basis.
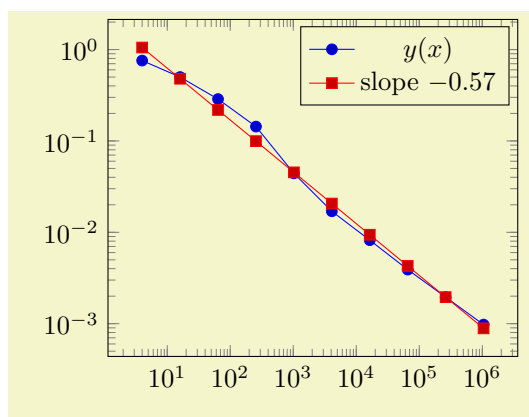

```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
\begin{loglogaxis}
 \addplot table[x=dof,y=error2]
    {pgfplotstable.example1.dat};
  \addlegendentry{$y(x)$}

\addplot table[
    x=dof,
    y={create col/linear regression={y=error2}}]
    {pgfplotstable.example1.dat};

  % might be handy occasionally:
  %\xdef\slope{\pgfplotstableregressiona}
 \addlegendentry{slope
    $\pgfmathprintnumber{\pgfplotstableregressiona}$}
\end{loglogaxis}
\end{tikzpicture}
```

The (commented) line containing `\slope` is explained above; it allows to remember different regression slopes in our example.

/pgfplots/table/create col/linear regression/variance list={⟨*list*⟩} (initially `empty`)
/pgfplots/table/create col/linear regression/variance={⟨*column name*⟩} (initially `empty`)

Both keys allow to provide uncertainties (variances) to single data points. A high (relative) variance indicates an unreliable data point, a value of 1 is standard.

The `variance list` key allows to provide variances directly as comma–separated list, for example

`variance list`={1000,1000,500,200,1,1}.

The `variance` key allows to load values from a table ⟨*column name*⟩. Such a column name is (initially, see below) loaded from the same table where data points have been found. The ⟨*column name*⟩ may also be a `create on use` name.
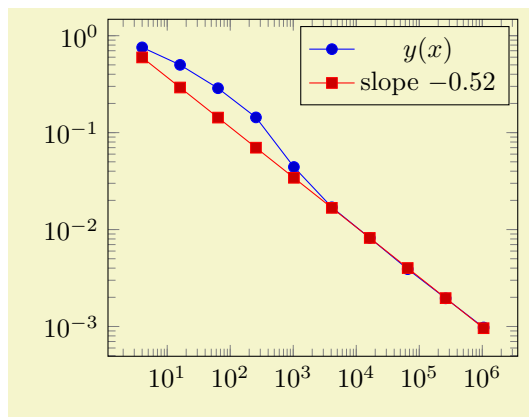
```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
\begin{loglogaxis}
 \addplot table[x=dof,y=error2]
    {pgfplotstable.example1.dat};
  \addlegendentry{$y(x)$}

 \addplot table[
      x=dof,
        y={create col/linear regression={
        y=error2,
        variance list={1000,800,600,500,400}}
        }
]
    {pgfplotstable.example1.dat};

 \addlegendentry{slope
  $\pgfmathprintnumber{\pgfplotstableregressiona}$}
\end{loglogaxis}
\end{tikzpicture}
```

If both, `variance list` and `variance` are given, the first one will be preferred. Note that it is not necessary to provide variances for every data point.

/pgfplots/table/create col/linear regression/**variance src**={⟨\table or file name⟩} (initially empty)

Allows to load the `variance` from another table. The initial setting is empty. It is acceptable if the `variance` column in the external table has fewer entries than expected, in this case, only the first ones will be used.

Limitations: Currently, PGFPLOTS supports only linear regression, and it only supports regression together with `\addplot table`. Furthermore, long input tables might need quite some time.

4.25   Miscellaneous Options

/pgfplots/**disablelogfilter**=true|false   (initially `false`, default `true`)

Disables numerical evaluation of $\log(x)$ in TEX. If you specify this option, any plot coordinates and tick positions must be provided as $\log(x)$ instead of x. This may be faster and – possibly – more accurate than the numerical log. The current implementation of $\log(x)$ normalizes x to $m \cdot 10^e$ and computes

$$\log(x) = \log(m) + e \log(10)$$

where $y = \log(m)$ is computed with a Newton method applied to $\exp(y) - m$. The normalization involves string parsing without TEX-registers. You can safely evaluate $\log(1 \cdot 10^{-7})$ although TEX-registers would produce an underflow for such small numbers.

/pgfplots/**disabledatascaling**=true|false   (initially `false`, default `true`)

Disables internal re-scaling of input data. Normally, every input data like plot coordinates, tick positions or whatever, are parsed without using TEX's limited number precision. Then, a transformation like

$$T(x) = 10^{q-m} \cdot x - a$$

is applied to every input coordinate/position where m is "the order of x" base 10. Example: $x = 1234 = 1.234 \cdot 10^3$ has order $m = 4$ while $x = 0.001234 = 1.234 \cdot 10^{-3}$ has order $m = -2$. The parameter q is the order of the axis' width/height.

The **effect** of the transformation is that your plot coordinates can be of *arbitrary magnitude* like 0.0000001 and 0.0000004. For these two coordinates, PGFPLOTS will use 100pt and 400pt internally. The transformation is quite fast since it relies only on period shifts. This scaling allows precision beyond TEX's capabilities.

The option "`disabledatascaling`" disables this data transformation. This has two consequences: first, coordinate expressions like (⟨`axis cs:`x,y⟩) have the same effect as (⟨x,y⟩), no re-scaling is applied. Second, coordinates are restricted to what TEX can handle[72].

So far, the data scale transformation applies only to normal axes (logarithmic scales do not need it).

/pgfplots/execute at begin plot=**{**⟨*commands*⟩**}**

This axis option allows to invoke ⟨*commands*⟩ at the beginning of each `\addplot` command. The argument ⟨*commands*⟩ can be any TEX content.

You may use this in conjunction with `x filter`=`...` to reset any counters or whatever. An example would be to change every 4th coordinate.

/pgfplots/execute at end plot=**{**⟨*commands*⟩**}**

This axis option allows to invoke ⟨*commands*⟩ after each `\addplot` command. The argument ⟨*commands*⟩ can be any TEX content.

/pgfplots/execute at begin axis=**{**⟨*commands*⟩**}**

Allows to invoke ⟨*commands*⟩ at the end of `\begin{axis}` (or the other "begin axis" statements).

The statement is execute as (almost) last statement before the preparation has been completed.

/pgfplots/execute at end axis=**{**⟨*commands*⟩**}**

The counterpart for `execute at begin axis`. The hook is actually superfluos, it is executed immediately after `before end axis`. It is executed in the same TEX group as `execute at begin axis`.

/pgfplots/execute at begin plot visualization=**{**⟨*commands*⟩**}**

Allows to add customized code which is executed at the beginning of each plot visualization. In contrast to `execute at begin plot`, this happens not immediately during `\addplot`, but late during the postprocessing of `\end{axis}` when actual drawing commands are generated.

One possible application is shown below[73]: suppose you want to use `\usepackage{ocg}` in order to switch layers dynamically, for example in a beamer package. This can be implemented as follows:

---
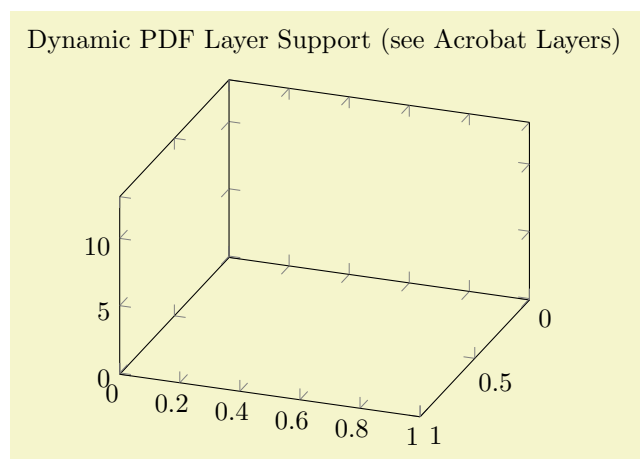
[72]Please note that the axis' scaling requires to compute $1/(x_{\max} - x_{\min})$. The option `disabledatascaling` may lead to overflow or underflow in this context, so use it with care! Normally, the data scale transformation avoids this problem.
[73]This example from the game theory was provided by Pavel Stříž.

```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
% requires \usepackage[pdftex]{ocg}
\begin{tikzpicture}
\begin{axis}[
    title=Dynamic PDF Layer Support (see Acrobat Layers),
    view={110}{35}]
\addplot3+[
    execute at begin plot visualization=\begin{ocg}{First Layer}{FirstLayer}{0},
    execute at end plot visualization=\end{ocg},
]
    coordinates {(0,0,12) (0,1,2) (1,0,6) (0,0,12)};

\addplot3+[
    execute at begin plot visualization=\begin{ocg}{Second Layer}{SecondLayer}{0},
    execute at end plot visualization=\end{ocg},
]
    coordinates {(0,0,9) (0,1,8) (1,0,4) (0,0,9)};

\addplot3+[
    execute at begin plot visualization=\begin{ocg}{Third Layer}{ThirdLayer}{0},
    execute at end plot visualization=\end{ocg},
]
    coordinates {(0,0,1) (0,1,7) (1,0,3) (0,0,1)};
\end{axis}
\end{tikzpicture}
```

The `execute *` hooks insert the OCG-statements at the correct positions, and the single plot commands are added to different dynamic layers. Use the Acrobat Reader and its "Layers" Tab to switch each of them on or off. Note that it would not be enough to add the `\begin{ocg}`... statements right into the text since PGFPLOTS postpones drawing commands until `\end{axis}` (splitting of survey and visualization phase).

See http://www.texample.net/weblog/2008/nov/02/creating-pdf-layers for more details on OCG and how to obtain it.

Technical note: these hooks are also inserted for `\pgfplotsextra` commands.

/pgfplots/execute at end plot visualization={⟨*commands*⟩}

This is the counter–part of `execute at begin plot visualization`.

/pgfplots/forget plot={⟨*true,false*⟩}   (initially `false`)

Allows to include plots which are not remembered for legend entries, which do not increase the number of plots and which are not considered for cycle lists.

A forgotten plot can be some sort of decoration which has a separate style and does not influence the axis state, although it is processed as any other plot. Provide this option to `\addplot` as in the following example.
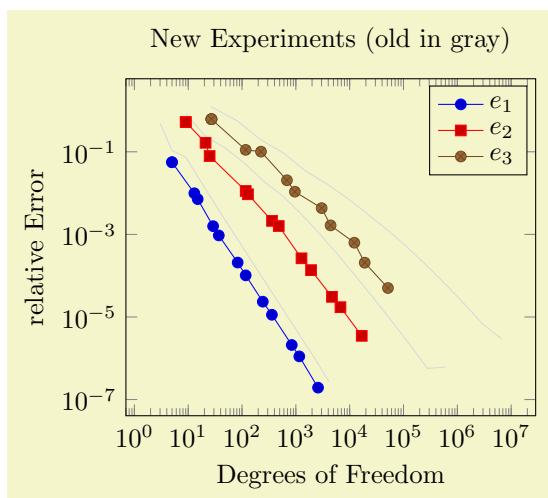

```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
    \begin{loglogaxis}[
        % some descriptions:
        table/x=Basis,
        table/y={L2/r},
        xlabel=Degrees of Freedom,
        ylabel=relative Error,
        title=New Experiments (old in gray),
        legend entries={$e_1$,$e_2$,$e_3$}
    ]
    \addplot[black!15,forget plot]
        table {plotdata/oldexperiment1.dat};
    \addplot[black!15,forget plot]
        table {plotdata/oldexperiment2.dat};
    \addplot[black!15,forget plot]
        table {plotdata/oldexperiment3.dat};
    \addplot table {plotdata/newexperiment1.dat};
    \addplot table {plotdata/newexperiment2.dat};
    \addplot table {plotdata/newexperiment3.dat};
    \end{loglogaxis}
\end{tikzpicture}
```

Since forgotten plots won't increase the plot index, they will use the same `cycle list` entry as following plots.

The style `every forget plot` can be used to configure styles for each such plot:
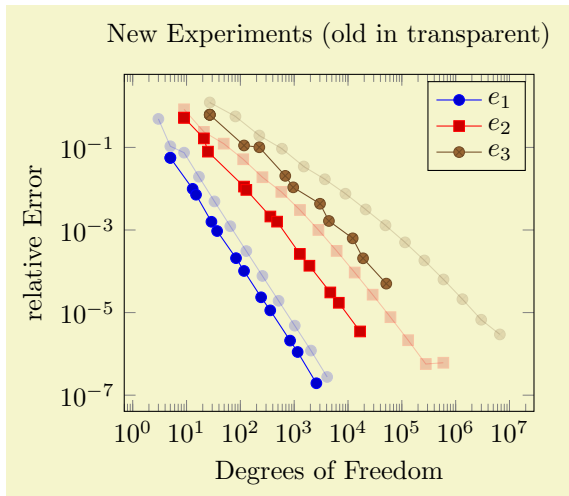

```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
    \begin{loglogaxis}[
        forget plot style={opacity=0.2},
        % same as above:
        table/x=Basis,
        table/y={L2/r},
        xlabel=Degrees of Freedom,
        ylabel=relative Error,
        title=New Experiments (old in transparent),
        legend entries={$e_1$,$e_2$,$e_3$},
    ]
    \foreach \exp in {1,2,3} {
      \addplot+[forget plot]
          table {plotdata/oldexperiment\exp.dat};
      \addplot table {plotdata/newexperiment\exp.dat};
    }
    \end{loglogaxis}
\end{tikzpicture}
```

Here, the `\addplot`+ command means we are using the same `cycle list` as the following plot and `forget plot style` modifies `every forget style` and yields transparency of the "old experiments".

Please note that `every plot no ⟨index⟩` styles are not applicable here.

A forgotten plot will be stacked normally if `stack plots` is enabled!

`/pgfplots/before end axis/.code`={⟨...⟩}

Allows to insert ⟨*commands*⟩ just before the axis is ended (see also `execute at end axis`). This option takes effect inside of the clipped area.
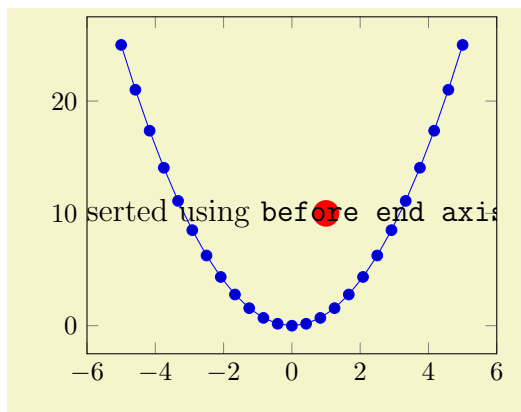

```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\pgfplotsset{every axis/.append style={
    before end axis/.code={
        \fill[red] (1,10) circle(5pt);
        \node at (-4,10)
            {\large This text has been inserted
              using \texttt{before end axis}.};
}}}
\begin{tikzpicture}
    \begin{axis}
    \addplot {x^2};
    \end{axis}
\end{tikzpicture}
```

`/pgfplots/after end axis/.code`={⟨...⟩}

Allows to insert ⟨*commands*⟩ right after the end of the clipped drawing commands. While `before end axis` has the same effect as if ⟨*commands*⟩ had been placed inside of your axis, `after end axis` allows to access axis coordinates without being clipped.
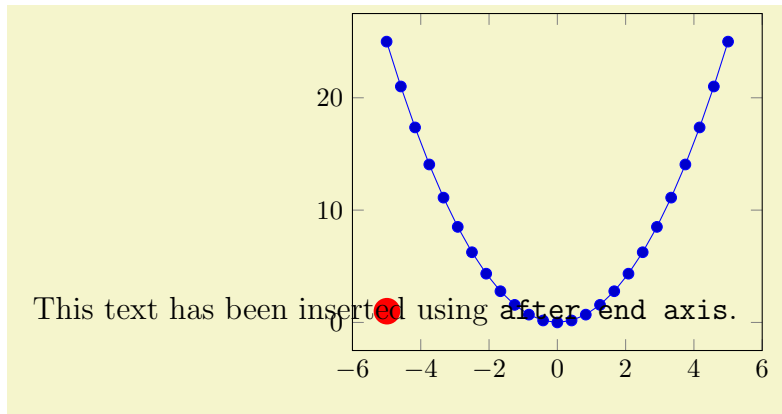
```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\pgfplotsset{every axis/.append style={
    after end axis/.code={
        \fill[red] (1,10) circle(5pt);
        \node at (-4,10)
            {\large This text has been inserted using \texttt{after end axis}.};
    }}}
\begin{tikzpicture}
    \begin{axis}
    \addplot {x^2};
    \end{axis}
\end{tikzpicture}
```

/pgfplots/axis on top=true|false   (initially false)

   If set to true, axis lines, ticks, tick labels and grid lines will be drawn on top of plot graphics.
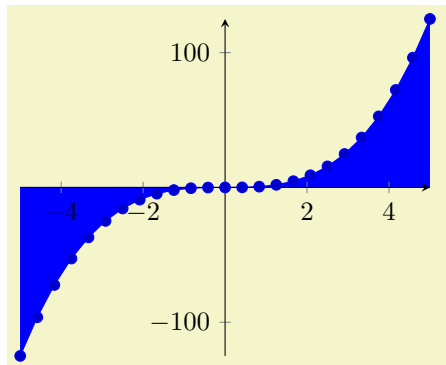

```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
    \begin{axis}[
        axis on top=true,
        axis x line=middle,
        axis y line=middle]
    \addplot+[fill] {x^3} \closedcycle;
    \end{axis}
\end{tikzpicture}
```
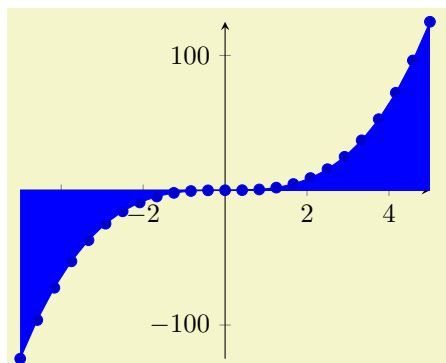


```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
    \begin{axis}[
        axis on top=false,
        axis x line=middle,
        axis y line=middle]
    \addplot+[fill] {x^3} \closedcycle;
    \end{axis}
\end{tikzpicture}
```

   Please note that this feature does not affect plot marks. I think it looks unfamiliar if plot marks are crossed by axis descriptions.

/pgfplots/visualization depends on=⟨\macro⟩   (initially empty)
/pgfplots/visualization depends on=⟨expression⟩\as⟨\macro⟩   (initially empty)
/pgfplots/visualization depends on=value ⟨content⟩\as⟨\macro⟩   (initially empty)

Allows to communicate data to PGFPLOTS which is essential to perform the visualization although PGFPLOTS isn't aware of it.

Suppose you want a scatter plot, which depends on the (x, y) coordinates, the `point meta` data to draw individual colors and furthermore data which influences the `mark size`. Thus, you need a total of 4 coordinates for every data point, although PGFPLOTS supports only 3 in its initial configuration.

Before we actually come to the main point of the problem, we'll talk about how to get a scatter plot which has individual colors *and* individual sizes. It is not sufficient to set `mark size` alone, since `mark size` is evaluated only once, before markers are processed (the same holds for `every mark`). Thus, we can use `scatter` combined with

`scatter/@pre marker code/.append style={/tikz/mark size=\perpointmarksize}`.

The `@pre marker code` is installed for every marker of a scatter plot individually. Now, we come to the problem as such: where can we get the value for `mark size`, in our case called `\perpointmarksize`?

A solution is `visualization depends on` (using the second input syntax at this point):
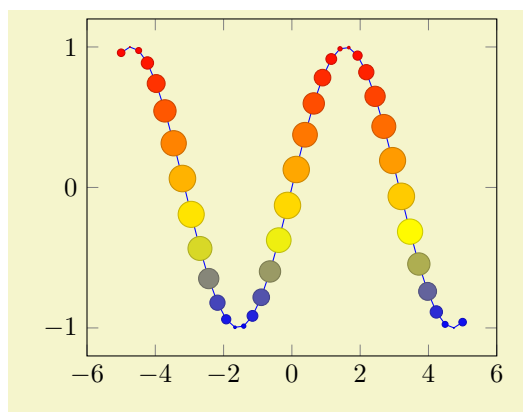
```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
\begin{axis}
    \addplot+[
        scatter,
        scatter src=y,
        samples=40,
        visualization depends on=
            {5*cos(deg(x)) \as \perpointmarksize},
        scatter/@pre marker code/.append style=
            {/tikz/mark size=\perpointmarksize}
    ]
        {sin(deg(x))};
\end{axis}
\end{tikzpicture}
```

Here, we define `\perpointmarksize` as `5*cos(deg(x))`. The expression will be evaluated together with all other coordinates. Thus, everything which is available during the survey phase can be used here. This includes the final coordinates `x`, `y`, `z`; the constant `meta` expands to the current per point meta data. Furthermore, `\thisrow{⟨colname⟩}` expands to the value of a table column.

The command `visualization depends on` evaluates and remembers every value in internal data structures. The remembered value is then available as ⟨\macro⟩ during the visualization phase. In our example, the `@pre marker code` is evaluated during the visualization phase and applies `mark size=5*cos(deg(x))`.

The first syntax, `visualization depends on`=⟨\macro⟩, tells PGFPLOTS to use an already defined ⟨\macro⟩. The second syntax with ⟨content⟩\as⟨\macro⟩ provides also the value.

There can be more than one `visualization depends on` phrase.

In case the stored value is not of numerical type[74], you can use the prefix 'value' before the argument, i.e.

`visualization depends on`=value ⟨\macro⟩ or

`visualization depends on`=value ⟨content⟩\as ⟨\macro⟩.

Such a value will be expanded and stored, but not parsed as number (at least not by PGFPLOTS).

`/pgf/fpu`={⟨*true,false*⟩}   (initially `true`)

This key activates or deactivates the floating point unit. If it is disabled (`false`), the core PGF math engine written by Mark Wibrow and Till Tantau will be used for `plot expression`. However, this engine has been written to produce graphics and is not suitable for scientific computing. It is limited to fixed point numbers in the range ±16384.00000.

If the `fpu` is enabled (`true`, the initial configuration) the high-precision floating point library of PGF written by Christian Feuersänger will be used. It offers the full range of IEEE double precision computing in TeX. This FPU is also part of PGFPLOTSTABLE, and it is activated by default for `create col/expr` and all other predefined mathematical methods.

---

[74]Or if it is just a constant and you'd like to improve speed.

Use

```
\pgfkeys{/pgf/fpu=false}
```

in order to de-activate the extended precision. If you prefer using the fp (fixed point) package, possibly combined with Mark Wibrows corresponding PGF library, the fpu will be deactivated automatically. Please note, however, that fp has a smaller data range (about $\pm 10^{17}$) and may be slower.

4.26   TikZ Interoperability

PGFPLOTS uses TikZ/PGF as its "backend layer". This implies that it inherits most of TikZ's graphical features and adds a lot of own stuff on top of it. However, the coordinate systems of TikZ and PGFPLOTS do not match up – for good reason: PGFPLOTS operates on logical (data) coordinates whereas TikZ operates on image coordinates.

Occasionally, one may want to synchronize both in order to generate a graphic. In this context, "synchronize both" means that they really use the same coordinate systems. This is far beyond the simple use-case of "enrich a PGFPLOTS picture by means of TikZ annotations", compare Section 4.17.

Consequently, this section addresses the question how to match the coordinates from TikZ to PGFPLOTS and vice–versa. It explains how to match coordinates and it discusses the necessary configuration.

There are a couple of keys in PGFPLOTS which control the mapping of coordinates. The purpose of these keys is to implement visualization techniques, but they do things different than TikZ (and they should). To match coordinates with TikZ, one needs the following aspects:

1. Restrict your visualization type: a logarithmic axis simply may not fit into TikZ (to be more precise: it may fit, but a TikZ unit will correspond to a log–unit in PGFPLOTS).

2. Configure matching unit vectors by means of the x and y keys. The default configuration of TikZ is to use x=1cm,y=1cm,z={(0,0)}. Note that these settings are usually overridden by PGFPLOTS in order to respect width and height (and view for three–dimensional axes).

3. Disable the data scaling by means of disabledatascaling: PGFPLOTS will internally apply linear coordinate transformations in order to provide the data range required for floating point arithmetics (using approximately floating point precision). Disabling the data scaling means to restrict yourself to the (small) data range supported by TikZ—but that's probably what you want in that case.

4. Define anchor and position of the axis, probably using anchor=origin,at={(0,0)}. The at={(0,0)} configures PGFPLOTS to place the axis at the TikZ position (0,0) whereas anchor=origin means that PGFPLOTS will place its data origin $(0,0,0)$ at the place designated by at (see Section 4.19 for details).

5. Make sure that the PGFPLOTS axis contains the data origin $(0,0,0)$ in the displayed data range (i.e. configure xmin, xmax, ymin, and ymax appropriately).

   Without this, the anchor=origin key required in the previous item will be truncated to the next coordinate which is part of the displayed range.

Here is a simple example, first with TikZ:
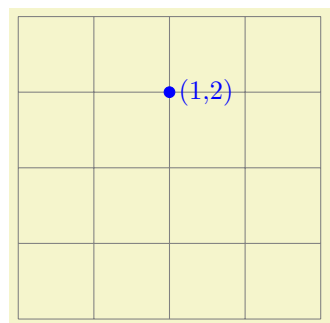

```
\begin{tikzpicture}
\coordinate (Point) at (1,2);

\draw [gray] (-1,-1) grid (3,3);
\draw [blue,fill] (Point) circle (2pt)
    node [right] {(1,2)};
\end{tikzpicture}
```

it displays a grid with $x, y \in [-1, 3]$ and shows a node inside of it. Now, we apply the keys discussed above to match this setting in PGFPLOTS:
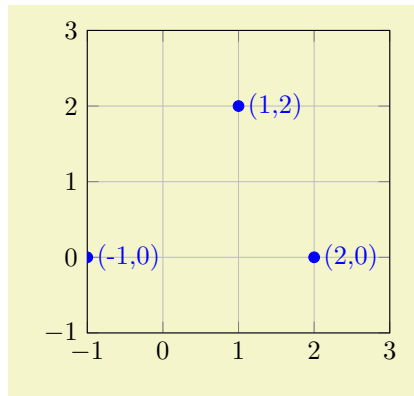
```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
    \coordinate (Point) at (1,2);

\begin{axis}[
    % tell pgfplots to "grab" the axis at its
    % internal (0,0) coord:
    anchor=origin,
    % tell pgfplots to place its anchor at (0,0):
    % (This is actually the default and can
    % be omitted)
    at={(0pt,0pt)},
    % tell pgfplots to use the "natural" dimensions:
    disabledatascaling,
    % tell pgfplots to use the same unit vectors
    % as tikz:
    x=1cm,y=1cm,
    %
    % this is just as usual in pgfplots. I guess
    % it is only useful if (0,0) is part of the
    % range... try it out.
    xmin=-1,xmax=3, ymin=-1,ymax=3,grid=both]
% this uses the point defined OUTSIDE of the axis
\draw [blue,fill] (Point) circle (2pt)
    node [right] {(1,2)};

% this uses a TIKZ coordinate (2,0) in the axis:
\draw [blue,fill] (2,0) circle (2pt)
    node [right] {(2,0)};

% this here will always work inside of an axis:
\draw [blue,fill] (-1,0) circle (2pt)
    node [right] {(-1,0)};
\end{axis}
\end{tikzpicture}
```

The example demonstrates several things: first, it defines a coordinate in the enclosing `tikzpicture` and uses it inside of the `axis` (at the correct position). Second, it uses the standard TikZ coordinate (2,0) inside of the `axis`, and it is placed at the expected position. Third, it uses the approach provided by PGFPLOTS by using the `axis cs` to designate a coordinate (this last approach does also work without the coordinate matching).

Here is an example which inserts a PGFPLOTS graphics correctly into a `tikzpicture`:
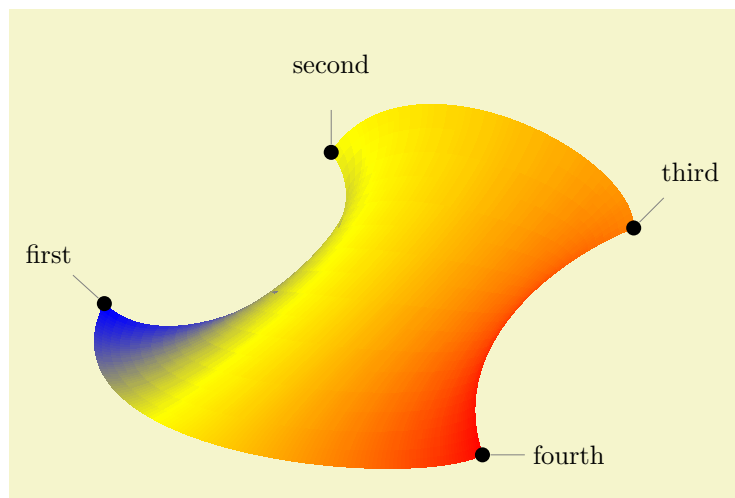
```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
% requires \usepgfplotslibrary{patchplots}
\begin{tikzpicture}
\begin{axis}[
    % tell pgfplots to "grab" the axis at its internal (0,0) coord:
    anchor=origin,
    % tell pgfplots to place its anchor at (0,0):
    % (This is actually the default and can be omitted)
    at={(0pt,0pt)},
    % tell pgfplots to use the "natural" dimensions:
    disabledatascaling,
    % tell pgfplots to use the same unit vectors as tikz:
    x=1cm,y=1cm,
    %
    hide axis,
]
\addplot[patch,patch type=coons,
    shader=interp,point meta=explicit]
coordinates {
    (0,0)   [0] % first corner
    (1,-1)  [0] % bezier control point between (0) and (3)
    (4,0.7) [0] % bezier control point between (0) and (3)
    %
    (3,2)   [1] % second corner
    (4,3.5) [1] % bezier control point between (3) and (6)
    (7,2)   [1] % bezier control point between (3) and (6)
    %
    (7,1)      [2] % third corner
    (6,0.6)    [2] % bezier control point between (6) and (9)
    (4.5,-0.5) [2] % bezier control point between (6) and (9)
    %
    (5,-2)   [3] % fourth corner
    (4,-2.5) [3] % bezier control point between (9) and (0)
    (-1,-2)  [3] % bezier control point between (9) and (0)
};
\end{axis}

% this requires pgf 2.10
\begin{scope}[every node/.style={circle,inner sep=2pt,fill=black}]
\node[pin=140:first] at (0,0) {};
\node[pin=second]    at (3,2) {};
\node[pin=45:third]  at (7,1) {};
\node[pin=0:fourth]  at (5,-2) {};
\end{scope}
\end{tikzpicture}
```

The example employs one of the patch plots of the patchplots library. Since these graphical elements typically require depth information (z buffering) and color data (point meta), they are only available inside of PGFPLOTS. However, the configuration above ensures that coordinates match one-to-one between PGFPLOTS and TikZ. The hide axis flag disables anything of PGFPLOTS, so only the visualized patch plot remains[75].

4.27   Layers

It is important that several parts of an axis are drawn "on top" of others. Usually, PGFPLOTS ensures this by drawing them in a suitable sequence (usually background followed by grid lines, followed by tick lines and tick labels, followed by plots and finally axis descriptions). While this works reasonable in most cases, there are cases where more control is desired. One common use-case is if multiple axes shall be drawn into the same picture: here, the sequence from above should be applied to all involved axes simultaneously.

4.27.1   Summary

This section is the technical reference for using and customizing layered graphics in PGFPLOTS. As such, it is hard reading.

For most purposes, the following is *completely* sufficient for you: If you want to enable layered graphics, put the following statement into the tikzpicture which is supposed to have layered graphics:

---

[75]Note that the $(0, 0, 0)$ coordinate of PGFPLOTS is part of the data range here.

```
\begin{tikzpicture}
    \pgfplotsset{set layers}
    \begin{axis}
        ...
    \end{axis}

    % perhaps a second axis which should use the same layers?
    \begin{axis}
        ...
    \end{axis}
\end{tikzpicture}
```

This enables layered graphics for that specific `tikzpicture`.

You may want layered graphics if you have multiple axes in the same picture, of if you have specific needs for your plot.

Consider reading `on layer` if you want to move particular elements of your axis to a different layer.

4.27.2 Using Predefined Layers

The main key to control layered graphics with PGFPLOTS is `set layers`:

/pgfplots/set layers=none|⟨*layer configuration name*⟩ (initially **none**)

This key enables layered graphics for either the current axis or for all following axes.

Enabling layered graphics has the effect that the order in which graphical elements are given is unrelated to the ordering in which they will be drawn. The main benefit is if you have multiple axes in the same figure: the axes can share the same layers.

The invocation `set layers`=none disables layered graphics.

The invocation `set layers` (without equal sign and without arguments) is the same as if you would write `set layers`=default.

In all other cases, `set layers` expects a ⟨*layer configuration name*⟩. There are two predefined configurations available (the prefix `/pgfplots/layers/` is optional):

/pgfplots/layers/standard (no value)

A layer configuration which defines the layers `axis background`, `axis grid`, `axis ticks`, `axis lines`, `axis tick labels`, `main`, `axis descriptions`, `axis foreground`. They are drawn in the order of appearance.

/pgfplots/layers/axis on top (no value)

A layer configuration which uses the same layer names as `layers/standard`, but with a different sequence: `axis background`, `main`, `axis grid`, `axis ticks`, `axis lines`, `axis tick labels`, `axis descriptions`, `axis foreground`.

This layer is automatically used if the key `axis on top` is used together with `set layers`=⟨*any layer configuration name*⟩.

As soon as the key `set layers`=⟨*layer configuration name*⟩ is encountered, PGFPLOTS starts the PGF command `\pgfsetlayers`{⟨*layer names*⟩} with the layer names of the respective configuration. Usually, this *replaces* the current layer configuration of the embedding `tikzpicture`. Furthermore, `set layers` stores the name of ⟨*layer configuration name*⟩ such that every following `axis` knows how to map graphical elements to layer names.

There is one huge difference to any other key which tunes PGFPLOTS: layer configurations are properties of a complete `tikzpicture` whereas any other option affects only axis objects and their contents. Layers, however, affect every graphical element of the embedding picture. Due to this property, layer configurations need to be given at one of several supported positions:

1. Directly within the picture:

   ```
   \begin{tikzpicture}
       \pgfplotsset{set layers=default}
       \begin{axis}
           ...
       \end{axis}
   \end{tikzpicture}
   ```

This option explicitly tells the reader of your source code that a significant portion of your picture has been changed: the complete picture has and uses a ⟨*layer configuration name*⟩ (in this case `default`).

2. As option for one or more axes which is/are directly within the picture:

```
\begin{tikzpicture}
    \begin{axis}[set layers]
        ...
    \end{axis}
\end{tikzpicture}
```

Here, PGFPLOTS implicitly communicates its layer configuration to the enclosing `tikzpicture`. Thus, the effect of `set layers` is *not local to an axis*; it survives until `\end{tikzpicture}`. Any other option only survives until `\end{axis}`.

In this case, only the *last* activated layer configuration will apply to the picture.

Limitation: no environments or local TEX groups allowed.   Standard usages as within the examples of this manual will always work. But since the layer name configuration is essentially part of a PGF picture (at a low level), one cannot arbitrarily set them; PGF will complain if they are changed within some nested TEX groups or LATEX environments. Typically, you will never need to worry about this.

In short, the following examples are *forbidden* because the axis is within locally nested groups.

```
\begin{tikzpicture}
    {% FORBIDDEN! Consider using case (1) above!
        \begin{axis}[set layers]
            ...
        \end{axis}
    }
\end{tikzpicture}
```

```
\begin{tikzpicture}
    \begin{scope} % FORBIDDEN! Consider using case (1) above!
        \begin{axis}[set layers]
            ...
        \end{axis}
    \end{scope}
\end{tikzpicture}
```

These examples are forbidden because the layer configuration will be cleared by the '`}`' of the first forbidden example and by the '`\end{scope}`' of the second example. A solution would be one of the different placement options (i.e. choice (1.) or (3.)).

3. outside of any picture:

```
\pgfplotsset{set layers=default}
\begin{tikzpicture}
    \begin{axis}
        ...
    \end{axis}
\end{tikzpicture}
```

This choice configures the layer configuration for *every* following `tikzpicture`.

Limitation: axis alignment restricted to inner anchors.   This applies only if you changed the default value of `anchor` (which is `anchor`=south west). Any axis which uses layered graphics should use one of the following values of `anchor`: `north`, `north west`, `west`, `south west`, `south`, `south east`, `east`, `north east`, `north`, `center`, `origin`, `above origin`, `left of origin`, `right of origin`, `below origin`. In case you really need another anchor, PGFPLOTS requires the use of `cell picture`=true, causing the layers to be local for that specific axis.

The technical background for this limitation is a hen-and-egg problem: outer anchors (like `outer south west`) are only available *after* the complete axis has been generated – and layers can only be drawn after each drawing instruction has been issued. The technical keys for further reading are `cell picture`=false or `cell picture`=if necessary (one of them is active for layered graphics).

`\pgfplotssetlayers`

An alias for `\pgfplotsset{`set layers`}`. It activates the `layers/default` layer configuration.

`\pgfplotssetlayers{`⟨*layer configuration name*⟩`}`

An alias for `\pgfplotsset{`set layers`={`⟨*layer configuration name*⟩`}}`.

Key handler ⟨*key*⟩`/.define layer set={`⟨*ordered layer names*⟩`}{`⟨*style definitions*⟩`}`

Allows to define a new layer set configuration named ⟨*key*⟩. Afterwards, ⟨*key*⟩ is a valid argument for `set layers=`⟨*key*⟩.

The first argument ⟨*ordered layer names*⟩ is a comma-separated list of layer names. The names are arbitrary, and `\pgfdeclarelayer` will be called for every encountered argument[76]. There is just one "magic" name: the layer `main` should be part of every ⟨*ordered layer names*⟩ as it will contain every graphical element which is not associated with a specific layer.

The second argument ⟨*style definitions*⟩ contains options – just as if you would have written ⟨*key*⟩`/.style={`⟨*style definitions*⟩`}`. The ⟨*style definitions*⟩ are supposed to contain PGFPLOTS style redefinitions which make use of each encountered element of ⟨*ordered layer names*⟩. This is probably best explained by an example: the `layers/standard` layer configuration is defined by

```
\pgfplotsset{
    layers/standard/.define layer set=
        {axis background,axis grid,axis ticks,axis lines,axis tick labels,main,%
            axis descriptions,axis foreground}
        {
            grid style=          {/pgfplots/on layer=axis grid},
            tick style=          {/pgfplots/on layer=axis ticks},
            axis line style=     {/pgfplots/on layer=axis lines},
            label style=         {/pgfplots/on layer=axis descriptions},
            legend style=        {/pgfplots/on layer=axis descriptions},
            title style=         {/pgfplots/on layer=axis descriptions},
            colorbar style=      {/pgfplots/on layer=axis descriptions},
            ticklabel style=     {/pgfplots/on layer=axis tick labels},
            axis background@ style={/pgfplots/on layer=axis background},
            3d box foreground style={/pgfplots/on layer=axis foreground},
        },
}
```

This definition declares a couple of layers, and it adjusts PGFPLOTS styles by adding `on layer` commands. The arguments for `on layer` are the elements of ⟨*ordered layer names*⟩.

Note that if you have an element in ⟨*ordered layer names*⟩ which is never referenced inside of ⟨*style definitions*⟩, this layer will always be empty. In other words: the *only* reference to the names in ⟨*ordered layer names*⟩ is ⟨*style definitions*⟩, PGFPLOTS has no hard-coded magic layer names (except for `main` as explained above).

Since the second argument ⟨*style definitions*⟩ defines ⟨*key*⟩ to be a normal style key, one can simply use ⟨*key*⟩ in order to set ⟨*style definitions*⟩. This allows to inherit them. For example, the `layers/axis on top` layer configuration is defined by means of

```
\pgfplotsset{
    /pgfplots/layers/axis on top/.define layer set=
        {axis background,main,axis grid,axis ticks,axis lines,axis tick labels,%
            axis descriptions,axis foreground}
        {/pgfplots/layers/standard}
}
```

i.e. it only redefines the *sequence* of the layers and re-uses the style definitions of `layers/standard`.

Any number of layer configurations can be defined.

4.27.3 Changing the Layer of Graphical Elements

There are a couple of keys which change the layer of a graphical element.

`/pgfplots/on layer={`⟨*layer name*⟩`}`

---

[76]To be more precise: `set layers` calls `\pgfdeclarelayer` when it uses ⟨*ordered layer names*⟩.

Providing this key somewhere in a PGFPLOTS style or inside of a PGFPLOTS axis will change the layer for all graphical elements for which the style applies.

For example,

```
...
\begin{axis}[set layers,grid style={/pgfplots/on layer=axis foreground}]
...
```

will change the layer for any grid lines to `axis foreground`.

The argument ⟨*layer name*⟩ is expected to be part of the current layer configuration, i.e. the argument of `set layers` should contain it.

Note that if you have two *plots* with different values of `on layer`, you may also want to enable `clip mode`=clip individual or to deactivate clipping altogether using `clip`=false. Clipping options need to be provided as option to the axis, not to the plot. The technical background is that clip paths needs to be replicated for the layer on which the drawing is supposed to happen – otherwise they will be applied to the wrong layer.

/pgfplots/**mark layer**=auto|like plot|⟨*layer name*⟩   (initially `auto`)

An advanced key which defines the layer for plot `mark`s. It is typically the best choice to leave it at `auto`.

If you write `\addplot`[on layer=⟨*layer name*⟩], the layer will be used for the complete plot. Plot marks are treated with special care, so you can define an own layer for plot marks.

The initial choice `auto` will automatically define a "suitable" choice, leaving the responsability with PGFPLOTS. Here, "suitable" means to respect `clip mode` and `clip marker paths` in a way such that plot marks will not be clipped even though the default layer for your plot will be clipped.

The choice `like plot` will pack the marks onto the same layer as the plot they belong to. This might cause clipped markers, i.e. markers which are only displayed partially if they are close to the boundary of the axis.

Finally, one can provide any ⟨*layer name*⟩, just as for `on layer` – but the layer can be different from the layer used for the plot.

4.28   Technical Internals

This section describes keys which are usually set by internal routines – it is typically unnecessary to use them. However, they may impose limitations or influence performance. Such cases are documented clearly in other sections of this manual. This here is the reference on the involved internals.

/pgfplots/**cell picture**=true|false|if necessary   (initially `true`)

This key is set automatically by PGFPLOTS if necessary (for example by `set layers`).

Typically, PGFPLOTS creates a so-called "cell picture". A cell picture is a separate picture which is typeset into a node. Finally, the node is shifted to fulfill special `anchor` requirements. The necessity for a cell picture is given if the `anchor` of an axis is only known after the complete axis has been drawn.

The initial choice `true` means that PGFPLOTS will create a cell picture for every axis. This allows all `anchor`s, but it is unsuited if multiple graphics layers are desired or if one wants SVG export. In order to create a cell picture, PGFPLOTS interrupts the embedding `tikzpicture`, draws a new `tikzpicture`, and finally typesets the result into a node.

The choice `false` tells PGFPLOTS to draw its paths directly into the embedding `tikzpicture`. Such an approach is necessary if the axis shall use layers of the embedding `tikzpicture`. This is possible if and only if the `anchor` can be determined without actually drawing the complete axis. If so, PGFPLOTS will modify the transformation matrix in advance. Note that axes with `cell picture`=false will *contain* all the usual anchors – the only difference is that the axis itsself can only use one of the following anchors for its alignment: `north`, `north west`, `west`, `south west`, `south`, `south east`, `east`, `north east`, `north`, `center`, `origin`, `above origin`, `left of origin`, `right of origin`, `below origin`.

The choice `if necessary` will check if the chosen anchor is one of the list above. If so, it will use `cell picture`=false. Otherwise, it will use `cell picture`=true.

/pgfplots/compat/show suggested version=true|false   (initially true)

> If enabled, PGFPLOTS will show you which value for compat=⟨*version*⟩ results in the largest active feature set and highest quality.
>
> This key will generate a warning if the current version is so old that the quality degrades seriously.
>
> The notification will be printed to your .log file (during \end{document}).

Chapter 5

Related Libraries

This section describes some libraries which come with PGFPLOTS, but they are more or less special and need to be activated separately.

5.1 Clickable Plots

```
\usepgfplotslibrary{clickable} % LaTeX and plain TeX
\usepgfplotslibrary[clickable] % ConTeXt
\usetikzlibrary{pgfplots.clickable} % LaTeX and plain TeX
\usetikzlibrary[pgfplots.clickable] % ConTeXt
```

A library which generates small popups whenever one clicks into a plot. The popup displays the coordinate under the mouse pointer, supporting the optional snap–to–nearest `clickable coords` feature with customizable displayed information. Furthermore, the library allows to display slopes if one holds the mouse pressed and drags it to another point in the plot.

The library has two purposes: to compute slopes in a simple way[1] and to provide related, optional information to single data points which are not important enough to be listed in the main text (like prototype parameters or other technical things).

5.1.1 Overview

It is completely sufficient to write

```
\usepgfplotslibrary{clickable}
```

in the document preamble. This will automatically prepare every plot.

The library works with Acrobat Javascript and PDF forms: every plot becomes a push–button.
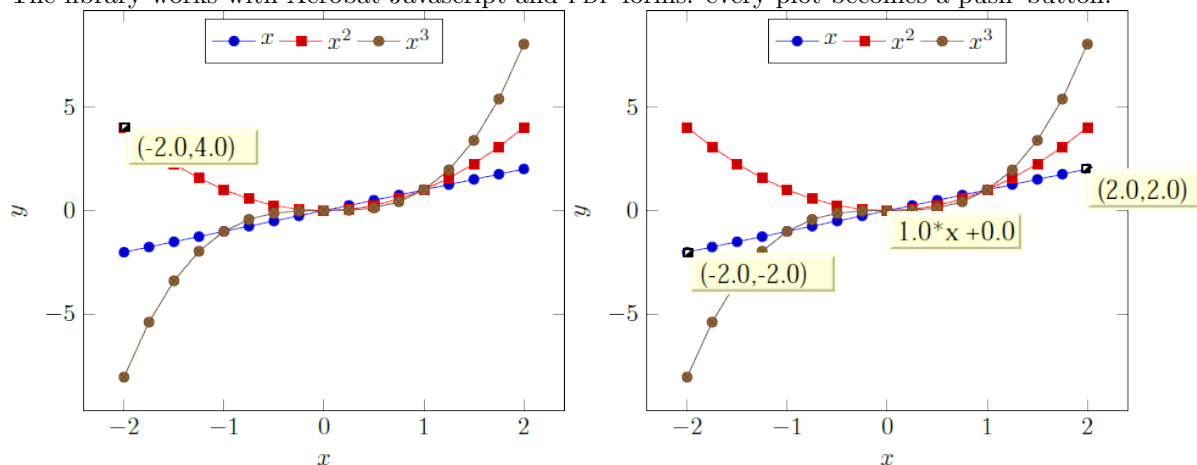
These screenshots show the result of clicking into the axis range (left column) and of dragging from one point to another (right column). The second case shows the result of Drag-and-Drop: it displays start- and

---

[1] The author is applied mathematician...

end points and the equation for the line segment between between the first point of the drag- and drop and the second point where the mouse has been released. The line segment is

$$l(x; x_0, y_0, x_1, y_1) = m \cdot x + n$$

where $m = (y_1 - y_0)/(x_1 - x_0)$ is the slope and n the offset chosen such that $l(x_0; \dots) = y_0$. For logarithmic plots, logarithms will be applied before computing slopes.
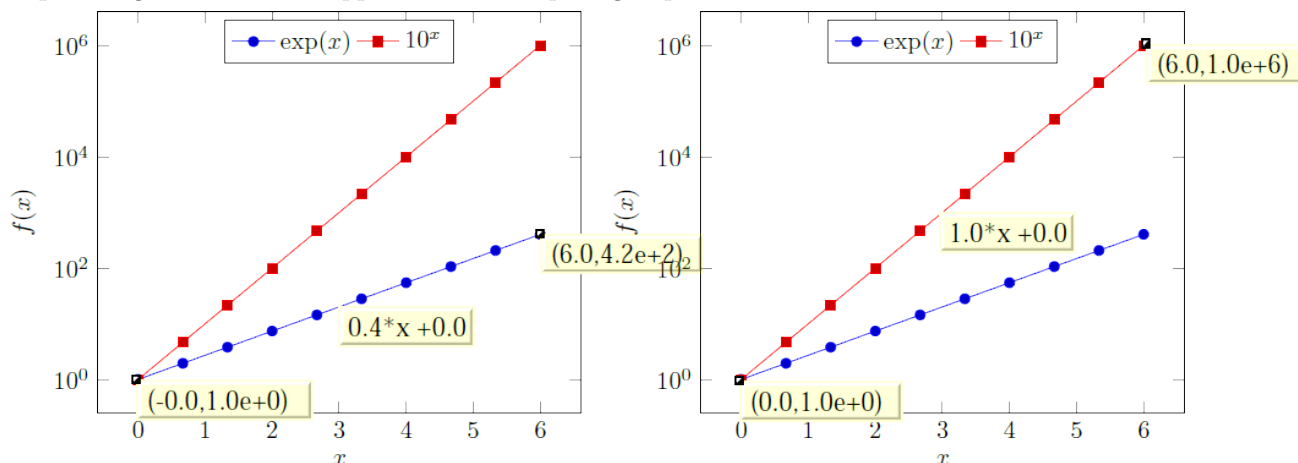
These screen shots show the result of drag- and drop for *logarithmic* axes: the end points show, again, the coordinates (without logs) and the form field in the middle shows the slope and offset of the linear equation in log coordinates.

The log basis for any logarithmic axes is usually 10, but it respects the current setting of `log basis x` and `log basis y`. The applied log will always use the same logarithm which is also used for the axis descriptions (this is not necessarily the same as used by PGFPLOTSTABLE!).

This document has been produced with the `clickable` library, so it is possible to load it into Acrobat Reader and simply click into a plot.

/pgfplots/**clickable coords**={⟨*displayed text*⟩}

Activates a snap–to–nearest feature when clicking onto plot coordinates. The ⟨*displayed text*⟩ is the coordinate's x and y value by default (i.e. you write just `clickable coords` without an equal sign).
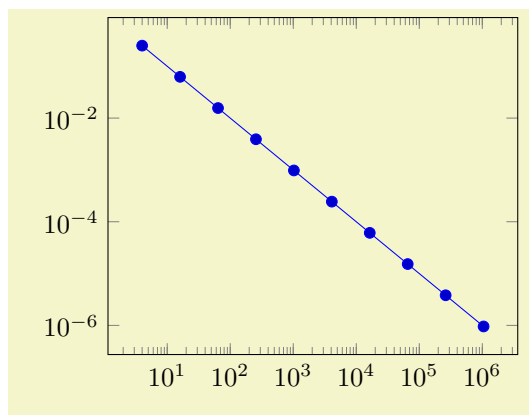

```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}\usepgfplotslibrary{clickable}
\begin{tikzpicture}
    \begin{loglogaxis}[clickable coords=
        {Level \thisrow{level} (q=\thisrow{q})}]
    \addplot table[x=dof,y=error] {
level   dof       error         q
1       4         2.50000000e-01    48
2       16        6.25000000e-02    25
3       64        1.56250000e-02    41
4       256       3.90625000e-03    8
5       1024      9.76562500e-04    22
6       4096      2.44140625e-04    46
7       16384     6.10351562e-05    40
8       65536     1.52587891e-05    3
9       262144    3.81469727e-06    1
10      1048576   9.53674316e-07    9
    };

    \end{loglogaxis}
\end{tikzpicture}
```

Now, clicking onto a data point yields 'Level 7 (q=40)' whereas clicking besides a data point results in the click coordinates as before,
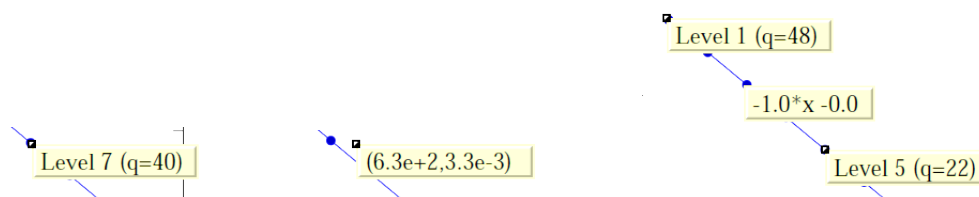
Note that logarithmic slopes work as before.

If you want the (x, y) values to be displayed, use the special placeholder string '(xy)' inside of ⟨displayed text⟩. As an example, we consider again the scatter/classes example of page 112:

```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}\usepgfplotslibrary{clickable}
\begin{tikzpicture}
    \begin{axis}[%
    clickable coords={(xy): \thisrow{label}},%
    scatter/classes={%
        a={mark=square*,blue},%
        b={mark=triangle*,red},%
        c={mark=o,draw=black}}]
    \addplot[scatter,only marks,%
        scatter src=explicit symbolic]%
    table[meta=label] {
x     y       label
0.1   0.15    a
0.45  0.27    c
0.02  0.17    a
0.06  0.1     a
0.9   0.5     b
0.5   0.3     c
0.85  0.52    b
0.12  0.05    a
0.73  0.45    b
0.53  0.25    c
0.76  0.5     b
0.55  0.32    c
    };
    \end{axis}
\end{tikzpicture}
```
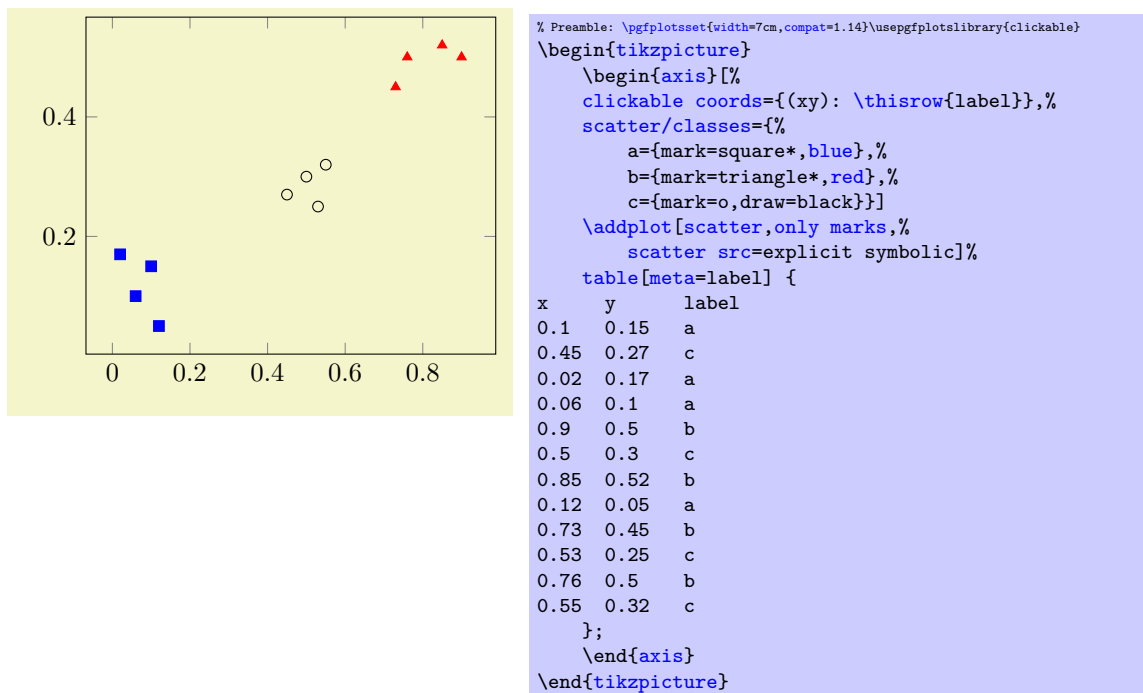
Here, we find popups like
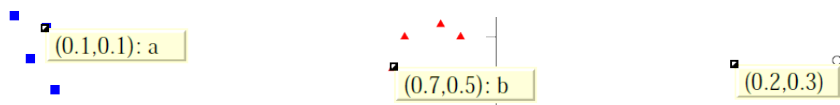
The ⟨displayed text⟩ is a richtext string displayed with *Javascript*. For most purposes, it is used like an unformatted C string: it contains characters, perhaps line breaks with '\n' or tabulators with '\t', but it should not contain TeX formatting instructions, especially no math mode (the '(xy)' replacement text is formatted with sprintf, see below). Consider clickable coords code in case you'd like to preprocess data before displaying it. If you experience problems with special characters, try prepending a backslash to them. If that doesn't work either, try to prefix the word with '\\' and/or with '\string'. Consider using clickable coords size if you intend to work with multiline fields and the size allocation needs improvements.

In fact, ⟨displayed text⟩ can even contain richtext (=XHTML) formatting instructions like '<br/>' (note the final slash) or 'text' (note the backslash before '#') which changes the color for text. The <span style=""> arguments are CSS fields, consider an HTML reference for a list of CSS attributes.

It is possible to use clickable coords together with three dimensional axes. Note that dynamic (clickable) features of a three dimensional axis without clickable coords will be disabled (they appear to be useless). Furthermore, three dimensional axes do not support slope calculations; only the snap–to–nearest feature is available.

Consider using annot/snap dist=6 to increase the snap–to–nearest distance.

The clickable coords can be specified for all plots in an axis (as in the examples above), but also once for every single \addplot commands for which the snap–to–nearest feature is desired (with different ⟨displayed text⟩).

If multiple clickable coords are on the same position, each click chooses the next one (in the order of appearance).

/pgfplots/clickable coords code={⟨TeX code which defines \pgfplotsretval⟩}

A variant of clickable coords which allows to prepare the displayed information before it is handed over to Javascript.

The value should be TEX code which defines \pgfplotsretval somehow. The result is used as simple, unformatted string which is associated to coordinates.

Consider using

    \pgfmathprintnumberto[verbatim]{⟨*number*⟩}\macroname

    \edef\pgfplotsretval{Number=\macroname}

to provide number printing. The \pgfmathprintnumberto[verbatim] doesn't use math mode to format a number[2], and it writes its result into \macroname. The name '\macroname' is arbitrary, use anything like '\eps' or '\info'. The \edef means "expanded definition" and has the effect of expanding all macros to determine the value, in our case "Number= ⟨*the value*⟩". The following example uses it twice to pretty–print the data:
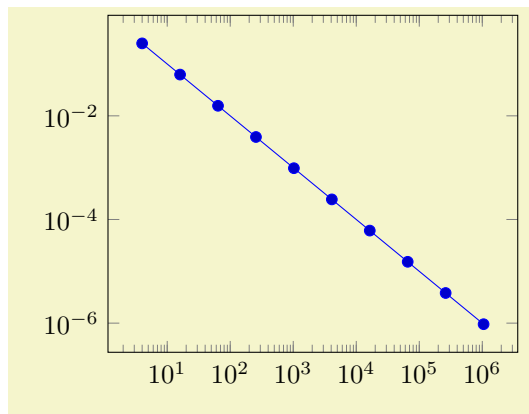
```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}\usepgfplotslibrary{clickable}
\begin{tikzpicture}
\begin{loglogaxis}[clickable coords code={%
    \pgfmathprintnumberto[verbatim,precision=1]%
        {\thisrow{error}}%
        \error%
    \pgfmathprintnumberto[verbatim,frac]%
        {\thisrow{frac}}%
        \fraccomp%
    \edef\pgfplotsretval{error \error, R=\fraccomp}%
}]%
\addplot table[x=dof,y=error] {
level   dof       error          frac
1       4         2.50000000e-01  0.5
2       16        6.25000000e-02  0.75
3       64        1.56250000e-02  0.1
4       256       3.90625000e-03  0.2
5       1024      9.76562500e-04  0.5
6       4096      2.44140625e-04  0.8
7       16384     6.10351562e-05  0.125
8       65536     1.52587891e-05  0.725
9       262144    3.81469727e-06  0.625
10      1048576   9.53674316e-07  1
};

\end{loglogaxis}
\end{tikzpicture}
```

resulting in

    log error 3.9e-3, R=1/5   log error 2.4e-4, R=4/5 .

The ⟨*TEX code*⟩ is evaluated inside of a local scope, all locally declared variables are freed afterwards (that's why you can use any names you want).

/pgfplots/**clickable coords size**=auto or {⟨*max chars*⟩} or {⟨*max chars x,max chars y*⟩}   (initially auto)

This is actually just another name for **annot/popup size snap**, see its documentation below.

5.1.2 Requirements for the Library

- The library relies on the LATEX packages insdljs ("Insert document level Javascript") and eforms which are both part of the freely available AcroTeX education bundle [6][3]. The insdljs package creates a temporary file with extension .djs.

- At the time of this writing, only Adobe Acrobat Reader interpretes Javascript and Forms properly. The library doesn't have any effect if the resulting document is used in other viewers (as far as I know).

Note that although this library has been written for PGFPLOTS, it can be used independently of a PGFPLOTS environment.

---

[2]See the PGFPLOTSTABLE manual for details about number printing.

[3]These packages rely on LATEX, so the library is only available for LATEX, not for plain TEX or ConTEXt.

Compatibility issues: There a several restrictions when using this library. Most of them will vanish in future versions – but up to now, I can't do magic.

- The library does not yet support rotated axes. Use `clickable`=false for those axes.

- The library works only with `pdflatex`; `dvips` or `dvipdfm` are not supported[4].

- Up to now, it is *not* possible to use this library together with the `external` library and other image externalization methods of Section 7.

  To be more precise, you can (with two extra preamble lines, see below) get correctly annotated, exported PDF documents, but the `\includegraphics` command does not import the dynamic features.

  In case you decide to use this work–around, you need to insert

  ```
  % \maxdeadcycles=10000 % in case you get the error 'Output loop---<N> consecutive dead cycles.'
  \usepackage[pdftex]{eforms}
  ```

  before loading PGF, TikZ or PGFPLOTS. The `\maxdeadcycles` appears to be necessary for large documents, try it out.

  As long as you are working on a draft version of your document, you might want to use

  ```
  \pgfkeys{/pgf/images/include external/.code={\href{file:#1}{\pgfimage{#1}}}}
  ```

  in your preamble. This will generate hyperlinks around the graphics files which link to the exported figures. Clicking on the hyperlinks opens the exported figure which, in turn, has been generated with the `clickable` library and allows dynamic features[5].

- The library automatically calls `\begin{Form}` at `\begin{document}` and `\end{Form}` at the end of the document. This environment of `hyperref` is necessary for dynamic user interaction and should be kept in mind if the document contains other form elements.

Acknowledgements:

- I have used a Javascript `sprintf` implementation of Kevin van Zonneveld [8] (the Javascript API has only a limited set of conversions).

5.1.3   Customization

It is possible to customize the library with several options.

/pgfplots/`clickable`=true|false   (initially `true`)

   Allows to disable the library for single plots.

/pgfplots/`annot/js fillColor`={⟨*Javascript color*⟩}   (initially `["RGB",1,1,.855]`)

   Sets the background (fill) color of the short popup annotations.

   Possible choices are `transparent`, `gray`, `RGB` or `CMYK` color specified as four–element–arrays of the form `["RGB"`, ⟨*red*⟩,⟨*green*⟩,⟨*blue*⟩`]`. Each color component is between 0 and 1.

   Again: this option is for Javascript. It is *not* possible to use colors as in PGF.

/pgfplots/`annot/point format`={⟨*sprintf-format*⟩}   (initially `(%.1f,%.1f)`)
/pgfplots/`annot/point format 3d`={⟨*sprintf-format*⟩}   (initially `(%.1f,%.1f,%.1f)`)

   Allows to provide an `sprintf` format string which is used to fill the annotations with text. The first argument to `sprintf` is the x-coordinate and the second argument is the y-coordinate.

   The `point format 3d` variant is used for any three–dimensional axis whereas the `point format` is used (only) for two–dimensional ones.

   The `every semilogx axis`, `every semilogy axis` and `every loglog axis` styles have been updated to

---

[4]In fact, they should be. I don't really know why they don't ... any hint is welcome.
[5]This special treatment needs the external files in the same base directory as the main document, so this approach is most certainly *not* suitable for a final document.

```
\pgfplotsset{
    every semilogy axis/.append style={/pgfplots/annot/point format={(\%.1f,\%.1e)}},
    every semilogx axis/.append style={/pgfplots/annot/point format={(\%.1e,\%.1f)}},
    every loglog axis/.append style={/pgfplots/annot/point format={(\%.1e,\%.1e)}}
}
```

such that every logarithmic coordinate is displayed in scientific format.

/pgfplots/annot/slope format={⟨*sprintf-format*⟩}   (initially `%.1f*x %+.1f`)

Allows to provide an `sprintf` format string which is used to fill the slope–annotation with text. The first argument is the slope and the second the line offset.

/pgfplots/annot/printable=true|false   (initially `false`)

Allows to configure whether the small annotations will be printed. Otherwise, they are only available on screen.

/pgfplots/annot/font={⟨*Javascript font name*⟩}   (initially `font.Times`)

Allows to choose a Javascript font for the annotations. Possible choices are limited to what Javascript accepts (which is *not* the same as LATEX). The default fonts and its names are shown below.

Font Name	Name in Javascript
Times-Roman	font.Times
Times-Bold	font.TimesB
Times-Italic	font.TimesI
Times-BoldItalic	font.TimesBI
Helvetica	font.Helv
Helvetica-Bold	font.HelvB
Helvetica-Oblique	font.HelvI
Helvetica-BoldOblique	font.HelvBI
Courier	font.Cour
Courier-Bold	font.CourB
Courier-Oblique	font.CourI
Courier-BoldOblique	font.CourBI
Symbol	font.Symbol
ZapfDingbats	font.ZapfD

/pgfplots/annot/textSize={⟨*Size in Point*⟩}   (initially `11`)

Sets the text size of annotations in points.

/pgfplots/annot/popup size generic=auto or {⟨*x*⟩} or {⟨*x,y*⟩}   (initially `auto`)
/pgfplots/annot/popup size snap=auto or {⟨*x*⟩} or {⟨*x,y*⟩}   (initially `auto`)
/pgfplots/annot/popup size={⟨*value*⟩}

The first key defines the size of popups if you just click into an axis. The second key defines the size of popups for the snap–to–nearest feature (i.e. those prepared by `clickable coords`). The third key sets both to the same ⟨*value*⟩.

The argument can be `auto` in which case PGFPLOTS tries to be smart and counts characters. This may fail for multiline texts. The choice ⟨*x*⟩ provides the *horizontal* size only, in units of `annot/textSize`. Thus, `annot/popup size generic`=6 makes the popup $6 \cdot 11$ points wide. In this case, only one line will be allocated. Finally, ⟨*x,y*⟩ allows to provide horizontal and vertical size, both in units of `annot/textSize`.

See also `clickable coords size` which is an alias for `annot/popup size snap`.

/pgfplots/annot/snap dist={⟨*Size in Point*⟩}   (initially `4`)

Defines the size within two mouse clicks are considered to be equivalent, meased in points (Euclidean distance).

/pgfplots/annot/richtext=true|false   (initially `true`)

Enables or disables richtext formatting in `clickable coords` arguments. Richtext is kind of XHTML and allows CSS styles like colors, font changes and other CSS attributes, see the documentation for `clickable coords` for details.

The case `annot/richtext`=false is probably more robust.

5.1.4   Using the Clickable Library in Other Contexts

This library provides essentially one command, \pgfplotsclickablecreate which creates a clickable area of predefined size, combined with Javascript interaction code. It can be used independently of PGFPLOTS.

\pgfplotsclickablecreate[⟨*required key-value-options*⟩]

Creates an area which is clickable. A click produces a popup which contains information about the point under the cursor.

The complete (!) context needs to be provided using key-value-pairs, either set before calling this method of inside of [⟨*required key-value-options*⟩].

This command actually creates an AcroForm which invokes Javascript whenever it is clicked. A Javascript Object is created which represents the context (axis limits and options). This Javascript object is available at runtime.

This method is public and it is *not* restricted to PGFPLOTS. The PGFPLOTS hook simply initializes the required key-value-pairs.

This method does not draw anything. It initializes only a clickable area and Javascript code.

The required key-value-pairs are documented below.

Attention: Complete key-value validation is *not* performed here. It can happen that invalid options will produce Javascript bugs when opened with Acrobat Reader. Use the Javascript console to find them.

All options described in the following are only interesting for users who intend to use this library without PGFPLOTS.

/pgfplots/annot/width={⟨*dimension*⟩}   (initially -)

This required key communicates the area's width to \pgfplotsclickablecreate. It must be a TEX dimension like 5cm.

/pgfplots/annot/height={⟨*dimension*⟩}   (initially -)

This required key communicates the area's height to \pgfplotsclickablecreate. It must be a TEX dimension like 5cm.

/pgfplots/annot/jsname={⟨*string*⟩}   (initially -)

This required key communicates a unique identifier to \pgfplotsclickablecreate. This identifier is used to identify the object in Javascript, so there can't be more than one of them. If it is empty, a default identifier will be generated.

/pgfplots/annot/xmin={⟨*number*⟩}
/pgfplots/annot/xmax={⟨*number*⟩}
/pgfplots/annot/ymin={⟨*number*⟩}
/pgfplots/annot/ymax={⟨*number*⟩}   (initially empty)

These required keys communicate the axis limits to \pgfplotsclickablecreate. They should be set to numbers which can be assigned to a Javascript floating point number (standard IEEE double precision).

/pgfplots/annot/collected plots={⟨*nested arrays*⟩}   (initially empty)

The low level interface to implement a snap–to–nearest feature. The value is an array of plots, where each plot is again an array of coordinates and each coordinate is an array of three elements, x, y and text. Please consult the code comments for details and examples.

5.2   ColorBrewer

An extension by Vincent A. Traag and Stefan Pinnow

```
\usepgfplotslibrary{colorbrewer} % LaTeX and plain TeX
\usepgfplotslibrary[colorbrewer] % ConTeXt
\usetikzlibrary{pgfplots.colorbrewer} % LaTeX and plain TeX
```

`\usetikzlibrary[pgfplots.colorbrewer] % ConTeXt`

This library brings the color schemes created by Cynthia Brewer published at http://colorbrewer2.org/ to PGFPlots. These where originally designed for cartography needs, but are also used in other kind of data visualization in the mean time. The ColorBrewer schemes are divided into the types

sequential for ordered data progressing from low to high,

diverging to highlight changes from a mean value, and

qualitative where colors have no special order.

They can consist of up to 12 different data classes, i.e. colors, per scheme and are provided as color maps as well as as cycle lists.

Diverging `colormap/PiYG-11`   Sequential `colormap/PuBu-9`

Diverging `colormap/RdGy-11`   Sequential `colormap/YlOrBr`

Qualitative `cycle list/Set1-5`   Diverging `cycle list/RdYlBu-4`
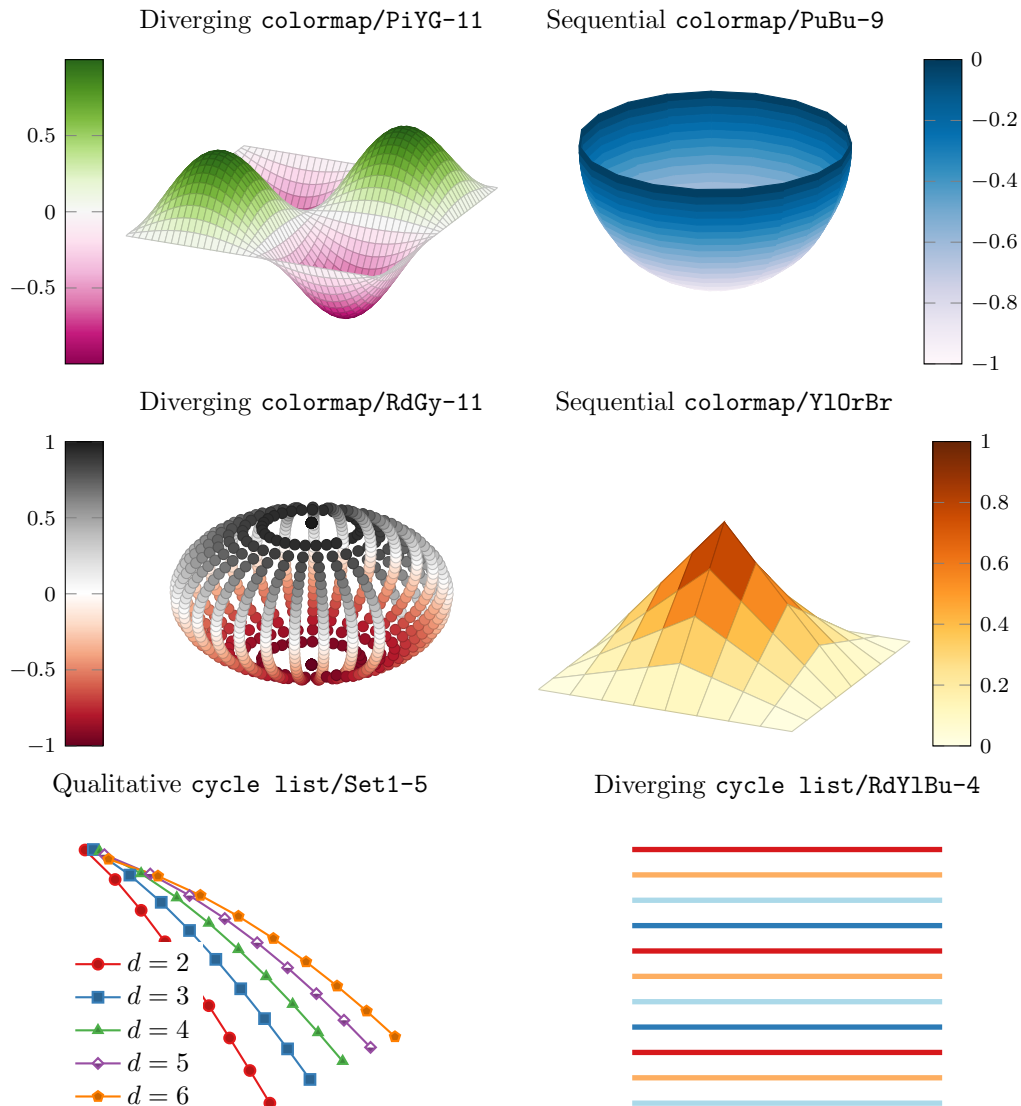
5.2.1   Usage

In the following the available schemes are presented in graphical form as "swatches".

Color Schemes as "Swatches"

A swatch is a matrix showing all available colors for a specific scheme, and the available color compilations.
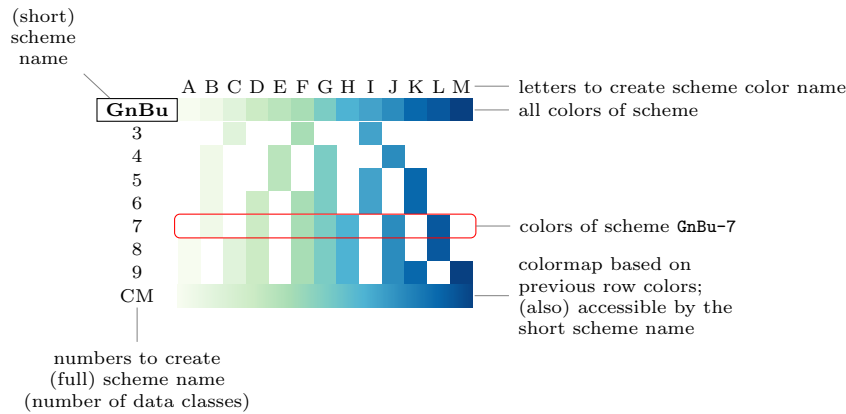
Such swatches are read as follows:

1. At the top left of the block you find the (short) name of the scheme.

2. The following color blocks are the colors the scheme consists of.

3. To get the (full) color name, combine the (short) scheme name with a hyphen and a letter of the first row, e.g.

   `\tikz \fill[color=GnBu-H] (0,0) rectangle (1em,2ex);`

   which results in ▮.

4. To get the full scheme name, which can be used as colormap or cycle list, combine the (short) scheme name with a hyphen and a number of the first column, e.g. `cycle list name`=GnBu-7. The special case of using the (short) scheme name only is also provided and is an alias for the full scheme name with the highest number, e.g. scheme name `GnBu` equals `GnBu-9`.

5. The last row shows a continuous color map based on the previous row, that is in the example `GnBu-9`.

6. The rest of the matrix shows the colors used in the corresponding scheme.

Activating Color Schemes

In order to activate a `colorbrewer colormap`, say, `BuGn-5`, you have to use the key

`colormap/BuGn-5`.

This will initialize and select the associated `colormap`. It will also initialize the associated `cycle list` (but will not select it). In order to initialize and select the `cycle list` of name `BuGn-5`, you have to use the key

`cycle list/BuGn-5`.

This will initialize and select the associated `cycle list`. It will also initialize (but not select) the associated `colormap`.

Note that `cycle list`s shipped with `colorbrewer` merely consist of *colors*. However, a good `cycle list` typically also comes with markers and perhaps line style variations. In order to combine a pure color-based `cycle list` with markers, you should make use of the features `cycle multi list`, `cycle multiindex list`, and `cycle multiindex* list`, for example using

```
\pgfplotsset{
    % initialize Set1-5:
    cycle list/Set1-5,
    % combine it with 'mark list*':
    cycle multiindex* list={
        mark list*\nextlist
        Set1-5\nextlist
    },
}
```

Please refer to the reference manual for `cycle multiindex* list` for details.

5.2.2 Sequential Schemes

Sequential schemes are useful for ordered data progressing low to high.
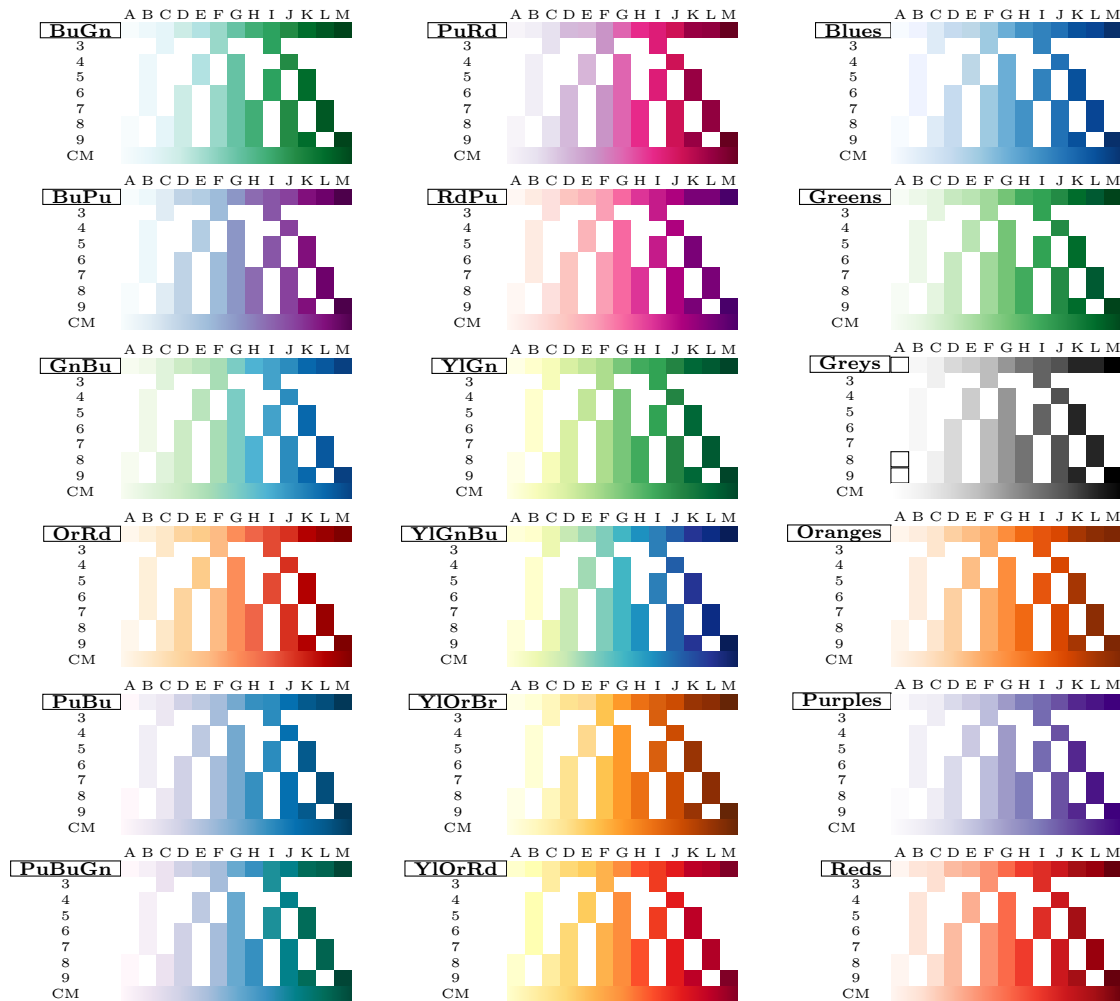
5.2.3 Diverging Schemes

Diverging schemes highlight changes from some mean value.
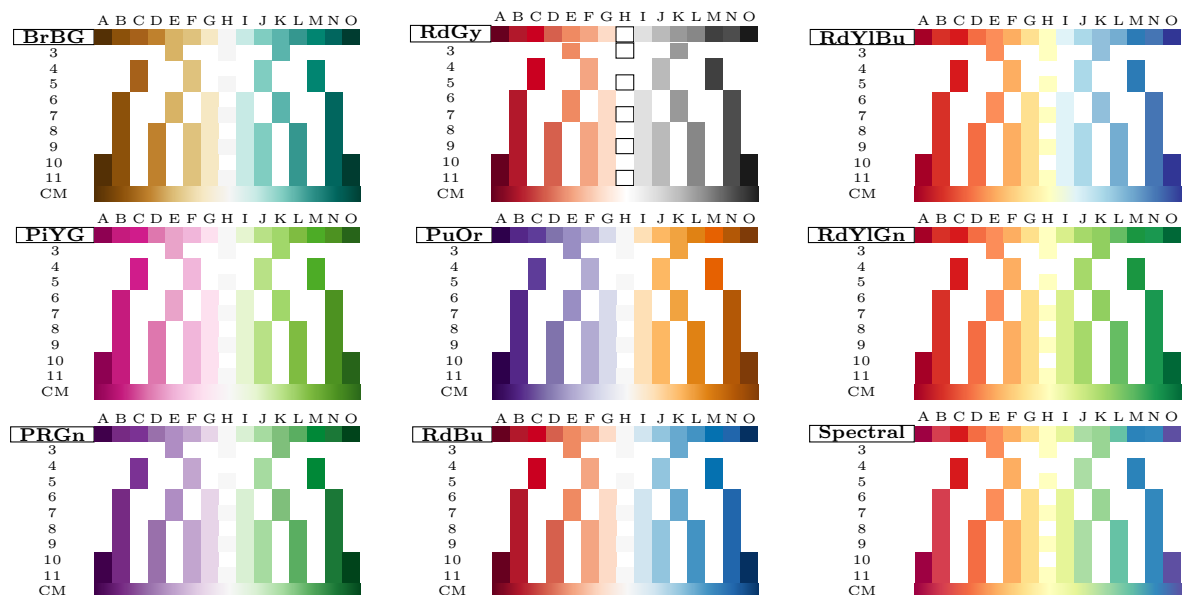
Note that you can adopt `point meta min` and `point meta max` such that the `colormap`'s mean value fits the data (for example by forcing `point meta min=-2` and `point meta max=+2`).

5.2.4   Qualitative Schemes

Qualitative schemes are useful if colors have no special order, but should be distinguishable.
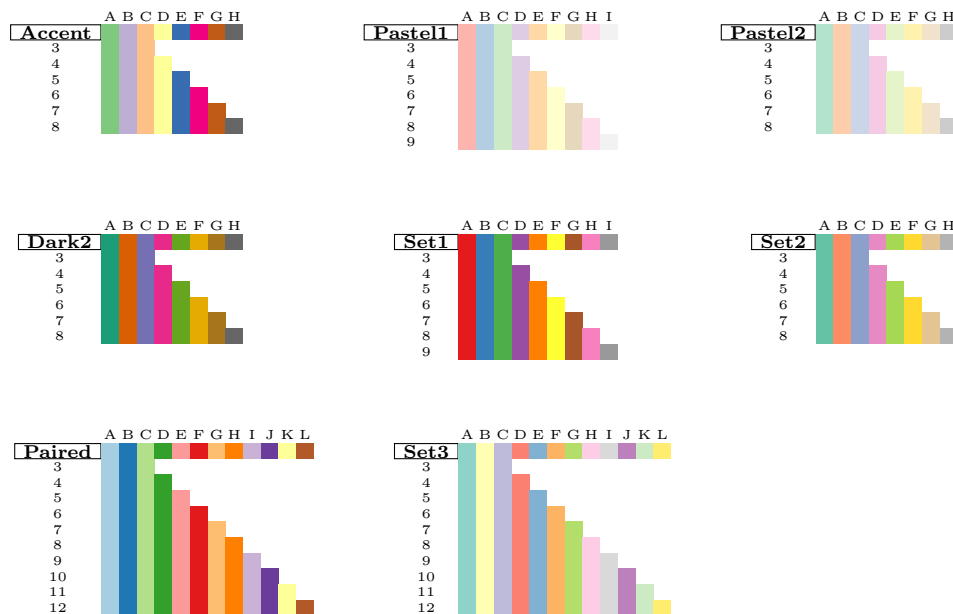
5.2.5   Interaction with the ColorBrewer website

To find a scheme, e.g. the above chosen `GnBu-7` on http://colorbrewer2.org/

- first select the "Nature of your data" type; in this case "sequential",

- then select the "Number of data classes", which is 7,

- and last select the corresponding scheme in the "Pick a color scheme" section. (This is a bit tricky, because you can only see the name at the top of the lower right corner, where all the colors are listed. When you have selected the right one you should read there "7-class GnBu". But perhaps it helps when you know that "Gn" stands for green and "Bu" for blue, so you are searching for a scheme going from green to blue, which in this case is the third color scheme in the first row of "Multi-hue".)

- The color names, e.g. `GnBu-H`, cannot be extracted from the page directly though, because you cannot simply count to the number and replace it with the corresponding letter. This intentionally was avoided, because then one would define the same color multiple times with different names, e.g. `GnBu-H` 3 times.

- If you should need let's say the 5th color of the scheme `GnBu-7` you don't have to trial and error or have a look at the manual.   You can simply extract this color from the corresponding color map via the `index of colormap` feature, e.g.

  `\tikz \fill`[index of colormap={4 of GnBu-7}] (0,0) rectangle (1em,2ex);

  which results in ▮. Note that the index is 4 instead of 5 because the index starts with 0. Note furthermore that you have to invoke `\pgfplotsset`{colormap/GnBu-7} before using this key.

5.2.6   External Examples

If you want to see some examples, where Brewer has used her schemes, have a look at https://www.census.gov/population/www/cen2000/atlas/index.html.

`\usetikzlibrary`{colorbrewer} % LaTeX and plain TeX

```
\usetikzlibrary[colorbrewer] % ConTeXt
```
A library which contains just the color definitions like `GnBu-B`. Please refer to Section 5.2.1 for a list of available colors.

5.3 Colormaps

An extension by Patrick Häcker

```
\usepgfplotslibrary{colormaps} % LaTeX and plain TeX
\usepgfplotslibrary[colormaps] % ConTeXt
\usetikzlibrary{pgfplots.colormaps} % LaTeX and plain TeX
\usetikzlibrary[pgfplots.colormaps] % ConTeXt
```
A small library providing a number of additional colormaps. Many of these colormaps originate from the free Matlab package "SC — powerful image rendering" of Oliver Woodford.

The purpose of this library is to provide further colormaps to all users and to provide some of them which are similar to those used by Matlab (Ⓡ).

/pgfplots/colormap/autumn   (style, no value)

A style which is equivalent to

```
\pgfplotsset{
    /pgfplots/colormap={autumn}{rgb255=(255,0,0) rgb255=(255,255,0)}
}
```

This colormap is similar to one shipped with Matlab (Ⓡ) under a similar name.

/pgfplots/colormap/bled   (style, no value)

A style which is equivalent to

```
\pgfplotsset{
    /pgfplots/colormap={bled}{rgb255=(0,0,0) rgb255=(43,43,0) rgb255=(0,85,0)
        rgb255=(0,128,128) rgb255=(0,0,170) rgb255=(213,0,213) rgb255=(255,0,0)}
}
```

This colormap is similar to one shipped with Matlab (Ⓡ) under a similar name.

/pgfplots/colormap/bright   (style, no value)

A style which is equivalent to

```
\pgfplotsset{
    /pgfplots/colormap={bright}{rgb255=(0,0,0) rgb255=(78,3,100) rgb255=(2,74,255)
        rgb255=(255,21,181) rgb255=(255,113,26) rgb255=(147,213,114) rgb255=(230,255,0)
        rgb255=(255,255,255)}
}
```

This colormap is similar to one shipped with Matlab (Ⓡ) under a similar name.

/pgfplots/colormap/bone   (style, no value)

A style which is equivalent to

```
\pgfplotsset{
    /pgfplots/colormap={bone}{[1cm]rgb255(0cm)=(0,0,0) rgb255(3cm)=(84,84,116)
        rgb255(6cm)=(167,199,199) rgb255(8cm)=(255,255,255)}
}
```

This colormap is similar to one shipped with Matlab (Ⓡ) under a similar name.

/pgfplots/colormap/cold   (style, no value)

A style which is equivalent to

```
\pgfplotsset{
    /pgfplots/colormap={cold}{rgb255=(0,0,0) rgb255=(0,0,255) rgb255=(0,255,255)
        rgb255=(255,255,255)}
}
```

This colormap is similar to one shipped with Matlab (Ⓡ) under a similar name.

/pgfplots/colormap/copper   (style, no value)

A style which is equivalent to

```
\pgfplotsset{
    /pgfplots/colormap={copper}{[1cm]rgb255(0cm)=(0,0,0) rgb255(4cm)=(255,159,101)
        rgb255(5cm)=(255,199,127)}
}
```

This colormap is similar to one shipped with Matlab (Ⓡ) under a similar name.

/pgfplots/colormap/copper2   (style, no value)

A style which is equivalent to

```
\pgfplotsset{
    /pgfplots/colormap={copper2}{rgb255=(0,0,0) rgb255=(68,62,63) rgb255=(170,112,95)
        rgb255=(207,194,138) rgb255=(255,255,255)}
}
```

This colormap is similar to one shipped with Matlab (Ⓡ) under a similar name.

/pgfplots/colormap/earth   (style, no value)

A style which is equivalent to

```
\pgfplotsset{
    /pgfplots/colormap={earth}{rgb255=(0,0,0) rgb255=(0,28,15) rgb255=(42,39,6)
        rgb255=(28,73,33) rgb255=(67,85,24) rgb255=(68,112,46) rgb255=(81,129,83)
        rgb255=(124,137,87) rgb255=(153,147,122) rgb255=(145,173,164) rgb255=(144,202,180)
        rgb255=(171,220,177) rgb255=(218,229,168) rgb255=(255,235,199) rgb255=(255,255,255)}
}
```

This colormap is similar to one shipped with Matlab (Ⓡ) under a similar name.

/pgfplots/colormap/gray   (style, no value)

A style which is equivalent to

```
\pgfplotsset{
    /pgfplots/colormap={gray}{rgb255=(0,0,0) rgb255=(255,255,255)}
}
```

This `colormap` is an alias for the standard `colormap/blackwhite`.

This colormap is similar to one shipped with Matlab (Ⓡ) under a similar name.

/pgfplots/colormap/hot2   (style, no value)

A style which is equivalent to

```
\pgfplotsset{
    /pgfplots/colormap={hot2}{[1cm]rgb255(0cm)=(0,0,0) rgb255(3cm)=(255,0,0)
        rgb255(6cm)=(255,255,0) rgb255(8cm)=(255,255,255)}
}
```

Note that this particular choice ships directly with PGFPLOTS, you do not need to load the `colormaps` library for this value.

This colormap is similar to one shipped with Matlab (Ⓡ) under a similar name.

/pgfplots/colormap/hsv   (style, no value)

A style which is equivalent to

```
\pgfplotsset{
    /pgfplots/colormap={hsv}{rgb255=(255,0,0) rgb255=(255,255,0) rgb255=(0,255,0)
        rgb255=(0,255,255) rgb255=(0,0,255) rgb255=(255,0,255) rgb255=(255,0,0)}
}
```

This colormap is similar to one shipped with Matlab (Ⓡ) under a similar name.

/pgfplots/colormap/hsv2   (style, no value)

A style which is equivalent to

```
\pgfplotsset{
    /pgfplots/colormap={hsv2}{rgb255=(0,0,0) rgb255=(128,0,128) rgb255=(0,0,230)
        rgb255=(0,255,255) rgb255=(0,255,0) rgb255=(255,255,0) rgb255=(255,0,0)}
}
```

This colormap is similar to one shipped with Matlab (Ⓡ) under a similar name.

/pgfplots/colormap/jet   (style, no value)

A style which is equivalent to

```
\pgfplotsset{
    /pgfplots/colormap={jet}{rgb255(0cm)=(0,0,128) rgb255(1cm)=(0,0,255)
        rgb255(3cm)=(0,255,255) rgb255(5cm)=(255,255,0) rgb255(7cm)=(255,0,0)
        rgb255(8cm)=(128,0,0)}
}
```

Note that this particular choice ships directly with PGFPLOTS, you do not need to load the `colormaps` library for this value.

This colormap is similar to one shipped with Matlab (Ⓡ) under a similar name.

/pgfplots/colormap/pastel   (style, no value)

A style which is equivalent to

```
\pgfplotsset{
    /pgfplots/colormap={pastel}{rgb255=(0,0,0) rgb255=(120,0,5) rgb255=(0,91,172)
        rgb255=(215,35,217) rgb255=(120,172,78) rgb255=(255,176,24) rgb255=(230,255,0)
        rgb255=(255,255,255)}
}
```

This colormap is similar to one shipped with Matlab (®) under a similar name.

/pgfplots/colormap/pink   (style, no value)

A style which is equivalent to

```
\pgfplotsset{
    /pgfplots/colormap={pink}{rgb255=(0,0,0) rgb255=(12,16,46) rgb255=(62,22,43)
        rgb255=(53,53,65) rgb255=(79,72,58) rgb255=(122,80,67) rgb255=(147,91,102)
        rgb255=(147,115,140) rgb255=(144,145,154) rgb255=(173,163,146) rgb255=(216,171,149)
        rgb255=(250,179,179) rgb255=(255,198,227) rgb255=(246,229,255) rgb255=(255,255,255)}
}
```

This colormap is similar to one shipped with Matlab (®) under a similar name.

/pgfplots/colormap/sepia   (style, no value)

A style which is equivalent to

```
\pgfplotsset{
    /pgfplots/colormap={sepia}{rgb255(0cm)=(0,0,0) rgb255(1cm)=(26,13,0)
        rgb255(18cm)=(255,230,204) rgb255(20cm)=(255,255,255)}
}
```

This colormap is similar to one shipped with Matlab (®) under a similar name.

/pgfplots/colormap/spring   (style, no value)

A style which is equivalent to

```
\pgfplotsset{
    /pgfplots/colormap={spring}{rgb255=(255,0,255) rgb255=(255,255,0)}
}
```

This colormap is similar to one shipped with Matlab (®) under a similar name.

/pgfplots/colormap/summer   (style, no value)

A style which is equivalent to

```
\pgfplotsset{
    /pgfplots/colormap={summer}{rgb255=(0,128,102) rgb255=(255,255,102)}
}
```

This colormap is similar to one shipped with Matlab (®) under a similar name.

/pgfplots/colormap/temp (style, no value)

A style which is equivalent to

```
\pgfplotsset{
    /pgfplots/colormap={temp}{rgb255=(36,0,217) rgb255=(25,29,247) rgb255=(41,87,255)
        rgb255=(61,135,255) rgb255=(87,176,255) rgb255=(117,211,255) rgb255=(153,235,255)
        rgb255=(189,249,255) rgb255=(235,255,255) rgb255=(255,255,235) rgb255=(255,242,189)
        rgb255=(255,214,153) rgb255=(255,172,117) rgb255=(255,120,87) rgb255=(255,61,61)
        rgb255=(247,40,54) rgb255=(217,22,48) rgb255=(166,0,33)}
}
```

This colormap is similar to one shipped with Matlab (Ⓡ) under a similar name.

/pgfplots/colormap/thermal (style, no value)

A style which is equivalent to

```
\pgfplotsset{
    /pgfplots/colormap={thermal}{rgb255=(0,0,0) rgb255=(77,0,179) rgb255=(255,51,0)
        rgb255=(255,255,0) rgb255=(255,255,255)}
}
```

This colormap is similar to one shipped with Matlab (Ⓡ) under a similar name.

/pgfplots/colormap/winter (style, no value)

A style which is equivalent to

```
\pgfplotsset{
    /pgfplots/colormap={winter}{rgb255=(0,0,255) rgb255=(0,255,128)}
}
```

This colormap is similar to one shipped with Matlab (Ⓡ) under a similar name.

/pgfplots/colormap/viridis high res (style, no value)

A style which installs the colormap "viridis" which has been defined by Stéfan van der Walt and Nathaniel Smith for Matplotlib. It is designated to be the default colormap for Matplotlib starting with version 2.0 and is released under the CC0[6]. This is the original suggestion as released by the authors.

Please refer to http://bids.github.io/colormap/ for details.

```
\pgfplotsset{
    colormap name=viridis,
}
```

```
\pgfplotsset{
    colormap/viridis high res,
}
```

_____

5.4   Dates as Input Coordinates

```
\usepgfplotslibrary{dateplot} % LaTeX and plain TeX
\usepgfplotslibrary[dateplot] % ConTeXt
\usetikzlibrary{pgfplots.dateplot} % LaTeX and plain TeX
\usetikzlibrary[pgfplots.dateplot] % ConTeXt
```

A library which allows to use dates like 2008-01-01 or dates with time like 2008-01-01 11:35 as input coordinates in plots. The library converts dates to numbers and tick labels will be pretty-printed dates (or times).

This library is documented in Section 4.21.2 on page 381.

5.5   Decoration: Soft Clipping

```
\usepgfplotslibrary{decorations.softclip} % LaTeX and plain TeX
\usepgfplotslibrary[decorations.softclip] % ConTeXt
\usetikzlibrary{pgfplots.decorations.softclip} % LaTeX and plain TeX
\usetikzlibrary[pgfplots.decorations.softclip] % ConTeXt
```

Activates decoration=softclip.

A "soft clip" is a part of an input path, namely that part which is inside of the "clip path". This is typically known as clipping: you set \clip ⟨path⟩; and all following paths are clipped against ⟨path⟩. Soft–clipping is similar, but instead of installing a low–level clip path, it modifies the input path in a way such that only parts inside of ⟨path⟩ remain. This makes a difference if decorations are to be applied. It also makes a difference for fill between/soft clip.

Note that this library is loaded implicitly by the fillbetween library in order to address its fill between/soft clip key.

ATTENTION: this library is considered to be experimental. It will work for paths which are similar to a plot, i.e. paths which do not intersect themselves and which have a clear direction. The library might fail, in general.

An application could be to draw a path twice, but the second time should only affect portions of the path:
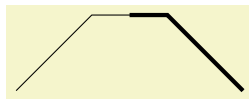
```
\begin{tikzpicture}
    \draw[
        postaction={decorate,draw,ultra thick},
        decoration={soft clip,soft clip path={
            (1.5,-1) rectangle (4,2)
            },
        },
    ]
        (0,0) -- (1,1) -- (2,1) -- (3,0);
\end{tikzpicture}%
```

The soft clip feature is tailored for use with fill between. Please refer to the documentation of fill between/soft clip for more examples and explanation on soft–clipping.

/pgf/decoration/soft clip path=⟨corner1⟩ rectangle ⟨corner2⟩

Assigns the path which is to be used for the soft clip decoration. This argument is mandatory in order to apply a soft clip decoration.

Please refer to the documentation of fill between/soft clip for details; it has the same syntax and a similar motivation.

/pgf/decoration/every soft clipped path   (style, no value)

A style which is applied just before the reduced path is generated.

5.6   Image Externalization

```
\usepgfplotslibrary{external} % LaTeX and plain TeX
\usepgfplotslibrary[external] % ConTeXt
```

```
\usetikzlibrary{pgfplots.external} % LATEX and plain TEX
\usetikzlibrary[pgfplots.external] % ConTEXt
```

The external library offers a convenient method to export every single tikzpicture into a separate .pdf (or .eps). Later runs of LATEX will simply include these graphics, thereby reducing typesetting time considerably.

This library is documented in more detail in Section 7.1 "Export to PDF/EPS".

The external library has been written by Christian Feuersänger (author of PGFPLOTS). It has been contributed to TikZ as general purpose library, so the reference documentation along with all tweaks can be found in [7, Section "Externalization Library"]. The command \usepgfplotslibrary{external} is actually just a wrapper which loads \usetikzlibrary{external} or, if this library does not yet exist because the installed PGF has at most version 2.00, it will load a copy which is shipped with PGFPLOTS.

5.7 Fill between

```
\usepgfplotslibrary{fillbetween} % LATEX and plain TEX
\usepgfplotslibrary[fillbetween] % ConTEXt
\usetikzlibrary{pgfplots.fillbetween} % LATEX and plain TEX
\usetikzlibrary[pgfplots.fillbetween] % ConTEXt
```

The fillbetween library allows to fill the area between two arbitrary named plots. It can also identify segments of the intersections and fill the segments individually.

5.7.1 Filling an Area

\addplot fill between [{⟨*options defined with prefix* /tikz/fill between⟩}];
\addplot[⟨*options*⟩] fill between [{⟨*options defined with prefix* /tikz/fill between⟩}] ⟨*trailing path commands*⟩;
\addplot3 ...

A special plotting operation which takes two named paths on input and generates one or more paths resembling the filled area between the input paths.
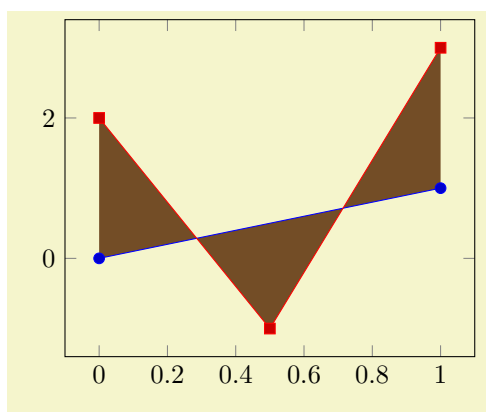

```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}\usepgfplotslibrary{fillbetween}
\begin{tikzpicture}
\begin{axis}
    \addplot+[name path=A,domain=0:1,samples=2] {x};

    \addplot+[name path=B] table {
        x y
        0 2
        0.5 -1
        1 3
    };

    \addplot fill between[of=A and B];
\end{axis}
\end{tikzpicture}
```

The operation fill between requires at least one input key within ⟨*options defined with prefix* /tikz/fill between⟩: the two involved paths in the form of=⟨*first*⟩ and ⟨*second*⟩. Here, both ⟨*first*⟩ and ⟨*second*⟩ need to be defined using name path (or name path global). The arguments can be exchanged[7], i.e. we would achieve the same effect for of=B and A.

The argument ⟨*options defined with prefix* /tikz/fill between⟩ can contain any number of options which have the prefix /tikz/fill between. Note that the prefix refers to the reference manual, you do not need to type the prefix. This excludes drawing options like fill=orange; these options should be given as ⟨*options*⟩ (or inside of styles like every segment). Allowed options include of, split, soft clip, and style definitions of every segment and its friends, i.e. those which define which paths are to be acquired and how they should be processed before they can be visualized.

---

[7]Note that some options refer explicitly to either the first or the second input path. These options are documented accordingly.

A `fill between` operation takes the two input paths, analyzes their orientation (i.e. are its coordinates given increasing in x direction?), connects them, and generates a `fill` path.

As mentioned above, the input paths need to be defined in advance (forward references are unsupported). If you would generate the filled path manually, you would draw it *before* the other ones such that it does not overlap. This is done implicitly by PGFPLOTS: as soon as PGFPLOTS encounters a `fill between` plot, it will activate layered graphics. The filled path will be placed on layer `pre main` which is between the main layer and the background layer.

A `fill between` operation is just like a usual plot: it makes use of the `cycle list`, i.e. it receives default plot styles. Our first example above uses the default `cycle list` which has a brown color. We can easily redefine the appearance just as for any other plot by adding options in square braces:
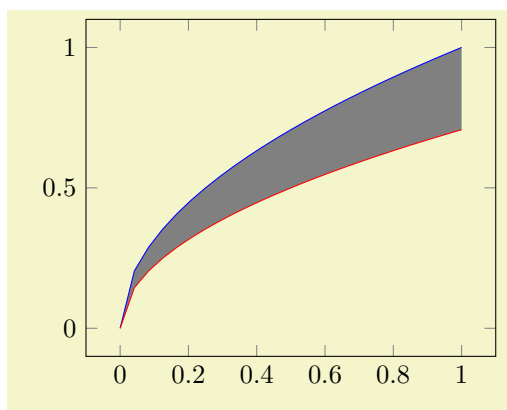
```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}\usepgfplotslibrary{fillbetween}
\begin{tikzpicture}
\begin{axis}
    \addplot[blue,name path=A,domain=0:1] {sqrt(x)};

    \addplot[red, name path=B,domain=0:1] {sqrt(x/2)};

    \addplot[gray] fill between[of=A and B];
\end{axis}
\end{tikzpicture}
```

Note that the number of data points does not restrict `fill between`. In particular, you can combine different arguments easily.
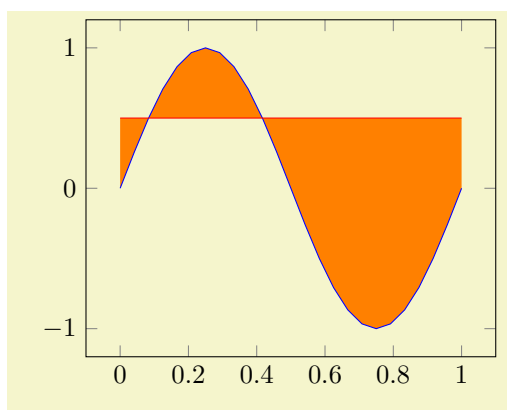
```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}\usepgfplotslibrary{fillbetween}
\begin{tikzpicture}
\begin{axis}
    \addplot[blue,name path=A,domain=0:1]
        {sin(360*x)};

    \addplot[red, name path=B,domain=0:1,samples=2]
        {0.5};

    \addplot[orange] fill between[of=A and B];
\end{axis}
\end{tikzpicture}
```

The combination of input plots is also possible if one or both of the plots make use of `smooth` interpolation:
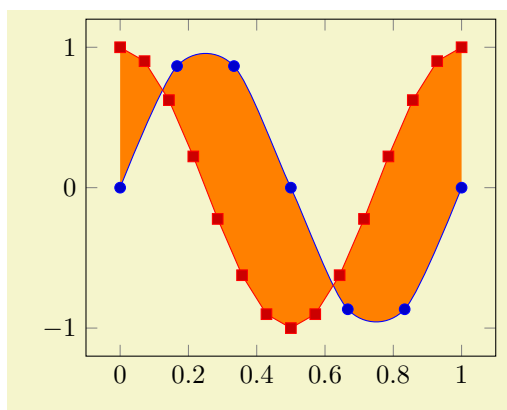
```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}\usepgfplotslibrary{fillbetween}
\begin{tikzpicture}
\begin{axis}
  \addplot+[name path=A,samples=7,smooth,domain=0:1]
        {sin(360*x)};

  \addplot+[name path=B,samples=15,domain=0:1]
        {cos(360*x)};

  \addplot[orange] fill between[of=A and B];
\end{axis}
\end{tikzpicture}
```

Actually, a `fill between` path operates directly on the low–level input path segments. As such, it is

much closer to, say, a TikZ decoration than to a plot; only its use-cases (legends, styles, layering) are tailored to the use as a plot. However, the input paths can be paths and/or plots. The example below combines one `\addplot` and one `\path`.
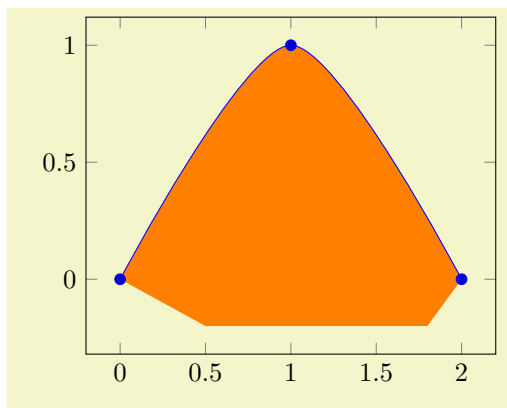
```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}\usepgfplotslibrary{fillbetween}
\begin{tikzpicture}
\begin{axis}[ymin=-0.2,enlargelimits]
    \addplot+[name path=A,smooth]
        coordinates {(0,0) (1,1) (2,0)};

    \path[name path=B]
        (0.5,-0.2) -- (1.8,-0.2);

    \addplot[orange] fill between[of=A and B];
\end{axis}
\end{tikzpicture}
```

As mentioned above, `fill between` takes the two input paths as such and combines them to a filled segment. To this end, it connects the end–points of both paths. This can be seen in the example above: the path named 'B' has different x coordinates than 'A' and results in a trapezoidal output.

Here is another example in which a plot and a normal path are combined using `fill between`. Note that the `\draw` path is generated using nodes of path 'A'. In such a scenario, we may want to fill only the second segment which is also possible, see `split` below.
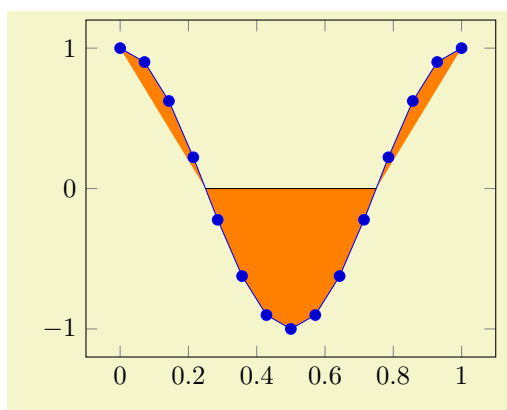
```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}\usepgfplotslibrary{fillbetween}
\begin{tikzpicture}
\begin{axis}
    \addplot+[name path=A,samples=15,domain=0:1]
        {cos(360*x)}
        coordinate[pos=0.25] (nodeA0) {}
        coordinate[pos=0.75] (nodeA1) {};

    \draw[name path=B]
        (nodeA0) -- (nodeA1);

    \addplot[orange] fill between[of=A and B];
\end{axis}
\end{tikzpicture}
```

A `fill between` plot is different from other plotting operations with respect to the following items:

1. It has no own markers and no `nodes near coords`. However, its input paths can have both.

2. It supports no `pos` nodes. However, its input paths can have any annotations as usual.

3. It supports no error bars. Again, its input paths support what PGFPLOTS offers for plots.

4. It cannot be stacked (its input plots can be, of course).

Note that more examples can also be found in Section 4.5.10 on page 103 which covers Area Plots and has a lot of examples on `fill between`.

5.7.2 Filling Different Segments of the Area

/tikz/fill between/**split**=true|false   (initially `false`)

Activates the generation of more than one output segment.

The initial choice `split`=false is quite fast and robust, it simply concatenates the input paths and generates exactly *one* output segment.

The choice `split`=true results in a computation of every intersection of the two curves (by means of the `tikz` library `intersections`). Then, each resulting segment results in a separate drawing instruction.

The choice `split`=false is the default and has been illustrated with various examples above.

The choice `split`=true is very useful in conjunction with the various styles. For example, we could use `every odd segment` to choose a different color for every odd segment:
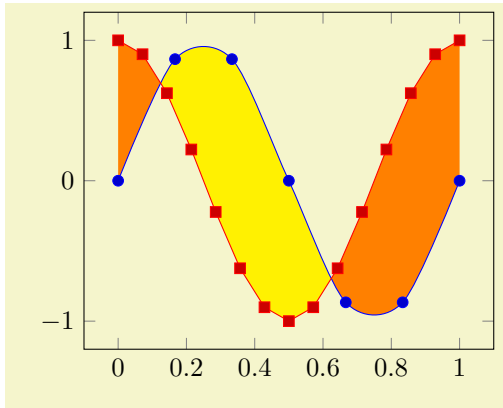
```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}\usepgfplotslibrary{fillbetween}
\begin{tikzpicture}
\begin{axis}
    \addplot+[name path=A,samples=7,smooth,domain=0:1]
        {sin(360*x)};

    \addplot+[name path=B,samples=15,domain=0:1]
        {cos(360*x)};

    \addplot[orange] fill between[of=A and B,
        split,
        every odd segment/.style={yellow},
        ];
\end{axis}
\end{tikzpicture}
```

Similarly, we could style the regions individually using `every segment no`:
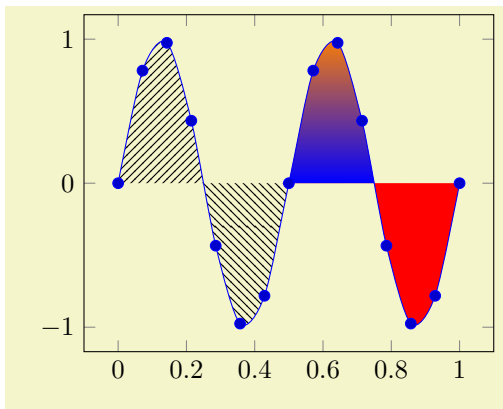
```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}\usepgfplotslibrary{fillbetween}
\begin{tikzpicture}
\begin{axis}
  \addplot+[name path=A,samples=15,smooth,domain=0:1]
        {sin(720*x)};

  \path[name path=B]
        (\pgfkeysvalueof{/pgfplots/xmin},0)
    --  (\pgfkeysvalueof{/pgfplots/xmax},0)
  ;

  \addplot fill between[of=A and B,
        split,
        every segment no 0/.style=
          {orange},
        every segment no 1/.style=
          {pattern=north east lines},
        every segment no 2/.style=
          {pattern=north west lines},
        every segment no 3/.style=
          {top color=orange, bottom color=blue},
  ];
\end{axis}
\end{tikzpicture}
```

The `split` option allows us to revisit our earlier example in which we wanted to draw only one of the segments:

```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}\usepgfplotslibrary{fillbetween}
\begin{tikzpicture}
\begin{axis}
    \addplot+[name path=A,samples=15,domain=0:1]
        {cos(360*x)}
        coordinate[pos=0.25] (nodeA0)
        coordinate[pos=0.75] (nodeA1);

    \draw[name path=B]
        (nodeA0) -- (nodeA1);

    \addplot[fill=none] % default: fill none
    fill between[of=A and B,
        split,
        % draw only selected ones:
        % every segment no 0/.style: invisible
        every segment no 1/.style={fill,orange},
        % every segment no 2/.style: invisible
    ];
\end{axis}
\end{tikzpicture}
```

Each segment results in an individual `\fill` instruction, i.e. each segment is its own, independent, path. This allows to use all possible TikZ path operations, including `pattern`, `shade`, or `decorate`.
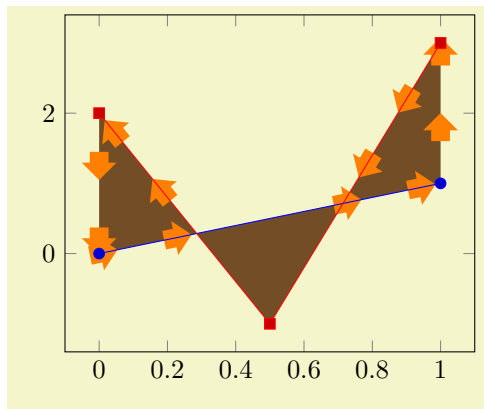
```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}\usepgfplotslibrary{fillbetween}
% requires
% \usetikzlibrary{decorations.markings,shapes.arrows}
\begin{tikzpicture}
\begin{axis}
    \addplot+[name path=A,domain=0:1,samples=2] {x};

    \addplot+[name path=B] table {
        x y
        0 2
        0.5 -1
        1 3
    };

    \addplot fill between[of=A and B,
        split,
        every even segment/.style={
            postaction={decorate},
            decoration={
                markings,
                mark=between positions 0 and 1
                  step 1cm with {
                    \node [single arrow,fill=orange,
                        single arrow head extend=3pt,
                        transform shape]
                    {};
                }
            },
        },
    ];
\end{axis}
\end{tikzpicture}
```

5.7.3   Filling only Parts Under a Plot (Clipping)

/tikz/fill between/**soft clip**=⟨*argument*⟩
/tikz/fill between/**soft clip first**=⟨*argument*⟩
/tikz/fill between/**soft clip second**=⟨*argument*⟩

Installs "soft–clips" on both or just one of the involved paths. Soft–clipping means to modify the input paths such that they respect a clipping region.

In its default configuration, `fill between` connects the start/end points of the two involved paths.

This is often what you want, but there are use–cases where only *parts* between the input parts should be filled: suppose we have $f(x) = x^2$ and we want to fill below the interval $[3, 5]$. The case "fill below" means to fill between our function and the x axis:
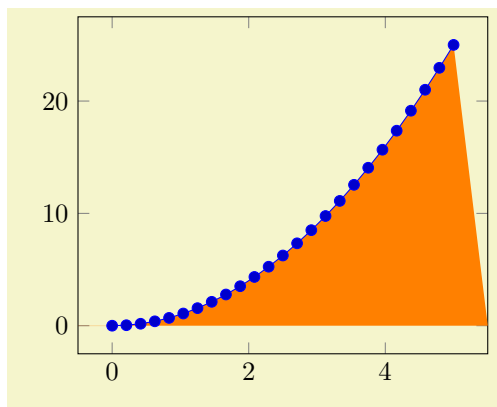
```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}\usepgfplotslibrary{fillbetween}
\begin{tikzpicture}
\begin{axis}
    \addplot+[name path=A,domain=0:5] {x^2};

    \path[name path=B]
        (\pgfkeysvalueof{/pgfplots/xmin},0) --
        (\pgfkeysvalueof{/pgfplots/xmax},0);

    \addplot[orange] fill between[of=A and B];
\end{axis}
\end{tikzpicture}
```

Clearly, we have filled too much. A solution might be to shorten the path `B` — but that would still connect the left and right end points of $f(x)$ with the shortened line.

This is where `soft clip` has its uses: we can select the area of interest by installing a soft clip path:
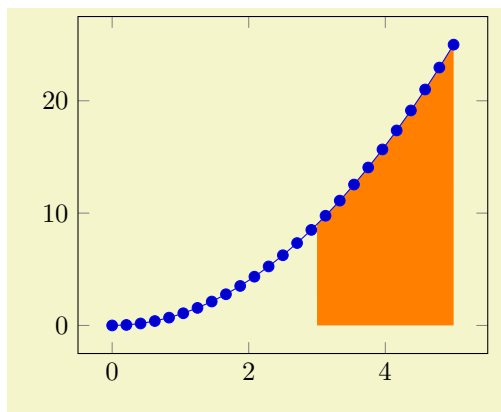
```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}\usepgfplotslibrary{fillbetween}
\begin{tikzpicture}
\begin{axis}
    \addplot+[name path=A,domain=0:5] {x^2};

    \path[name path=B]
        (\pgfkeysvalueof{/pgfplots/xmin},0) --
        (\pgfkeysvalueof{/pgfplots/xmax},0);

    \addplot[orange] fill between[of=A and B,
        soft clip={domain=3:5},
        ];
\end{axis}
\end{tikzpicture}
```

Soft–clipping is similar to clipping. In fact, we could have installed a clip path to achieve the same effect[8]. However, soft–clipping results in a new path which is aware of the boundaries. Consequently, decorations will be correct, without suffering from missing image parts due to the clipping:
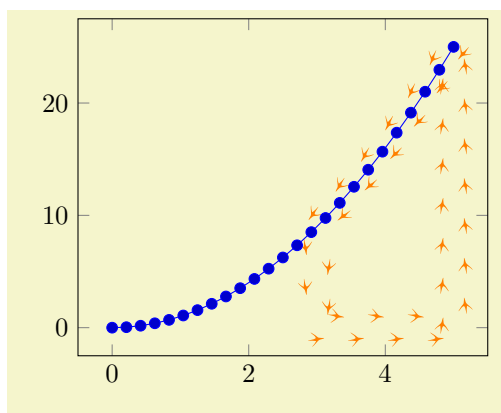
```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}\usepgfplotslibrary{fillbetween}
\begin{tikzpicture}
\begin{axis}
    \addplot+[name path=A,domain=0:5] {x^2};

    \path[name path=B]
        (\pgfkeysvalueof{/pgfplots/xmin},0) --
        (\pgfkeysvalueof{/pgfplots/xmax},0);

    \addplot[
        orange,
        decorate,decoration={
            footprints,
            foot of=bird,
            stride length=15pt,
            foot sep=2pt,
            foot length=6pt},
    ]
    fill between[of=A and B,
        soft clip={domain=3:5},
        ];
\end{axis}
\end{tikzpicture}
```

The feature `soft clip` is a part of `fill between` in the sense that it determines the fill path.

The ⟨*argument*⟩ can be one of the following items:

- It can be of the form `domain`=⟨*xmin*⟩:⟨*xmax*⟩. This choice is equivalent to
  (⟨*xmin*⟩,`\pgfkeysvalueof{/pgfplots/ymin}`) `rectangle`
  (⟨*xmax*⟩,`\pgfkeysvalueof{/pgfplots/ymax}`).

- It can be of the form `domain y`=⟨*ymin*⟩:⟨*ymax*⟩. This choice is equivalent to
  (`\pgfkeysvalueof{/pgfplots/xmin}`,⟨*ymin*⟩) `rectangle`
  (`\pgfkeysvalueof{/pgfplots/xmax}`,⟨*ymax*⟩).

- It can be (⟨*x*⟩,⟨*y*⟩) `rectangle` (⟨*X*⟩,⟨*Y*⟩). In this case, it is the rectangle defined by the given points.

- It can be the name of a named path, i.e. `soft clip`=A if there exists a path with `name path`=A.
  In this case, the named path has to be "reasonable simple". In particular, it should be convex, that is like a rectangle, a circle, or some cloud. It should also be closed.

In any case, the soft clip path should be *larger* than the paths it applies to. Please avoid infinitely many intersections points.

---

[8]Installing a clip path might need to adopt layers: `fill between` is on layer `pre main` and the clip path would need to be on the same layer.
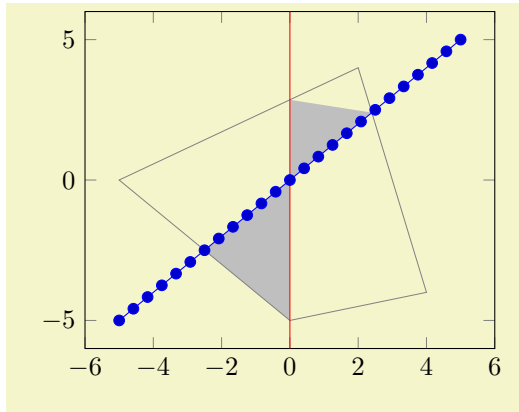
```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}\usepgfplotslibrary{fillbetween}
\begin{tikzpicture}
    \begin{axis}
    \draw[help lines,name path=clippath]
        (0,-5) -- (-5,0)
    -- (2,4) -- (4,-4) --cycle;

    \addplot+[name path=A] {x};

    \draw[red,name path=B]
        (0,\pgfkeysvalueof{/pgfplots/ymin})
    -- (0,\pgfkeysvalueof{/pgfplots/ymax});

    \addplot[gray!50] fill between[of=A and B,
        soft clip={clippath}];
    \end{axis}
\end{tikzpicture}
```

The previous example defines three named paths: the path A is $f(x) = x$. The named path `clippath` serves as clip path, it is some rotated rectangular form. Finally, the path named B is a straight line – and we fill between A and B with the given `clippath`.

The choice `soft clip first` applies the clip path only to the first input path ("A" in our case).

The choice `soft clip second` applies the clip path only to the second input path ("B" in our case).

Finally, `soft clip` applies the clip path to both input paths.
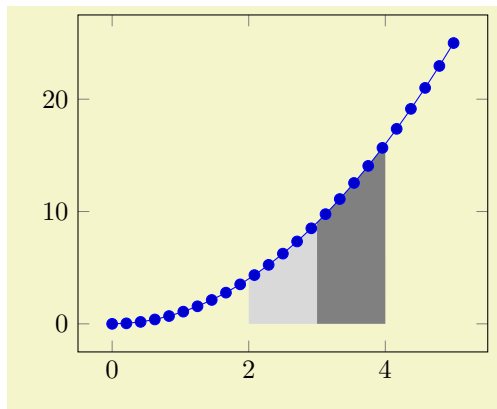
```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}\usepgfplotslibrary{fillbetween}
% requires \usepgfplotslibrary{fillbetween}
\begin{tikzpicture}
\begin{axis}
    \addplot+[name path=A,domain=0:5] {x^2};

    \path[name path=B]
        (\pgfkeysvalueof{/pgfplots/xmin},0) --
        (\pgfkeysvalueof{/pgfplots/xmax},0);

    \addplot[gray] fill between[of=A and B,
        soft clip={
            (3,-1)
            rectangle
            (4,100)
        },
    ];

    \addplot[gray!30] fill between[of=A and B,
        soft clip={
            (2,-1)
            rectangle
            (3,100)
        },
    ];
\end{axis}
\end{tikzpicture}
```

Note that there is also a separate module which allows to apply soft–clipping to individual paths. To this end, a `decoration`=soft clip is available. A use–case could be to highlight parts of the input path:
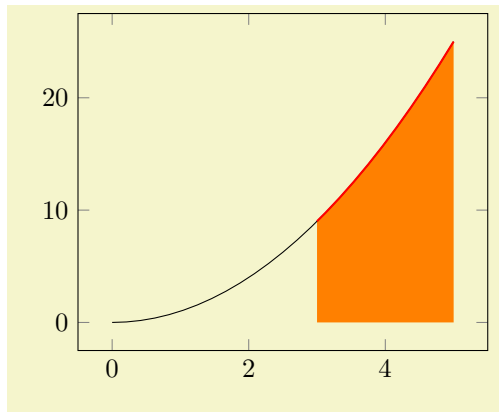
```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}\usepgfplotslibrary{fillbetween}
\begin{tikzpicture}
\begin{axis}
    \addplot[name path=A,domain=0:5,
        postaction={decorate,red,thick},
        decoration={
            soft clip,
            soft clip path={domain=3:5},
        },
    ] {x^2};

    \path[name path=B]
        (\pgfkeysvalueof{/pgfplots/xmin},0) --
        (\pgfkeysvalueof{/pgfplots/xmax},0);

    \addplot[orange] fill between[of=A and B,
        soft clip={
            (3,-1)
            rectangle
            (5,100)},
    ];
\end{axis}
\end{tikzpicture}
```

Note that more examples can also be found in Section 4.5.10 on page 103 which covers Area Plots and has a lot of examples on `fill between`.

5.7.4   Styles Around Fill Between

/tikz/fill between/every segment   (style, no value)

A style which installed for every segment generated by `fill between`.

The sequence of styles which are being installed is

`every segment`, any ⟨*options*⟩ provided after `\addplot`[⟨*options*⟩] `fill between`, then the appropriate `every segment no` ⟨*index*⟩, then one of `every odd segment` or `every even segment`, then `every last segment`.

/tikz/fill between/every odd segment   (style, no value)

A style which is installed for every odd segment generated by `fill between`.

Attention: this style makes only sense if `split` is active.

See `every segment` for the sequence in which the styles will be invoked.

/tikz/fill between/every even segment   (style, no value)

A style which is installed for every even segment generated by `fill between`.

Attention: this style makes only sense if `split` is active.

See `every segment` for the sequence in which the styles will be invoked.

/tikz/fill between/every segment no ⟨*index*⟩   (style, no value)

A style which is installed for every segment with the designated index ⟨*index*⟩ generated by `fill between`.

An index is a number starting with 0 (which is used for the first segment).

Attention: this style makes only sense if `split` is active.

See `every segment` for the sequence in which the styles will be invoked.

/tikz/fill between/every last segment   (style, no value)

A style which installed for every *last* segment generated by `fill between`.

\tikzsegmentindex

A command which is valid while the paths of `\addplot fill between` are generated.

It expands to the segment ⟨*index*⟩, i.e. the same value which is used by `every segment no` ⟨*index*⟩.

An index is a number starting with 0 (which is used for the first segment).

/pgfplots/every fill between plot   (style, no value)

A style which is installed for every `\addplot fill between`. Its default is

```
\pgfkeys{
    /pgfplots/every fill between plot/.style={
        /pgfplots/area legend,/tikz/fill},
}
```

5.7.5 Key Reference

/tikz/fill between/of=⟨*first*⟩ **and** ⟨*second*⟩

This key is mandatory. It defines which paths should be combined.

The arguments are names which have been assigned to paths or plots in advance using `name path`. Paths with these two names are expected in the same `tikzpicture`.

The `fillbetween` library supports a variety of input paths, namely

- plots of functions, i.e. each x coordinate has at most one y coordinate,
- plots with interruptions,
- TikZ paths which meet the same restrictions and are labelled by `name path`,
- `smooth` curves or `curveto` paths,
- mixed smooth / non-smooth parts.

However, it has at most restricted support (or none at all) for paths which

- have self-intersections (i.e. parametric plots might pose a problem),
- have coordinates which are given in a strange input sequence,
- consist of lots of individually separated sub-paths (like `mesh` or `surf` plots).

Note that the input paths do not necessarily need to be given in the same sequence, see `fill between/reverse`.

/tikz/name path={⟨*name*⟩}

A TikZ instruction which assigns a name to a path or plot.[9]

This is mandatory to define input arguments for `fill between/of`.

/tikz/fill between/reverse=auto|true|false   (initially `auto`)

Configures whether the input paths specified by `of` need to be reversed in order to arrive at a suitable path concatenation.

The initial choice `auto` will handle this automatically. To this end, it applies the following heuristics: it compares the two first coordinates of each plot: if both plots have their x coordinates in ascending order, one of them will be reversed (same if both are in descending order). If one is in ascending and on in descending, they will not be reversed. If the x coordinates of the first two points are equal, the y coordinates are being compared.

The choice `true` will always reverse one of the involved paths. This is suitable if both paths have the same direction (for example, both are specified in increasing x order).

The choice `false` will not reverse the involved paths. This is suitable if one path has, for example, coordinates in increasing x order whereas the other path has coordinates in decreasing x order.

Manual reversal is necessary if PGFPLOTS chose the wrong one.

---

[9] Note that TikZ also knows `name path global`. This key has the same effect and is an alias for `name path` within a PGFPLOTS environment.
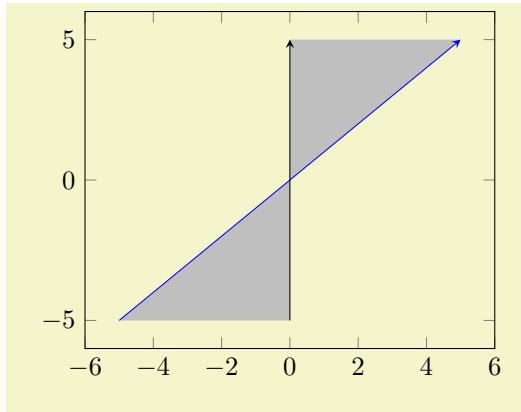
```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}\usepgfplotslibrary{fillbetween}
\begin{tikzpicture}
    \begin{axis}

    \addplot[blue,-stealth,name path=A] {x};

    \draw[-stealth,name path=B]
        (0,-5)
    -- (0,5);

    \addplot[gray!50] fill between[of=A and B,
        reverse=true];
    \end{axis}
\end{tikzpicture}
```

In this case, we chose `reverse`=true. This is essentially equivalent to the instruction

- use path `A`
- append the reversed path `B`
- fill the result.

In other words, it is equivalent to the following path construction based on `intersection segments`:
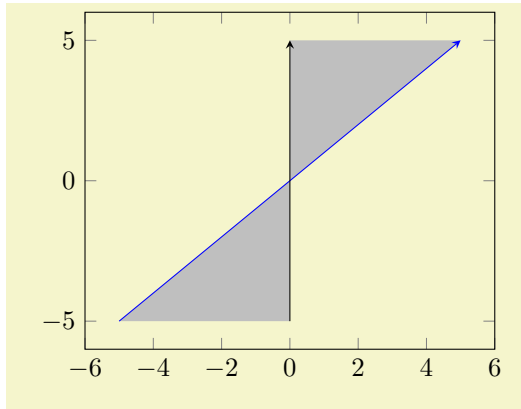
```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}\usepgfplotslibrary{fillbetween}
\begin{tikzpicture}
    \begin{axis}[set layers]

    \addplot[blue,-stealth,name path=A] {x};

    \draw[-stealth,name path=B]
        (0,-5)
    -- (0,5);

    \pgfonlayer{pre main}
    \fill[gray!50,intersection segments={of=A and B,
        sequence={A* -- B*[reverse]}}];
    \endpgfonlayer
    \end{axis}
\end{tikzpicture}
```

Here, we filled the `intersection segments` of `A` and `B` by taking all (indicated by `*`) segments of `A` and all of `B` in reversed order.
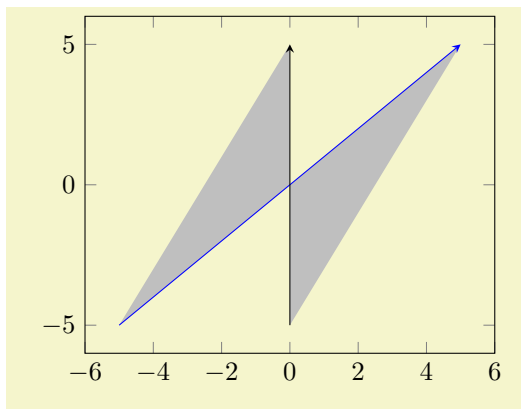
```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}\usepgfplotslibrary{fillbetween}
\begin{tikzpicture}
    \begin{axis}

    \addplot[blue,-stealth,name path=A] {x};

    \draw[-stealth,name path=B]
        (0,-5)
    -- (0,5);

    \addplot[gray!50] fill between[of=A and B,
        reverse=false];
    \end{axis}
\end{tikzpicture}
```

In this case, we chose `reverse`=false. This, in turn, can be expressed as

- use path `A`,
- connect with path `B`,
- fill the result.

In other words, it resembles the follower `intersections segments` construction:
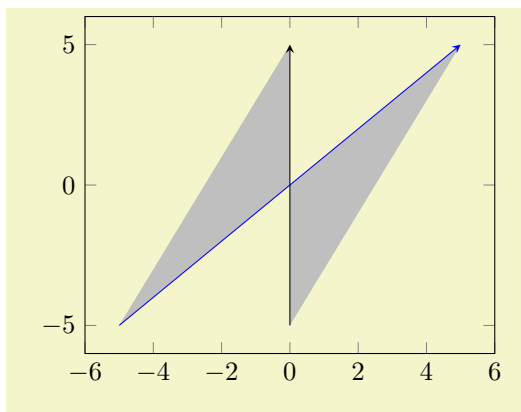
```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}\usepgfplotslibrary{fillbetween}
\begin{tikzpicture}
    \begin{axis}[set layers]

        \addplot[blue,-stealth,name path=A] {x};

        \draw[-stealth,name path=B]
            (0,-5)
         -- (0,5);

        \pgfonlayer{pre main}
        \fill[gray!50,intersection segments={of=A and B,
            sequence={A* -- B*}}];
        \endpgfonlayer
    \end{axis}
\end{tikzpicture}
```

/tikz/fill between/on layer={⟨layer name⟩}   (initially pre main)

Defines the layer on which \addplot fill between will be drawn. PGFPLOTS defines the layer pre main to be right before the main layer and pre main is also the initial configuration for any fill between path.

As soon as you type \addplot fill between, PGFPLOTS will activate layered graphics using set layers such that this works automatically. PGFPLOTS will also install a clip path the first time it encounters this layer.

Set ⟨layer name⟩ to the empty string to place deactivate special layer support for fill between.

Note that this auto-activation of set layers and the installation of a clip path is done for \addplot fill between, not for the lower–level drawing instructions like \tikzfillbetween or intersection segments. If you need them, you have to install a layer list manually using either set layers (if inside of an axis) or \pgfsetlayers. The clip path for an axis can be installed manually using

```
\pgfplotsextra{
    \pgfonlayer{pre main}
    \pgfplotspathaxisoutline
    \pgfusepath{clip}
    \endpgfonlayer
}
```

(should this ever be necessary).

/tikz/fill between/inner moveto=connect|keep   (initially connect)

Sometimes input paths contain the leading moveto operation *and* some inner movetos. This key configures how to deal with them.

The initial choice connect replaces them by lineto operations (and connects them)[10].

The choice keep keeps them.

Typically, fill between requires the initial choice connect as it allows to deal with interrupted paths:
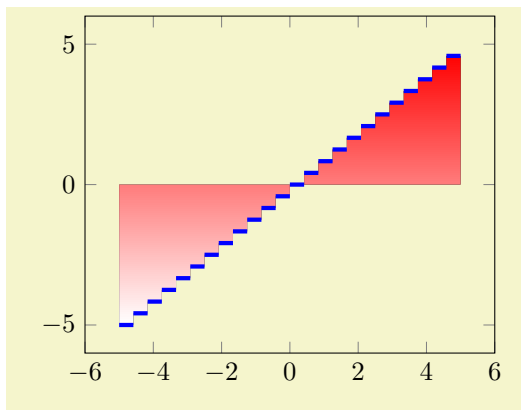
```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}\usepgfplotslibrary{fillbetween}
\begin{tikzpicture}
    \begin{axis}

        \addplot[blue,ultra thick,name path=A,
            jump mark left] {x};

        \path[name path=B]
            (-5,0)
         -- (5,0);

        \addplot[top color=red, bottom color=white]
            fill between[of=A and B];
    \end{axis}
\end{tikzpicture}
```

---

[10]Note that the actual implementation of inner moveto=connect is more complicated: it also deduplicates multiple adjacent movetos and it eliminates "empty" moveto operations at the end of a path (i.e. moveto operations which are not followed by any path operation).

5.7.6   Intersection Segment Recombination

The implementation of `fill between` relies on path recombination internally: all `intersection segments` are computed and concatenated in a suitable order (possibly reversed).

This method can also be applied to plain TikZ paths to achieve interesting effects:
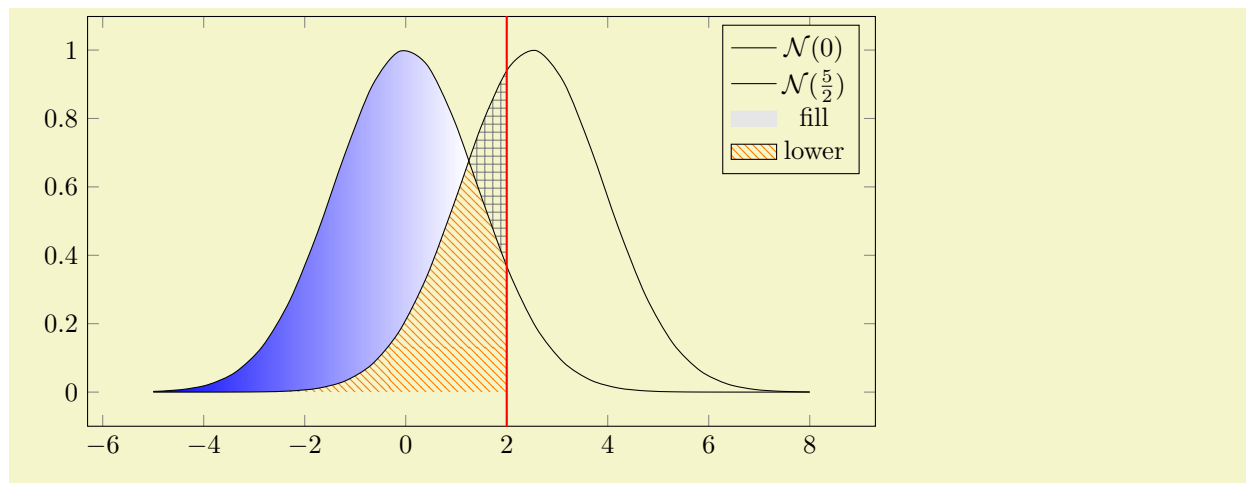

```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}\usepgfplotslibrary{fillbetween}
\begin{tikzpicture}

\def\verticalbar{2}
\begin{axis}[domain=-5:8,samples=25,smooth,width=12cm,height=7cm]

% Draw curves
\addplot[name path=g0,thin] {exp(-x^2/4)};
\addlegendentry{$\mathcal{N}(0)$}
\addplot[name path=g2.5,thin] {exp(-(x-2.5)^2/4)};
\addlegendentry{$\mathcal{N}(\frac52)$}

% Draw vertical bar:
\draw [name path=red,red,thick]
    (\verticalbar,-1) -- (\verticalbar,2);

\path[name path=axis] (-10,0) -- (16,0);

\addplot[black!10] fill between[of=g0 and g2.5,
    soft clip={domain=-6:\verticalbar},
    split,
    every segment no 0/.style={left color=blue,right color=white},
    every segment no 1/.style={pattern=grid,pattern color=gray},
];
\addlegendentry{fill}

% compute + label the lower segment (but do not draw it):
\path[name path=lower,
    %draw=red,ultra thick,
    intersection segments={of=g0 and g2.5,sequence=R1 -- L2}
];

\addplot[pattern=north west lines, pattern color=orange]
    fill between[
    of=axis and lower,
    soft clip={domain=-6:\verticalbar},
];
\addlegendentry{lower}

\end{axis}
\end{tikzpicture}
```

This example has two plots, one with a Gauss peak at $x = 0$ and one with a Gauss peak at $x = \frac{5}{2}$. Both have standard legend entries. Then we have a red line drawn at $x =$`\verticalbar` which is defined as $x = 2$. The third plot is a `fill between` with `split`ted segments where the left segment has a shading and the right one has a pattern – and both are clipped to the part which is left of `\verticalbar`. The option list which comes directly after `\addplot`, i.e. the `[black!10]` will be remembered for the legend entry of this plot. The

next `\path...` instruction has no visible effect (and does not increase the size of the document[11]). However, it contains the key `intersection segments` which computes a path consistent of intersection segments of the two functions. In our case, we connect the first (1st) segment of the path named `g2.5` (which is referred to as `R` in the context of `sequence`) and the second (2nd) segment of the path named `g0` (which is referred to as `L` in the context of `sequence`). The result receives `name path`=`lower`. Finally, the last `\addplot` is a `fill between` which fills everything between the axis and this lower path segment, again clipped to the parts left of `\verticalbar`. Note that `axis` is no magic name; it has been defined in our example as well. This is explained in more detail in the following paragraphs.

/tikz/intersection segments={⟨*options with prefix* `/tikz/segments`⟩}

Evaluates ⟨*options*⟩ and appends intersection segments to the current path.

This key is actually more a command: it acquires the two input paths which are argument of the mandatory `of` key and it parses the ⟨*series specification*⟩ which is argument of `sequence`. Afterwards, it computes the intersection segments and concatenates them according to ⟨*series specification*⟩. Each resulting segment is appended to the current path as–is.

The key `intersection segments` can occur more than once in the current path. Since the key generates path elements, it is sufficient to terminate the path right after options have been processed (i.e. to add ';' right after the option list).

Note that this method operates on the transformed paths and does not apply coordinate transformations on its own. It is more like a decoration than a standard path command, although it does not have an input path.

There is also a related key `name intersections` in the `intersections` library of TikZ which assigns names to all intersections, see the manual of TikZ for details.

/tikz/segments/of={⟨*name1*⟩} and {⟨*name2*⟩}

Defines the two input paths.

/tikz/segments/sequence={⟨*series specification*⟩}   (initially `L1 -- R2`)

Selects the `intersection segments` and their sequence.

The ⟨*series specification*⟩ consists of a sequence of entries of the form `L`⟨*index*⟩ `-- R`⟨*index*⟩ `-- L`⟨*index*⟩. It is probably best shown before we delve into the details:
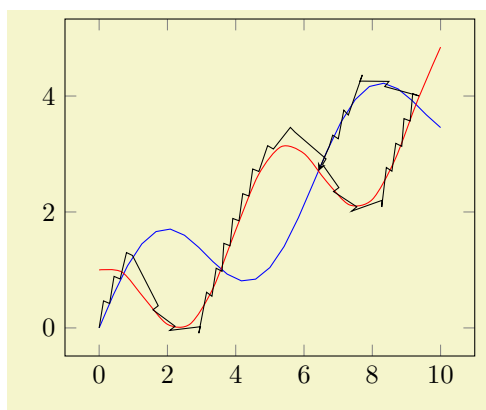

```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}\usepgfplotslibrary{fillbetween}
\begin{tikzpicture}
\begin{axis}[domain=0:10]

\addplot[name path=first,blue]
    {sin(deg(x)) + 2/5*x};

\addplot[name path=second,red,
    samples=16,smooth]
    {cos(deg(1.2*x)) + 2/5*x};

\draw[black,-stealth,
    decorate,decoration={
        saw,
        post=lineto,
        post length=10pt},
    intersection segments={
        of=first and second,
        sequence={L1 -- R2 -- R3
            -- R4 -- L4[reverse]}
    },
];

\end{axis}
\end{tikzpicture}
```

The preceding example defines two input plots of different sampling density, one is a `sharp plot` and one is `smooth`. Afterwards, it draws a third path with a `saw` decoration – and that path concatenates intersection segments.

---

[11]Well, perhaps 8 byte for scopes.

The entry `L1` means to take the first intersection segment of the first input path. In this context, the first input path is always called 'L', regardless of its actual name. Note that `L1` refers to an entire *segment* (not just a point).

The second item is `--` which means to connect the previous segment with the next one. Without this item, it would have moved to the next one, leaving a gap. Note that `--` is normally a connection between two points. In this context, it is a connection between two segments.

The third item is `R2` which means to use the second intersection segment of the second input path. Again, the second input path is always called 'B', regardless of its actual name. The other items are straightforward until we arrive at `L4[reverse]`: it is possible to append an *reversed* path segment this way.

The general syntax is to add an (arbitrary) sequence of `[--] [L|R]{⟨index⟩}[⟨options⟩]` where ⟨options⟩ is optional. There is one special case: if ⟨index⟩ is `*`, the *entire* path will be used. If all encountered indices are `*`, the intersection will not be computed at all (in this case, intersection segments degenerates to "path concatenation"). Consequently, the following example is a degenerate case in which we did "path concatenation" rather than intersection concatenation:
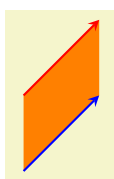
```
\pgfdeclarelayer{pre main}
\begin{tikzpicture}
    \pgfsetlayers{pre main,main}
    \draw[-stealth,thick,name path=A,red]
    (0,0) -- (1,1);
    \draw[-stealth,thick,name path=B,blue]
    (0,-1) -- (1,0);

    \pgfonlayer{pre main}
    \fill[
        orange,
        intersection segments={
            of=A and B,
            sequence={L* -- R*[reverse]}}];
    \endpgfonlayer
\end{tikzpicture}
```

Note that segment indices start at 1. They will be processed by means of PGF's math parser and may depend on `\pgfintersectionsolutions` (which is the number of intersections).

Note that there is actually another syntax: you can use `A⟨0-based-index⟩` for the first input path and `B⟨0-based-index⟩` for the second input path. These identifiers were introduced in PGFPLOTS 1.10, but have been deprecated in favor of 1-based indices. The old syntax with 0-based indices will still remain available. It is advised to use `L` and `R` instead of `A` and `B`.

Note that curly braces around `{⟨index⟩}` can be omitted if the index has just one digit: `L1`, `L2`, or `L-2` are all valid.

It is also possible to use negative indices to count from the last:
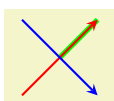
```
\pgfdeclarelayer{pre main}
\begin{tikzpicture}
    \pgfsetlayers{pre main,main}
    \draw[-stealth,thick,name path=A,red]
    (0,0) -- (1,1);
    \draw[-stealth,thick,name path=B,blue]
    (0,1) -- (1,0);

    \pgfonlayer{pre main}
    \draw[
        green,
        line width=2pt,
        intersection segments={
            of=A and B,
            sequence={L-1}}];
    \endpgfonlayer
\end{tikzpicture}
```

In this case, −1 denotes the first segment in reverse ordering.

Note that `\pgfintersectionsegments` is the number of segments in this context.

/tikz/segments/reverse=true|false (false)

Allows to reverse affected path segments.
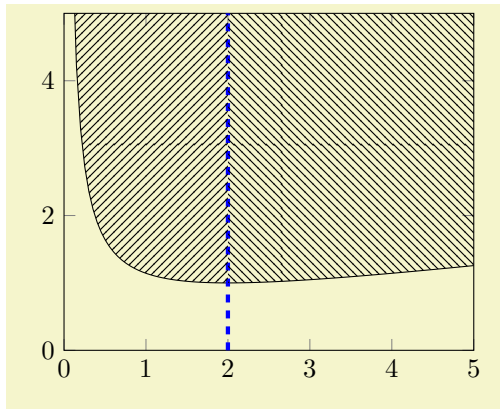
```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}\usepgfplotslibrary{fillbetween}
\begin{tikzpicture}
    \begin{axis}[xmin=0,xmax=5,ymin=0,ymax=5]
    \addplot [name path=f,domain=0:5,samples=100]
        {(x - 2)^2/(7*x) + 1};

    \addplot [name path=border,
        color=blue, ultra thick, dashed]
        coordinates {(2,0) (2,5) } ;

    \fill[
        intersection segments={
            of=f and border,
            sequence={L1 -- R2}},
        pattern=north east lines,
    ]
    -- cycle;

    \fill[
        intersection segments={
            of=f and border,
            sequence={R2[reverse] -- L2}},
        pattern=north west lines,
    ]
    -- (rel axis cs:1,1) -- cycle;

    \end{axis}
\end{tikzpicture}
```

The preceding example defines two input plots: the plot named `f` which is the plot of the curve and the blue `border` line.

It then computes fills paths relying on two `intersection segments`, one which resembles the part above the curve which is *left* of the border and one which resembles the part on the *right* of the border.

It works by concatenating `intersection segments` in a suitable `sequence` (add further `\draw` statements to visualize the individual segments). Note that `R2` is used twice: once in normal direction and once `reverse`d. The `intersection segments` merely constitute the start of the paths; they are extended by `--cycle` and `-- (rel axis cs:1,1) -- cycle`, respectively. Keep in mind that `rel axis cs` is a relative coordinate system in which `1` means 100% of the respective axis – in this case, we have the upper right corner which is 100% of x and 100% of y.

5.7.7 Basic Level Reference

There are a couple of basic level functions which allow to control `fillbetween` on a lower level of abstraction. The author of this package lists them here for highly experienced power-users (only). It might be suitable to study the source code to get details about these methods and how and where they are used.

`\tikzfillbetween`[⟨*options*⟩]{⟨*draw style*⟩}

This is the low-level interface of `fill between`; it generates one or more paths.

This command can be used inside of a plain TikZ picture, it is largely independent of PGFPLOTS:
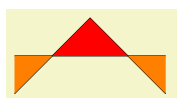
```
\begin{tikzpicture}

    \draw[name path=first] (0,0) -- (1,1) -- (2,0);

    \draw[name path=second] (0,0.5) -- (2,0.5);

    \tikzfillbetween[of=first and second,
        split,
        every even segment/.style={orange}]
        {red}
\end{tikzpicture}
```

The first argument ⟨*options*⟩ describes how to compute the filled regions like `of` or `split`. It corresponds to those items which are in `\addplot fill between`[⟨*options*⟩].

The second argument ⟨*draw style*⟩ is the default draw style which is installed for every generated path segment.

Note that `\tikzfillbetween` is *no* typically `\path` statement: it generates one or more of TikZ `\path` statements (each with their own, individual *draw style*).

Inside of `\tikzfillbetween`, the macro `\tikzsegmentindex` will expand to the current segment index. It can be used inside of styles.

The key `on layer` is respected here: if `on layer` has a valid layer name (`pre main` by default), the generated paths will be on that layer. However, unlike `\addplot fill between`, this command does not *ensure* that layered graphics is active. As soon as you write, say, `\pgfsetlayers{pre main,main}`, it will automatically use these layers. If not, you will see a warning message in your `.log` file.

`\pgfcomputeintersectionsegments{`⟨*1 or 2*⟩`}`

Given that some intersections have been computed already (and are in the current scope), this command computes the intersection segments for one of the input arguments.

On output, `\pgfretval` contains the number of computed segments. The segments as such can be accessed via `\pgfgetintersectionsegmentpath`.

The argument ⟨*1 or 2*⟩ should be `1` if intersection segments of the *first* argument of `\pgfintersectionofpaths` are to be computed and `2` if the *second* argument should be used as input.

This macro is part of `fillbetween`.

Let us illustrate the effects of some of these methods on the following example.
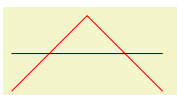
```
\begin{tikzpicture}
    \draw[red] (0,0) -- (1,1) -- (2,0);
    \draw[blue] (0,0.5) -- (2,0.5);
\end{tikzpicture}
```

We have two lines, both start on the left-hand-side. Our goal is to get a new path consisting of the intersections segments on the lower part of the picture, i.e. we would like to see
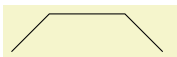
```
\begin{tikzpicture}
    % this is our goal - but computed automatically.
    \draw[black] (0,0) -- (0.5,0.5) --
        (1.5,0.5) -- (2,0);
\end{tikzpicture}
```

In order to let `fillbetween` compute the target path, we assign names to the input paths, compute the intersections – and recombined them using `\pgfcomputeintersectionsegments`.

Attention: Before you want to replicate this example, you may want to read about `intersection segments` which is a much simpler way to get the same effect!
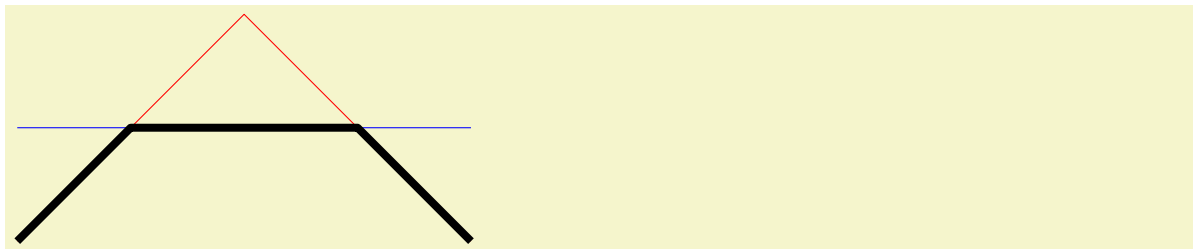
```
\begin{tikzpicture}[line join=round,x=3cm,y=3cm]
    \draw[name path=first,red] (0,0) -- (1,1) -- (2,0);
    \draw[name path=second,blue] (0,0.5) -- (2,0.5);

    % from 'name path' to softpaths...
    \tikzgetnamedpath{first}
    \let\A=\pgfretval
    \tikzgetnamedpath{second}
    \let\B=\pgfretval

    % compute intersections using the PGF intersection lib...
    \pgfintersectionofpaths{\pgfsetpath\A}{\pgfsetpath\B}%

    % ... and compute the intersection *segments* for both input
    % paths...
    \pgfcomputeintersectionsegments1
    \pgfcomputeintersectionsegments2

    % ... recombine the intersection segment paths!
    \pgfgetintersectionsegmentpath{1}{0}% path 1, segment 0
    \pgfsetpathandBB\pgfretval% this starts a new path
    \pgfgetintersectionsegmentpath{2}{1}% path 2, segment 1
    % connect, not move. Try to eliminate this line to see the effect
    \pgfpathreplacefirstmoveto\pgfretval%
    \pgfaddpathandBB\pgfretval% append
    \pgfgetintersectionsegmentpath{1}{2}%
    \pgfpathreplacefirstmoveto\pgfretval
    \pgfaddpathandBB\pgfretval
    \pgfsetlinewidth{3}
    \pgfsetcolor{black}
    \pgfusepath{stroke}
\end{tikzpicture}
```

Note that this operates on a relatively low level. However, you can easily insert these statements into a \pgfextra in order to embed it into Ti*k*Z. This allows access to any Ti*k*Z options, including decorate:
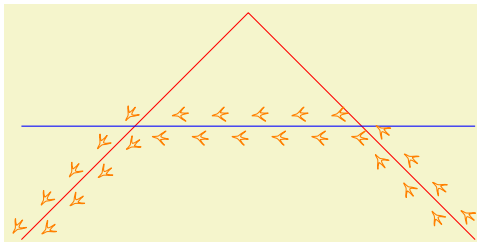
```
\begin{tikzpicture}[line join=round,x=3cm,y=3cm]
    \draw[name path=first,red] (0,0) -- (1,1) -- (2,0);
    \draw[name path=second,blue] (0,0.5) -- (2,0.5);

    \draw[orange,
        decorate,decoration={
            footprints,
            foot of=bird,
            stride length=15pt,
            foot sep=2pt,
            foot length=6pt},
    ]
    \pgfextra
        % from 'name path' to softpaths...
        \tikzgetnamedpath{first}
        \let\A=\pgfretval
        \tikzgetnamedpath{second}
        \let\B=\pgfretval
        %
        % compute intersections using the PGF intersection lib...
        \pgfintersectionofpaths{\pgfsetpath\A}{\pgfsetpath\B}%
        %
        % ... and compute the intersection *segments* for both input
        % paths...
        \pgfcomputeintersectionsegments1
        \pgfcomputeintersectionsegments2
        %
        % ... recombine the intersection segment paths!
        \pgfgetintersectionsegmentpath{1}{0}% path 1, segment 0
        \pgfsetpathandBB\pgfretval% this starts a new path
        \pgfgetintersectionsegmentpath{2}{1}% path 2, segment 1
        \pgfpathreplacefirstmoveto\pgfretval% connect, not move
        \pgfaddpathandBB\pgfretval% append
        \pgfgetintersectionsegmentpath{1}{2}%
        \pgfpathreplacefirstmoveto\pgfretval
        \pgfaddpathandBB\pgfretval
    \endpgfextra
    ;
\end{tikzpicture}
```

Attention: Before you want to replicate this example, you may want to read about intersection segments which is a much simpler way to get the same effect!

\pgfgetintersectionsegmentpath{⟨1 or 2⟩}{⟨index⟩}

Defines `\pgfretval` to contain the desired path segment as softpath.

The result has the same quality as a path returned by `\pgfgetpath` and can be used by means of `\pgfsetpath`, `\pgfsetpathandBB`, or `\pgfaddpathandBB`.

The value ⟨1 or 2⟩ resembles the argument of a preceding call to `\pgfcomputeintersectionsegments`: it identifies which of the two paths for which intersections have been computed is to be selected.

The second argument ⟨index⟩ is a number $0 \leq i < N$ where N is the total number of computed segments. The total number of computed segments is returned by `\pgfcomputeintersectionsegments`.

This macro is part of fillbetween.

\tikzgetnamedpath{⟨string name⟩}

Defines `\pgfretval` to contain the softpath associated with ⟨string name⟩. The ⟨string name⟩ is supposed to be the value of name path or name path global.

The resulting value is a softpath, i.e. it has the same quality as those returned by `\pgfgetpath`.

This macro is part of fillbetween.

\tikznamecurrentpath{⟨string name⟩}

Takes the current softpath (the one assembled by previous moveto, lineto, or whatever operations), and assigns the name ⟨string name⟩ to it.

This macro is part of fillbetween.

\pgfcomputereversepath{⟨*softpathmacro*⟩}

Takes a softpath ⟨*softpathmacro*⟩ and computes its reversed path.

It stores the resulting softpath into \pgfretval.

This macro is part of fillbetween.

\pgfgetpath{⟨*softpathmacro*⟩}

Stores the current softpath into the macro ⟨*softpathmacro*⟩.

See also \tikzgetnamedpath.

This macro is part of PGF.

\pgfsetpath{⟨*softpathmacro*⟩}

Replaces the current softpath from the macro ⟨*softpathmacro*⟩.

This does not update any bounding boxes. Note that this takes a soft–path as it is, no transformation will be applied. The only way to modify the path and its coordinates is a decoration or a canvas transformation.

This macro is part of PGF.

\pgfaddpath{⟨*softpathmacro*⟩}

Appends the softpath from the macro ⟨*softpathmacro*⟩ to the current softpath.

This does not update any bounding boxes. Note that this takes a soft–path as it is, no transformation will be applied. The only way to modify the path and its coordinates is a decoration or a canvas transformation.

This macro is part of PGF.

\pgfsetpathandBB{⟨*softpathmacro*⟩}

Replaces the current softpath from the macro ⟨*softpathmacro*⟩.

This updates the picture's bounding box by the coordinates found inside of ⟨*softpathmacro*⟩. Aside from that, the same restrictions as for \pgfsetpath hold here as well.

This macro is part of fillbetween.

\pgfaddpathandBB{⟨*softpathmacro*⟩}

Appends the softpath of macro ⟨*softpathmacro*⟩ to the current softpath.

This updates the picture's bounding box by the coordinates found inside of ⟨*softpathmacro*⟩. Aside from that, the same restrictions as for \pgfsetpath hold here as well.

This macro is part of fillbetween.

\pgfpathreplacefirstmoveto{⟨*softpathmacro*⟩}

Takes a macro containing a softpath on input, replaces its first moveto operation by a lineto operation and returns it as \pgfretval.

The argument ⟨*softpathmacro*⟩ is one which can be retrieved by \pgfgetpath.

This macro is part of fillbetween.

\pgfintersectionofpaths{⟨*first*⟩}{⟨*second*⟩}

The PGF basic layer command to compute intersections of two softpaths. In contrast to the name path method provided by TikZ, this command accepts *different* argument: ⟨*first*⟩ and ⟨*second*⟩ are supposed to set paths, i.e. they should contain something like \pgfsetpath{\somesoftpath}.

Results are stored into variables of the current scope.

This macro is part of PGF.

\tikzpathintersectionsegments[⟨*options with prefix* /tikz/segments⟩]

An alias for \tikzset{intersection segments={⟨*options*⟩}}.

\pgfpathcomputesoftclippath{⟨*inputsoftpath*⟩}{⟨*softclippath*⟩}

Does the work for soft clip: it computes the soft–clip–path of ⟨*inputsoftpath*⟩ when it is clipped against ⟨*softclippath*⟩.

The algorithm has been tested and written for rectangular soft clip paths. It will accept complicated clip paths, and might succeed with some of them. Nevertheless, rectangular soft clip paths are the ones which are supported officially.

See `soft clip` for details.

5.7.8   Pitfalls and Limitations

The `fillbetween` backend is quite powerful and successfully computes many use–cases around "filling path segments of arbitrary plots" out of the box.

However, it has a couple of limitations which may or may not be overcome by future releases:

1. The first limitation is scalability. The underlying algorithms are relatively inefficient and scale badly if the number of samples is large. Please apply it to "reasonable sample sizes" and plots with a "reasonable number of intersections". That means: if it takes too long, you may need to reduce the sampling density.

2. The second limitation is accuracy. The `fillbetween` functionality relies on the `intersections` library of PGF which, in turn, may fail to find all intersections (although its accuracy and reliability has been improved considerably as part of the work on `fillbetween`, thanks to Mark Wibrow of the PGF team for his assistance).

   The work-around for this limitation might be to reduce the sampling density – and to file bug reports.

3. Another limitation is generality. The `fillbetween` library allows to combine `smooth` and `sharp plots`, even `const plots` with jumps, and all out of the box. It will do so successfully as long as you have "plot–like" structures. But it may fail if

   - plots intersect themselves and you try to compute individual segments using `split` or `intersection segments`,
   - the plot has circles,
   - the two involved plots have infinitely many intersections (i.e. are on top of each other).

Many of these limitations are present in PGF as well, especially when `decorate`ing paths or when using `name intersections`.

5.8   Grouping plots

by Nick Papior Andersen

```
\usepgfplotslibrary{groupplots} % LaTeX and plain TeX
\usepgfplotslibrary[groupplots] % ConTeXt
\usetikzlibrary{pgfplots.groupplots} % LaTeX and plain TeX
\usetikzlibrary[pgfplots.groupplots] % ConTeXt
```

A library which allows the user to typeset several plots in a matrix like structure. Often one has to compare two plots to one another, or you simply need to display two plots in conjunction with each other. Either way the following section describes this library which makes matrix structure easier than alternative methods discussed in Section 4.19.4.

```
\begin{groupplot}[⟨options⟩]
  ⟨environment contents⟩
\end{groupplot}
```

Once you have loaded the `groupplots` library you will gain access to this environment. This environment is limited to the same restrictions as the `axis` environment. It actually utilizes this environment so consider it as an extension of this. What is important to note is that [⟨options⟩] are applied to all plots in the entire environment. This can be really handy when you need the same `xmin`, `xmax`, `ymin` and `ymax`.

With such an environment one can typeset plots in matrix like styles
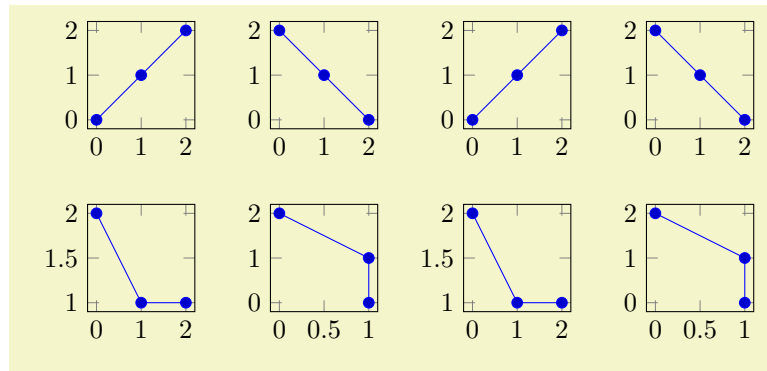
```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}\usepgfplotslibrary{groupplots}
% Example using groupplots library
\begin{tikzpicture}
  \begin{groupplot}[group style={group size=2 by 2},height=3cm,width=3cm]
    \nextgroupplot
    \addplot coordinates {(0,0) (1,1) (2,2)};
    \nextgroupplot
    \addplot coordinates {(0,2) (1,1) (2,0)};
    \nextgroupplot
    \addplot coordinates {(0,2) (1,1) (2,1)};
    \nextgroupplot
    \addplot coordinates {(0,2) (1,1) (1,0)};
  \end{groupplot}
\end{tikzpicture}
% Same example created as done without the library
\begin{tikzpicture}
  \begin{axis}[name=plot1,height=3cm,width=3cm]
    \addplot coordinates {(0,0) (1,1) (2,2)};
  \end{axis}
  \begin{axis}[name=plot2,at={($(plot1.east)+(1cm,0)$)},anchor=west,height=3cm,width=3cm]
    \addplot coordinates {(0,2) (1,1) (2,0)};
  \end{axis}
  \begin{axis}[name=plot3,at={($(plot1.south)-(0,1cm)$)},anchor=north,height=3cm,width=3cm]
    \addplot coordinates {(0,2) (1,1) (2,1)};
  \end{axis}
  \begin{axis}[name=plot4,at={($(plot2.south)-(0,1cm)$)},anchor=north,height=3cm,width=3cm]
    \addplot coordinates {(0,2) (1,1) (1,0)};
  \end{axis}
\end{tikzpicture}
```

The equivalent code is seen as the second example and it is clear that you have to type a lot less. So how do you use it? First of all you need to utilize the new environment `groupplot`. Within this environment the following command works.

`\nextgroupplot`[⟨*axis options*⟩] ⟨*normal plot commands*⟩

This command shifts the placement of the plot. Therefore one should always start the environment `groupplot` with the command `\nextgroupplot` in order to create the first plot. The [⟨*axis options*⟩] are the options that are supplied to the following axes until the next `\nextgroupplot` command is seen by TeX. The order in which figures are typeset are as seen in the next example.
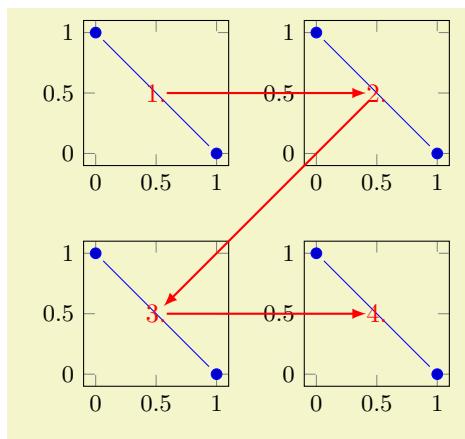
```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}\usepgfplotslibrary{groupplots}
\begin{tikzpicture}[shorten >=4pt,shorten <=4pt]
  \begin{groupplot}[group style={group size=2 by 2},
    height=3.5cm,width=3.5cm,/tikz/font=\small]
    \nextgroupplot%1
    \addplot coordinates {(0,1) (1,0)};
    \nextgroupplot%2
    \addplot coordinates {(0,1) (1,0)};
    \nextgroupplot%3
    \addplot coordinates {(0,1) (1,0)};
    \nextgroupplot%4
    \addplot coordinates {(0,1) (1,0)};
  \end{groupplot}
  \draw[thick,>=latex,->,red]
    (group c1r1.center) node {1.}  --
    (group c2r1.center) node {2.};
  \draw[thick,>=latex,->,red]
    (group c2r1.center)  --
    (group c1r2.center) node {3.};
  \draw[thick,>=latex,->,red]
    (group c1r2.center)  --
    (group c2r2.center) node {4.};
\end{tikzpicture}
```

The plot first fills the first row, then the next row and so on. Just like a table, thus the names `group c⟨column⟩r⟨row⟩`. The power of the groupplot is to quickly create an aligned structure of plots. But you can also utilize it to structure data more creatively. Consider the next example.
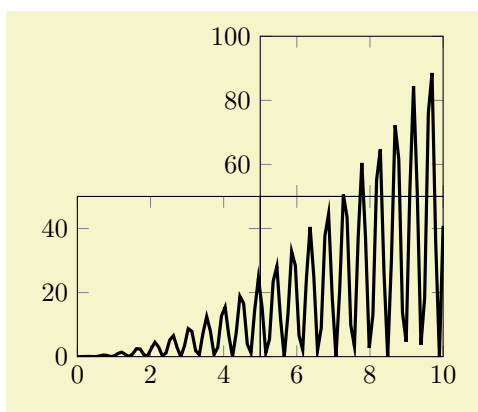

```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}\usepgfplotslibrary{groupplots}
\begin{tikzpicture}
 \begin{groupplot}[group style={group size=2 by 2,
     horizontal sep=0pt,vertical sep=0pt,
     xticklabels at=edge bottom},
     xmin=0,ymin=0,
     height=3.7cm,width=4cm,no markers]
  \nextgroupplot[group/empty plot]
  \nextgroupplot[xmin=5,xmax=10,ymin=50,ymax=100]
  \addplot[very thick] file {plotdata/group-1.dat};
  \nextgroupplot[xmax=5,ymax=50]
  \addplot[very thick] file {plotdata/group-1.dat};
  \nextgroupplot[xmin=5,xmax=10,ymax=50,
     yticklabels={}]
  \addplot[very thick] file {plotdata/group-1.dat};
 \end{groupplot}
\end{tikzpicture}
```

Or for instance zooming in on data as in the next example.
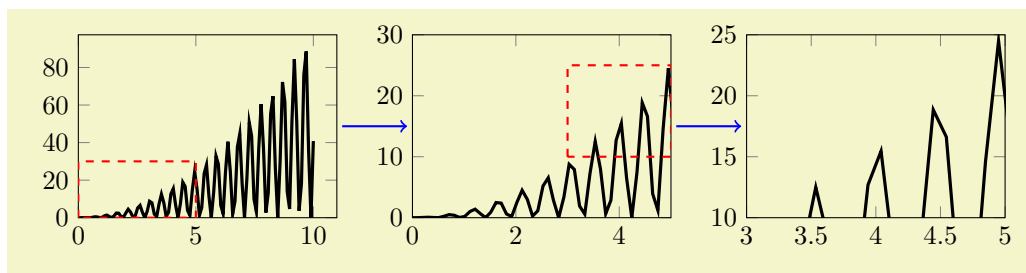
```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}\usepgfplotslibrary{groupplots}
\begin{tikzpicture}
  \begin{groupplot}[group style={group size=3 by 1},xmin=0,ymin=0,height=4cm,width=5cm,no markers]
    \nextgroupplot
    \addplot[very thick] file {plotdata/group-1.dat};
    \draw[red,dashed,thick] (0,0) rectangle (5,30);
    \nextgroupplot[xmax=5,ymax=30]
    \addplot[very thick] file {plotdata/group-1.dat};
    \draw[red,dashed,thick] (3,10) rectangle (5,25);
    \nextgroupplot[xmin=3,xmax=5,ymin=10,ymax=25]
    \addplot[very thick] file {plotdata/group-1.dat};
  \end{groupplot}
  \draw[thick,blue,->,shorten >=2pt,shorten <=2pt]
        (group c1r1.east) -- (group c2r1.west);
  \draw[thick,blue,->,shorten >=2pt,shorten <=2pt]
        (group c2r1.east) -- (group c3r1.west);
\end{tikzpicture}
```

5.8.1 Grouping options

/pgfplots/**group style**={⟨*options with* group/ *prefix*⟩}

 This key sets all ⟨*options*⟩ using the /pgfplots/group/ prefix.

 Note that the distinction between group/ and normal options is important as some of them are quite similar.

 For example, the following statements are all equivalent:

```
\pgfplotsset{group style={a=2,b=3}}
\pgfplotsset{group/a=2,group/b=3}
\pgfplotsset{group/.cd,a=2,b=3}
```

All the following keys are in the subdirectory group.

/pgfplots/**group/group size**=⟨*columns*⟩ by ⟨*rows*⟩	(initially 1 by 1)
/pgfplots/**group/columns**=⟨*columns*⟩	(initially 1)
/pgfplots/**group/rows**=⟨*rows*⟩	(initially 1)

 These keys determine the total number of plots that can be in one environment groupplot. It is thus important not to add more \nextgroupplot in the environment than ⟨*columns*⟩×⟨*rows*⟩. This is critical to set if one uses more than 1 more plot. As the key group size uses columns and rows you should stick to either group size or both columns and rows.

/pgfplots/**group/horizontal sep**=⟨*dimension*⟩	(initially 1cm)
/pgfplots/**group/vertical sep**=⟨*dimension*⟩	(initially 1cm)

 The spacing between the plots in the horizontal and vertical direction, respectively. If you thus want them to be *glued* together you should set them both to a length of 0pt.

/pgfplots/**group/every plot**/.style={⟨*style*⟩} (initially empty)

 This style is used on every plot as the first style. It is thus equivalent as ⟨*options*⟩ in the groupplot environment.

/pgfplots/**group/xlabels at**=all|edge bottom|edge top	(initially all)
/pgfplots/**group/ylabels at**=all|edge left|edge right	(initially all)

 In order to determine which plots get labels typeset one can use these keys. By default all axes get typeset normally and thus have both x and y axis labels.
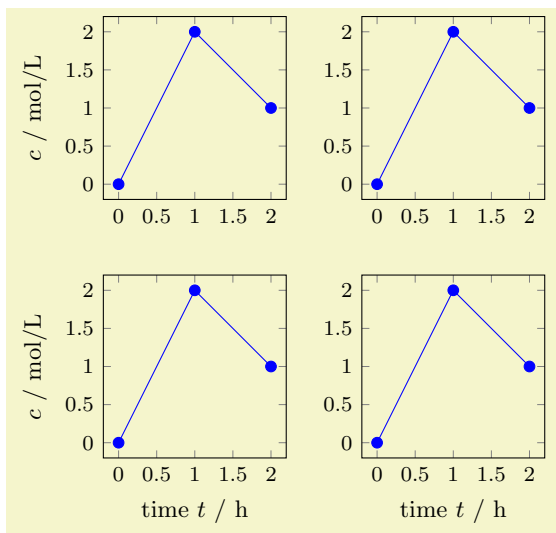
```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}\usepgfplotslibrary{groupplots}
\begin{tikzpicture}
    \begin{groupplot}[
        group style={
            group name=my plots,
            group size=2 by 2,
            xlabels at=edge bottom,
            ylabels at=edge left,
        },
        footnotesize,
        width=4cm,
        height=4cm,
        %
        xlabel=time $t$ / h,
        ylabel=$c$ / mol/L,
    ]
    \nextgroupplot
        \addplot coordinates{(0,0) (1,2) (2,1)};
    \nextgroupplot
        \addplot coordinates{(0,0) (1,2) (2,1)};
    \nextgroupplot
        \addplot coordinates{(0,0) (1,2) (2,1)};
    \nextgroupplot
        \addplot coordinates{(0,0) (1,2) (2,1)};
    \end{groupplot}
\end{tikzpicture}
```

In the example above, only the bottom row gets the label defined in the beginning `groupplot`-environment on the x axis and only the first column of plots gets labels on the y axis on their left side. These keys are especially handy when using *glued* plots.

/pgfplots/**group/xticklabels at**=all|edge top|edge bottom   (initially `all`)
/pgfplots/**group/yticklabels at**=all|edge left|edge right   (initially `all`)

In order to determine which plots get tick labels typeset one can use these keys. By default all axes gets typeset normally and thus have both x and y axis tick labels. If one sets

`\pgfplotsset{group/xticklabels at=edge bottom,group/yticklabels at=edge right}`

only the bottom row gets tick labels on the x axis and only the last column gets tick labels on the y axis on their right side. These keys are specially handy when using *glued* plots.

Keep in mind that this is implies the same ticks for all plots.

/pgfplots/**group/x descriptions at**=all|edge top|edge bottom   (initially `all`)
/pgfplots/**group/y descriptions at**=all|edge left|edge right   (initially `all`)

These are simply a short hand for using both `xticklabels at` and `xlabels at` simultaneously:
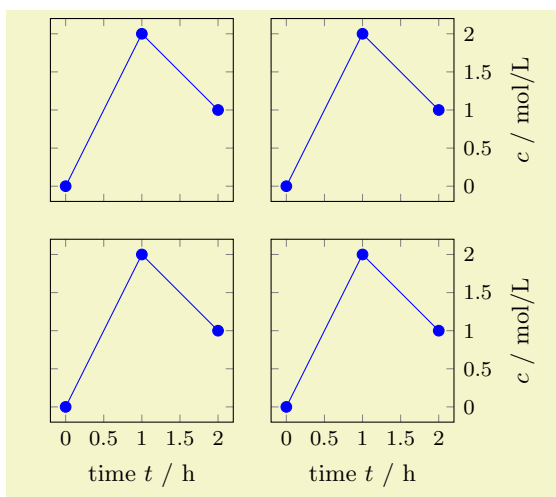
```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}\usepgfplotslibrary{groupplots}
\begin{tikzpicture}
    \begin{groupplot}[
        group style={
            group name=my plots,
            group size=2 by 2,
            %
            x descriptions at=edge bottom,
            y descriptions at=edge right,
            horizontal sep=0.5cm,
            vertical sep=0.5cm,
        },
        footnotesize,
        width=4cm,
        height=4cm,
        %
        xlabel=time $t$ / h,
        ylabel=$c$ / mol/L,
    ]
    \nextgroupplot
        \addplot coordinates{(0,0) (1,2) (2,1)};
    \nextgroupplot
        \addplot coordinates{(0,0) (1,2) (2,1)};
    \nextgroupplot
        \addplot coordinates{(0,0) (1,2) (2,1)};
    \nextgroupplot
        \addplot coordinates{(0,0) (1,2) (2,1)};
    \end{groupplot}
\end{tikzpicture}
```

Here, `x descriptions at`=edge `bottom` yields that x descriptions (`xlabel` and `xticklabel`) are only used for the lowest row. Furthermore, `y descriptions at`=edge `right` places y descriptions only for the rightmost column. Consider modifying the `horizontal sep` and `vertical sep` for your needs.

As for `xticklabels at`, usage of this key implies the same ticks for all plots.

This might *require* `compat`=1.3 (or newer).

/pgfplots/group/group name={⟨*name*⟩}   (initially `group`)

This sets what you can refer the plots to after typesetting. Thus you can use their anchors later. See the following example
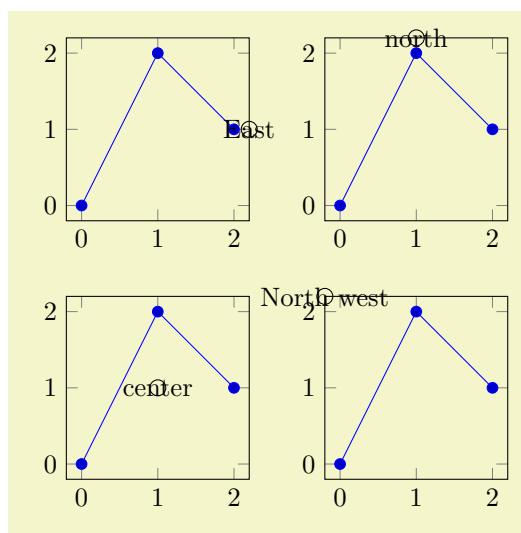

```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}\usepgfplotslibrary{groupplots}
\begin{tikzpicture}
  \begin{groupplot}[group style={
        group name=my plots,group size=2 by 2},
    width=4cm,height=4cm]
    \nextgroupplot
    \addplot coordinates{(0,0) (1,2) (2,1)};
    \nextgroupplot
    \addplot coordinates{(0,0) (1,2) (2,1)};
    \nextgroupplot
    \addplot coordinates{(0,0) (1,2) (2,1)};
    \nextgroupplot
    \addplot coordinates{(0,0) (1,2) (2,1)};
  \end{groupplot}
  \draw (my plots c1r1.east)
      circle (3pt) node {East};
  \draw (my plots c2r1.north)
      circle (3pt) node {north};
  \draw (my plots c1r2.center)
      circle (3pt) node {center};
  \draw (my plots c2r2.north west)
      circle (3pt) node {North west};
\end{tikzpicture}
```

/pgfplots/group/empty plot/.style={⟨*style*⟩}   (initially /pgfplots/hide axis)

This key can be used as an option to the command `\nextgroupplot`. This makes the next plot invisible (only the axes) but maintains it anchors and name. If you want it to behave in another style then you can redefine it. Consider the same example as before.

```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}\usepgfplotslibrary{groupplots}
\begin{tikzpicture}
  \begin{groupplot}[group style={
        group name=my plots,group size=2 by 2},
    width=4cm,height=4cm]
    \nextgroupplot[group/empty plot]
    \nextgroupplot
    \addplot coordinates{(0,0) (1,2) (2,1)};
    \nextgroupplot
    \addplot coordinates{(0,0) (1,2) (2,1)};
    \nextgroupplot
    \addplot coordinates{(0,0) (1,2) (2,1)};
  \end{groupplot}
  \draw (my plots c1r1.east)
      circle (3pt) node {East};
  \draw (my plots c2r1.north)
      circle (3pt) node {north};
  \draw (my plots c1r2.center)
      circle (3pt) node {center};
  \draw (my plots c2r2.north west)
      circle (3pt) node {North west};
\end{tikzpicture}
```

Notice that you need to call a `\nextgroupplot` againwards to jump to the next plot.

5.9   Patchplots Library

```
\usepgfplotslibrary{patchplots} % LaTeX and plain TeX
\usepgfplotslibrary[patchplots] % ConTeXt
\usetikzlibrary{pgfplots.patchplots} % LaTeX and plain TeX
\usetikzlibrary[pgfplots.patchplots] % ConTeXt
```

A library for advanced `patch` plots. Its strength is the creation of patches with smooth boundaries and smoothly shaded colors.

A `patch` plot is a plot in which each individual patch is available. Here, "available" means that the user provided each individual patch manually. This can be achieved by means of a long series of patches which have been concatenated in a suitable way (compare the description of `patch` plots in section 4.6.13) or by means of a mathematical expression which is sampled (compare the key `patch type sampling`). Most `patch type`s expect a series of point evaluations in a specific sequence.

Note that even though each individual patch might have a smooth boundary, the `patchplots` library *does not interpolate smoothly between adjacent patches.* Consequently, it is task of the one who creates the patches (which means: evaluated some function at its vertices) to ensure that patches can be glued together in an adequate way. This allows a lot of freedom, including both jumps and smoothly concatenated edges.

The `patchplots` library comes with a couple of inherently two–dimensional `patch type`s (including second order triangles/rectangular patches and cubic tensor product patches known for finite elements). Typically, these patches live in a three–dimensional axis. Often, they are used to visualize the surface of function values $f(x, y)$. The `patchplots` library ensures that such patches are drawn in a way which respects the current view. In particular, if a patch folds over itsself (which is possible), it is drawn such that foreground areas are in the foreground and background areas are in the background.

The `patchplots` library comes with smoothly shaded patches. More precisely, both the boundary of patches and their color shading are smooth. Note, however, that the patch boundary typically has much more smoothness than the color shading.

The `patchplots` library also allows automatic conversion from a higher–order patch to triangles (triangulation) by means of the key `patch to triangles`. Furthermore, it features automatic `patch refines`.

Use the `patchplots` library if you want to have smooth boundaries for your patches, or if you need advanced shadings, or if you want polygon plots, or if you want more freedom in one–dimensional patches.

5.9.1 Additional Patch Types

/pgfplots/patch type=default|rectangle|triangle|line|quadratic spline|cubic spline|
        bilinear|triangle quadr|biquadratic|bicubic|polygon|coons|tensor bezier   (initially
        default)

The patchplots library supports several new patch types in addition to the initially available
choices (which are rectangle,triangle and line). The documentation of the two–dimensional
choices from page 179 is repeated here.

The new patch types are discussed in detail on the following pages.

One–Dimensional Patch Types

There are two new one–dimensional patch types, namely quadratic spline and cubic spline. Here,
patch type=quadratic spline consists of quadratic patches of $n = 3$ vertices each. The vertices are
interpolated exactly:
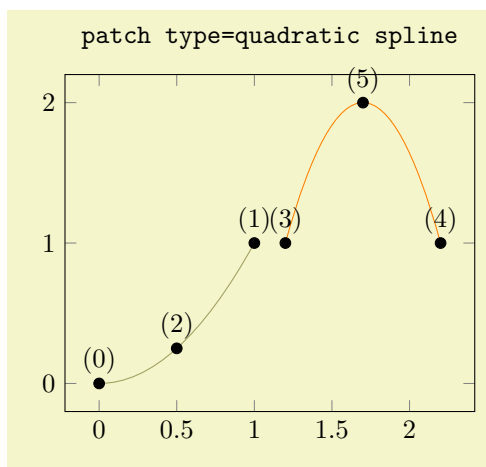
```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}\usepgfplotslibrary{patchplots}
\begin{tikzpicture}
\begin{axis}[nodes near coords={(\coordindex)},
    title={\texttt{patch type=quadratic spline}}]
\addplot[
    mark=*,
    patch,
    patch type=quadratic spline]
coordinates {
    % left, right, middle-> first segment
    (0,0) (1,1) (0.5,0.5^2)
    % left, right, middle-> second segment
    (1.2,1) (2.2,1) (1.7,2)
};
\end{axis}
\end{tikzpicture}
```

In our example, the first segment interpolates $f(x) = x^2$ at the points $\{0, 1/2, 1\}$. The quadratic spline
is actually nothing but piecewise Lagrangian interpolation with quadratic polynomials: it expects three
points in the sequence '(left end), (right end), (middle)' and interpolates these three points with a
quadratic polynomial. Unlike the default 1d mesh visualization (which uses patch type=line implic-
itly), you have to use the special syntax above (or the equivalent approach by means of patch table).
Note that patch type=quadratic spline results in correct shapes, but uses *just constant color* for
each segment; high–order color shading is only supported approximately using patch refines.

The patch type=cubic spline is very similar: it expects patches of $n = 4$ vertices and interpolates
them with a cubic polynomial:
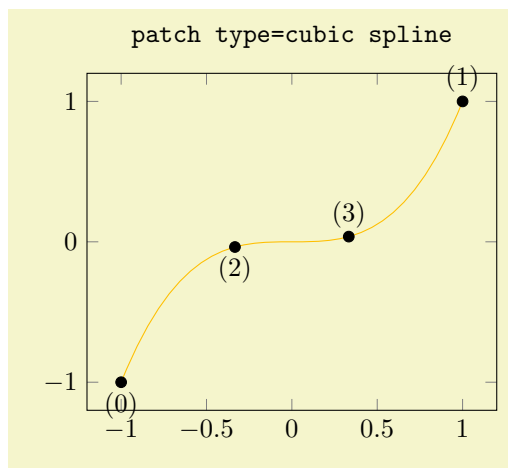
```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}\usepgfplotslibrary{patchplots}
\begin{tikzpicture}
\begin{axis}[nodes near coords={(\coordindex)},
    title={\texttt{patch type=cubic spline}}]
\addplot[
    mark=*,
    patch,
    patch type=cubic spline]
coordinates {
    % left, right, left middle, right middle
    (-1,-1)
    (1,1)
    (-1/3,{(-1/3)^3})
    (1/3,{(1/3)^3})
};
\end{axis}
\end{tikzpicture}
```

Here, we interpolated $f(x) = x^3$ at the four equidistant points $\{-1, -1/3, 1/3, 1\}$ with a cubic polynomial
(which is x^3). The cubic spline expects a sequence of patches, each with four coordinates, given in

the sequence '(left end), (right end), (interpolation point at $^1/_3$), (interpolation point at $^2/_3$)'. It has limitations and features like quadratic spline, see above.

Providing Patches by means of Mathematical Expressions

Most patch types expect a specific number of vertices in a specific sequence. This is part of what the patchplots library is. But is is still tedious to provide this sort of data.

For simple patch types like line, rectangle and bilinear, you can provide the input coordinates with any of the input methods which are available for all other plot handlers. In particular, line is just a sharp plot (with individually colored segments) and rectangle is nothing but a surf plot. Note that both rectangle and bilinear also accept the standard matrix input (with scanlines, see mesh/ordering and its documentation). In summary: *simple patch types accept a simple input format*.

/pgfplots/patch type sampling=true|false   (initially false)

There are some complicated patch types. In particular, all patch types of higher order (i.e. quadratic spline, cubic spline, triangle quadr, biquadratic, bicubic) need more points than just their corners. For such patch types, you need to resort to mesh input=patches. That means you need to provide extra vertices and their function evaluation values in a specific sequence.

The patch type sampling method allows to simplify the procedure for such complicated patch types[12]: it works together with \addplot expression and evaluates the mathematical expression at each of the required vertices (in the correct sequence):
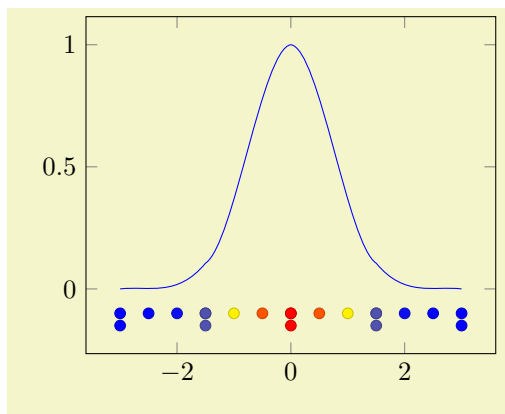

```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}\usepgfplotslibrary{patchplots}
\begin{tikzpicture}
  \begin{axis}
  \addplot[
    samples=5,domain=-3:3,
      mesh,patch type=cubic spline,
      patch type sampling,
    % avoid individual colors per segment:
      blue,point meta=none,
  ]
      {exp(-x^2)};

  % a second plot which shows the
  % generated x positions:
  \addplot[
    mark=*,only marks,scatter,
    samples=5,domain=-3:3,
      patch type=cubic spline,
      patch type sampling,
      point meta={exp(-x^2)},
  ]
      {-0.1};

  % a third plot which shows the marks
  % without patch type sampling:
  \addplot[
    mark=*,only marks,scatter,
    samples=5,domain=-3:3,
      point meta={exp(-x^2)},
  ]
      {-0.15};

  \end{axis}
\end{tikzpicture}
```

The first plot above is almost a normal plot by expression. The samples and domain key controls the sampling procedure, and blue,point meta=none defines the global color to use. Note that the special choice point meta=none simply disables individual colors per mesh segment (which is the default for mesh plots). However, the patch type sampling key here makes a huge difference: it tells PGFPLOTS to check the current value of patch type and to sample a coordinate sequence which is suitable as input for that patch type. We see that the outcome is a partially smooth function (more about that below).

---

[12]Note that patch type sampling is more or less useless for simple patch types.

The method `patch type sampling` samples x just as usual. The result is a sequence $[x_0, x_1, \ldots, x_k]$. For each interval $[x_i, x_{i+1}]$, a `patch type` is sampled inside of the interval. To this end, the current `patch type` is used to generate a standardized vertex pattern in the unit cube. For `patch type`=cubic spline, this generates four points $0, 1/3, 2/3, 1$. These standardized numbers are mapped into $[x_i, x_{i+1}]$. Then, any mathematical expressions (in our case `exp(-x^2)`) are evaluated at the resulting positions.

The second plot in our example above shows the `mark`ers resulting from `patch type sampling`. Note that we see 13 markers even though we have said `samples`=5. These 5 samples are shown in the third plot. This is because `patch type`=cubic spline needs 4 points for each patch (i.e. 4 points in each sampled interval).

Note that even though the result in our example above is *partially* smooth, it is *not* globally smooth. In other words: each resulting mesh segment is a polynomial of third order. But: the five cubic polynomials are determined independently; and they are simple glued together without any intelligence. In particular, they are *unsmooth* at the five initial sampling points! This key cannot apply global smoothing. It is really just a convenient method which simplifies sampling of such patch types.

The method `patch type sampling` can also be used for `surf` plots, i.e. for matrix sampling. It works in the same way:
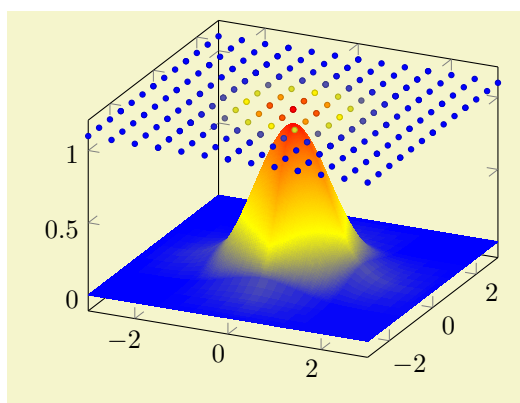

```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}\usepgfplotslibrary{patchplots}
\begin{tikzpicture}
\begin{axis}
    \addplot3[surf,shader=interp,
        patch type=bicubic,
        patch type sampling,
        samples=5,domain=-3:3]
    {exp(-x^2-y^2)};

  % show the generated grid on top:
  \addplot3[
    mark=*,mark size=1pt,only marks,scatter,
    samples=5,domain=-3:3,
      patch type=bicubic,
      patch type sampling,
      point meta={exp(-x^2-y^2)},
  ]
  {1.1};
\end{axis}
\end{tikzpicture}
```

The example is similar to our one–dimensional example above: it uses the same 1d function as product. We see that it has 13^2 samples instead of just 5^2, and we see that the geometry is partially smooth (see above for "partially"). Note, however, that the color interpolation is only applied once per patch. The following example shows a `bilinear` patch with unsmooth geometry, but higher resolution for the color data, on a 13×13 mesh:
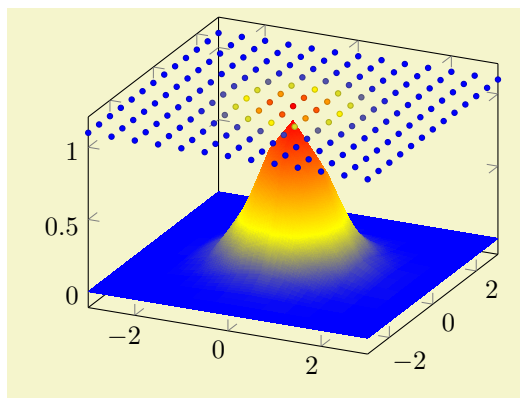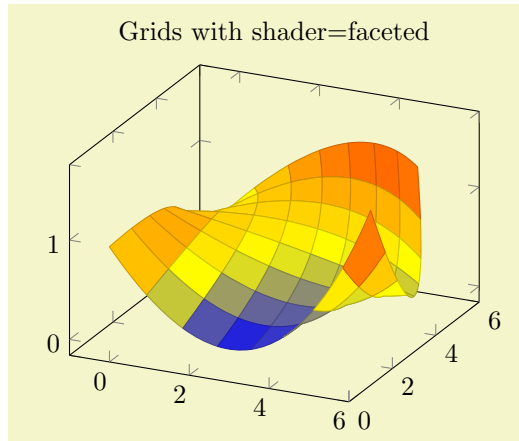


```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}\usepgfplotslibrary{patchplots}
\begin{tikzpicture}
\begin{axis}
    \addplot3[surf,shader=interp,
        patch type=bilinear,
        samples=13,domain=-3:3]
    {exp(-x^2-y^2)};

  % show the generated grid on top:
  \addplot3[
    mark=*,mark size=1pt,only marks,scatter,
    samples=13,domain=-3:3,
      point meta={exp(-x^2-y^2)},
  ]
  {1.1};
\end{axis}
\end{tikzpicture}
```

Note that you may want to view the preceding examples in Acrobat Reader. Many free pdf viewers cannot display these shadings properly.

Global One–Dimensional Curves with Smooth Splines

Typically, PGFPLOTS assumes that you want individually colored patch segments whenever you use one of the plot handlers mesh, surf, or patch. The individual colors are determined by the current colormap and the value of point meta (compare section 4.8).

Technically, individually colored path segments are one unit. If you fill them, you fill only one segment. You cannot fill them against the axis. In particular, you cannot use \closedcycle for individually colored mesh or patch plots.

The patchplots library comes with one–dimensional patch types like quadratic spline or cubic spline. It would be useful to draw a global path, that is: one which has a single color such that \closedcycle works. This is supported if you write point meta=none:



```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}\usepgfplotslibrary{patchplots}
\begin{tikzpicture}
\begin{axis}[
    axis lines=middle,
    axis on top,
    enlargelimits,
    title={Global path with
        \texttt{cubic spline}}]
\addplot[
    mark=*,
    patch,
    patch type=cubic spline,
    point meta=none,% allow \closedcycle
    blue,
    fill=blue!60!black,
]
table {
    % left, right, left middle, right middle
    -1          -1
    1           1
    -0.333333    -0.037037
    0.333333    +0.037037

    1           1
    2           -0.5
    1.333333    1.5
    1.666666    1
}
\closedcycle;
\end{axis}
\end{tikzpicture}
```
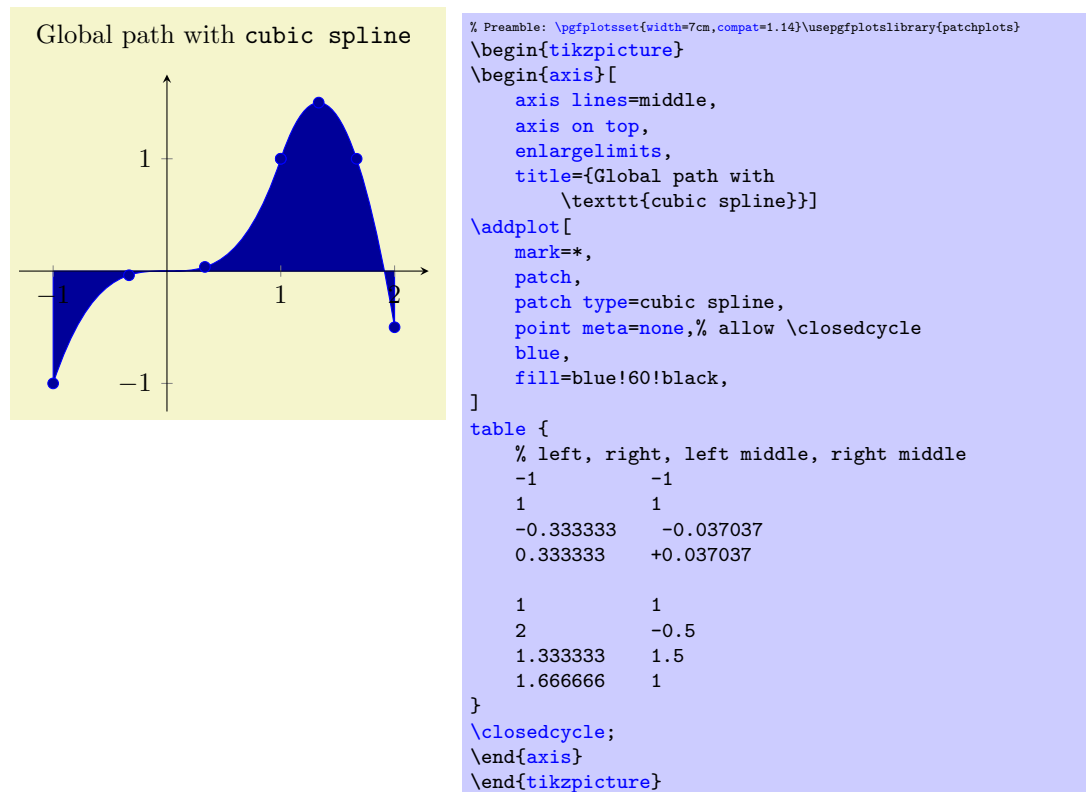
The use of point meta=none activates a special processing: the outcome is precisely one path.

Two–Dimensional Patch Types

The patchplots library is especially strong for shader=interp, so this is our main focus in the remaining documentation here.

Attention: At the time of this writing, many free pdf viewers do not fully support the following shadings[13]. The preferred viewer is Adobe Acrobat Reader.

The choice rectangle expects one or more rectangular patches with $n = 4$ vertices each. These vertices are either encoded as a matrix or as individual patches (using mesh input=patches), in the sequence in which you would connect the vertices:

---

[13]The author of this package has submitted bugfixes to Linux viewers based on xpdf/libpoppler, so the problem will (hopefully) vanish in future versions.
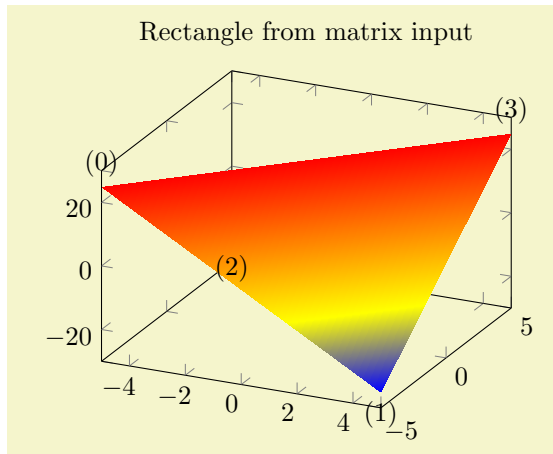
Rectangle from matrix input

```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}\usepgfplotslibrary{patchplots}
\begin{tikzpicture}
\begin{axis}[nodes near coords={(\coordindex)},
    title=Rectangle from matrix input]

% note that surf implies 'patch type=rectangle'
\addplot3[surf,shader=interp,samples=2,
    patch type=rectangle]
    {x*y};
\end{axis}
\end{tikzpicture}
```
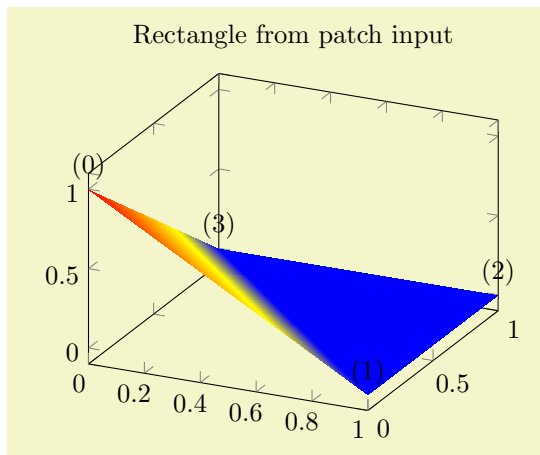

Rectangle from patch input

```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}\usepgfplotslibrary{patchplots}
\begin{tikzpicture}
\begin{axis}[nodes near coords={(\coordindex)},
    title=Rectangle from patch input]

\addplot3[patch,shader=interp,patch
type=rectangle] coordinates {
    (0,0,1) (1,0,0) (1,1,0) (0,1,0)
};
\end{axis}
\end{tikzpicture}
```

As already documented on page 179, the shader=interp implementation for rectangle uses two triangles and interpolates them linearly. The differences between the two examples above arise due to z buffering approaches: the matrix input reorders the matrix in linear time, whereas the second example would sort complete rectangles. In our case, this yields to the different corner sequence.

The choice bilinear is essentially the same as rectangular with respect to its input formats and stroke paths, but it uses correct bilinear shading for shader=interp. Moreover, the geometry is also interpolated bilinearly instead of just two triangles. The two examples from above now become
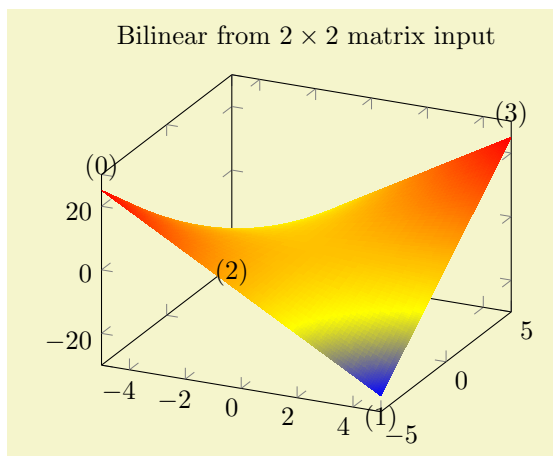
Bilinear from 2×2 matrix input

```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}\usepgfplotslibrary{patchplots}
\begin{tikzpicture}
\begin{axis}[nodes near coords={(\coordindex)},
    title=Bilinear from $2\times 2$ matrix input]

% note that surf implies 'patch type=rectangle'
\addplot3[surf,shader=interp,samples=2,
    patch type=bilinear]
    {x*y};
\end{axis}
\end{tikzpicture}
```
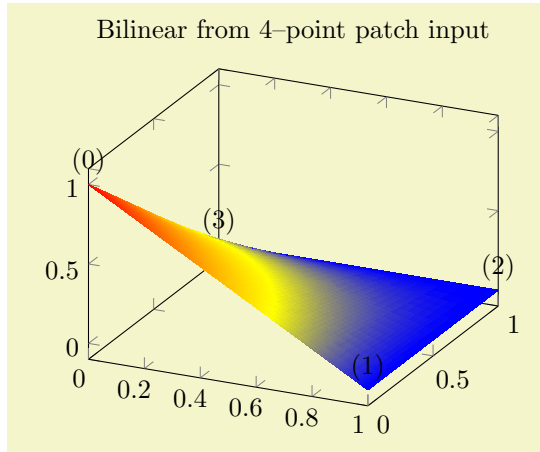
```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}\usepgfplotslibrary{patchplots}
\begin{tikzpicture}
\begin{axis}[nodes near coords={(\coordindex)},
    title=Bilinear from $4$--point patch input]

\addplot3[patch,shader=interp,patch type=bilinear]
coordinates {
    (0,0,1) (1,0,0) (1,1,0) (0,1,0)
};
\end{axis}
\end{tikzpicture}
```

Use `patch type=bilinear` if you want to improve the shape of individual patches and the quality of the color interpolation. In contrast to the simpler `patch type=rectangle`, it might result in a huger output document.

The choice `triangle` expects a sequence of linear triangles, each encoded using $n = 3$ vertices:
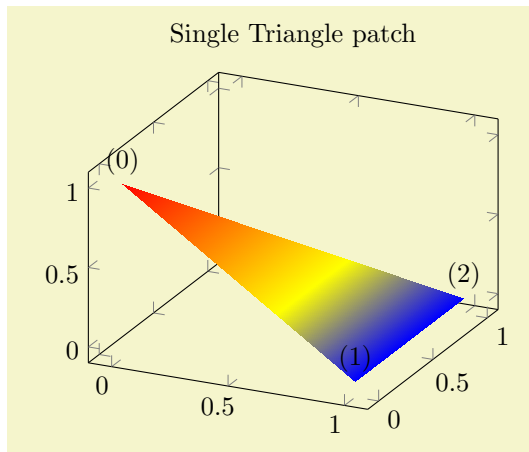

```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}\usepgfplotslibrary{patchplots}
\begin{tikzpicture}
\begin{axis}[enlargelimits,
    nodes near coords={(\coordindex)},
    title=Single Triangle patch]

\addplot3[patch,shader=interp] coordinates {
    (0,0,1)
    (1,0,0)
    (1,1,0)
};
\end{axis}
\end{tikzpicture}
```

The choice `triangle quadr` expects a sequence of isoparametric quadratic triangles, each defined by $n = 6$ vertices:
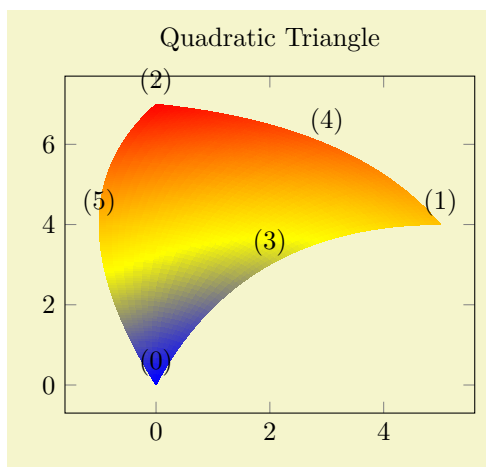

```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}\usepgfplotslibrary{patchplots}
\begin{tikzpicture}
\begin{axis}[nodes near coords={(\coordindex)},
    title=Quadratic Triangle]

\addplot[patch,patch type=triangle quadr,
    shader=interp,point meta=explicit]
coordinates {
    (0,0) [1] (5,4) [2] (0,7) [3]
    (2,3) [1] (3,6) [2] (-1,4)  [3]
};
\end{axis}
\end{tikzpicture}
```
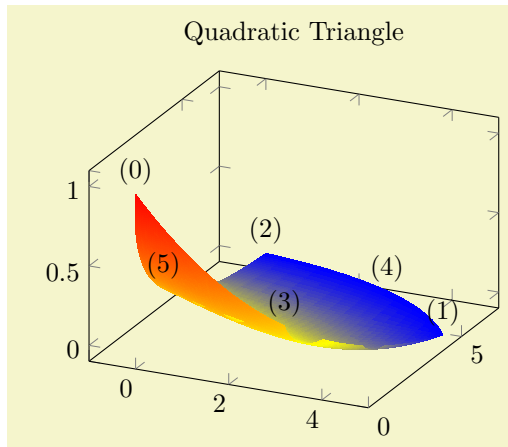
```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}\usepgfplotslibrary{patchplots}
\begin{tikzpicture}
\begin{axis}[nodes near coords={(\coordindex)},
    title=Quadratic Triangle]

\addplot3[patch,patch type=triangle quadr,
    shader=interp]
coordinates {
    (0,0,1) (5,4,0) (0,7,0)
    (2,3,0) (3,6,0) (-1,4,0)
};
\end{axis}
\end{tikzpicture}
```

Here, the edges have the correct quadratic shape. However, the color interpolation is just *bilinear*; using the color values of the corners and ignoring the rest (consider using `patch refines` to improve the color interpolation). For three dimensions, PGFPLOTS checks the depth of corners to determine foreground/background. For two dimensions, strongly distorted elements may fold over each other in unexpected ways.

The choice `biquadratic` expects a sequence of isoparametric biquadratic quadrilaterals each defined by $n = 9$ vertices. Their main use is to get "rectangles" with smooth boundaries:
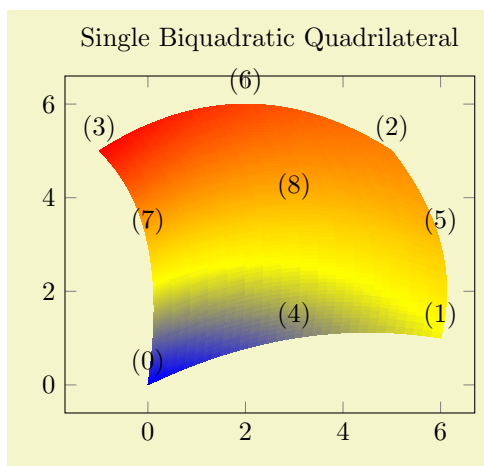

```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}\usepgfplotslibrary{patchplots}
\begin{tikzpicture}
\begin{axis}[nodes near coords={(\coordindex)},
    title=Single Biquadratic Quadrilateral]

\addplot[patch,patch type=biquadratic,
    shader=interp,point meta=explicit]
coordinates {
    (0,0) [1] (6,1) [2] (5,5) [3] (-1,5) [4]
    (3,1) [1] (6,3) [2] (2,6) [3] (0,3) [4]
    (3,3.75) [4]
};
\end{axis}
\end{tikzpicture}
```
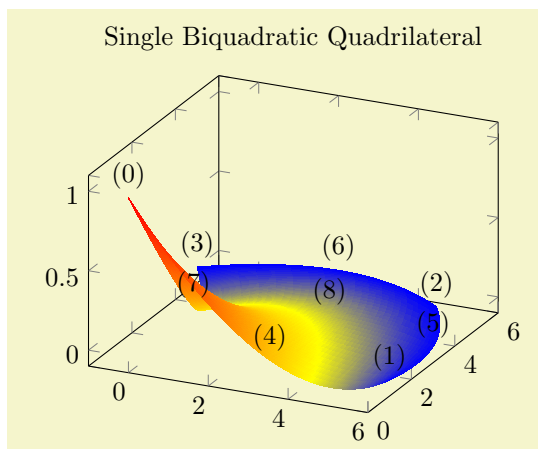


```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}\usepgfplotslibrary{patchplots}
\begin{tikzpicture}
\begin{axis}[nodes near coords={(\coordindex)},
    title=Single Biquadratic Quadrilateral]

\addplot3[patch,patch type=biquadratic,shader=interp]
coordinates {
    (0,0,1) (6,1,0) (5,5,0) (-1,5,0)
    (3,1,0) (6,3,0) (2,6,0) (0,3,0)
    (3,3.75,0)
};
\end{axis}
\end{tikzpicture}
```

Similar to `triangle quadr`, the edges have the correct quadratic shape – but the color interpolation is just *bilinear*; using the color values of the corners and ignoring the rest. Again, ensure that the mesh width is small enough in order to improve the quality of the color interpolation (see also `patch refines`).

Note that a function of (x, y) is biquadratic if it is quadratic w.r.t. x if $y = $ const and also quadratic w.r.t. y if $x = $ const (note that this is not an "if and only if"). For example, $f(x, y) = x^2 - y^2$ is biquadratic. Consequently, we can represent a surface plot of f with just one biquadratic patch – only the color interpolation is just bilinear. We do so using \addplot table[z expr=⟨*expression*⟩]:
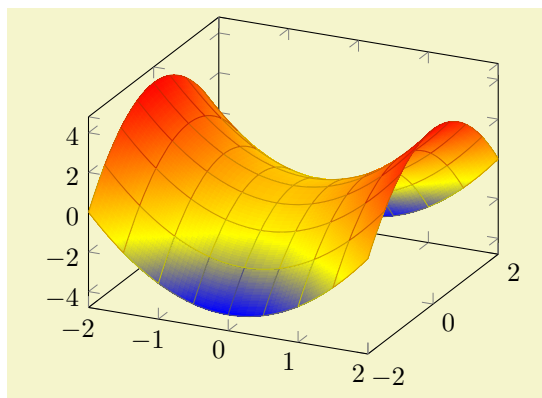
```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}\usepgfplotslibrary{patchplots}
\begin{tikzpicture}
    \begin{axis}
    \addplot3[patch,patch refines=3,
        shader=faceted interp,
        patch type=biquadratic]
    table[z expr=x^2-y^2]
    {
        x   y
        -2 -2
        2  -2
        2   2
        -2  2
        0  -2
        2   0
        0   2
        -2  0
        0   0
    };
    \end{axis}
\end{tikzpicture}
```

We see that the shape's boundary is reconstructed exactly using the `biquadratic` patch. In addition, `patch refines` improves the (first order) color interpolation. Details for `patch refines` are discussed in Section 5.9.2 and details and limitations regarding superimposed grid lines are discussed in Section 5.9.4.

Note that `biquadratic` can easily be combined with `patch type sampling` in order to sample an arbitrary `surf`ace plot with smooth boundaries.

A patch with type `biquadratic` and `shader`=`interp` has a bounding box which is determined from the input vertices. Due to the high order of the patch, parts of the patch can be outside of that bounding box. This holds for all advanced patch types.

The choice `bicubic` is similar to `biquadratic`: it allows to defines two–dimensional patches whose boundary is defined by four cubic polynomials. Consequently, it allows very smooth boundaries – especially since the viewer constructs these boundaries at every zoom level. A `bicubic` patch is constructed from 16 points which are arranged in a 4×4 matrix. Each consecutive 16 points make up a single `bicubic` patch. The 17th point starts the next `bicubic` patch (just as for any other `patch type`).
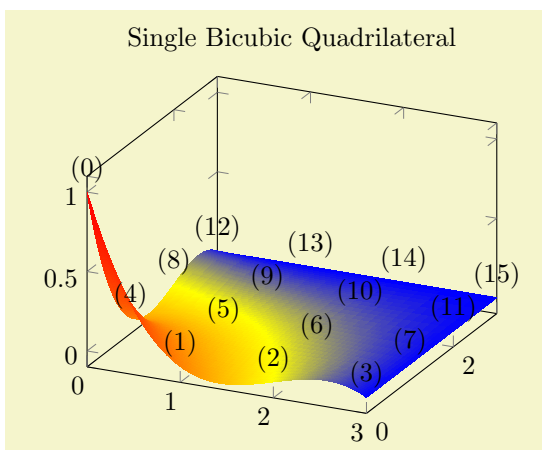
```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}\usepgfplotslibrary{patchplots}
\begin{tikzpicture}
\begin{axis}[nodes near coords={(\coordindex)},
    title=Single Bicubic Quadrilateral]
\addplot3[patch,patch type=bicubic,shader=interp]
coordinates {
    (0,0,1) (1,0,0) (2,0,0) (3,0,0)
    (0,1,0) (1,1,0) (2,1,0) (3,1,0)
    (0,2,0) (1,2,0) (2,2,0) (3,2,0)
    (0,3,0) (1,3,0) (2,3,0) (3,3,0)
};
\end{axis}
\end{tikzpicture}
```

Just as for `biquadratic`, the color interpolation of `bicubic` is (just) bilinear, even though the geometry is of higher order. The color interpolation uses the `point meta` values determined at the four corners of each patch; all other values of `point meta` are ignored by the shader (although their values are used to compute `point meta min` and `point meta max`).
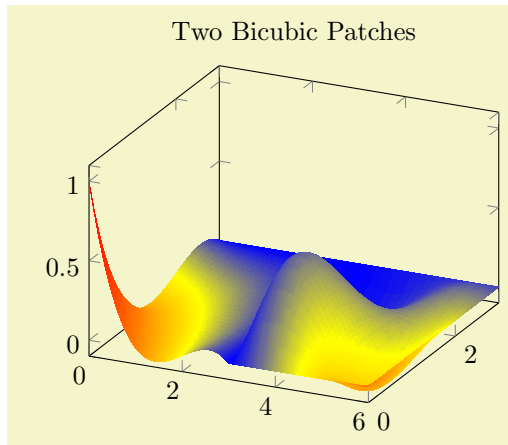
```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}\usepgfplotslibrary{patchplots}
\begin{tikzpicture}
\begin{axis}[
    title=Two Bicubic Patches]
\addplot3[patch,patch type=bicubic,
    shader=interp,point meta=explicit]
coordinates {
    (0,0,1)[1] (1,0,0)[0]  (2,0,0)[0]  (3,0,0)[0]
    (0,1,0)[0] (1,1,0)[0]  (2,1,0)[0]  (3,1,0)[0]
    (0,2,0)[0] (1,2,0)[0]  (2,2,0)[0]  (3,2,0)[0]
    (0,3,0)[0] (1,3,0)[0]  (2,3,0)[0]  (3,3,0)[0]

    (3,0,0)[0] (4,0,0)[0]  (5,0,0)[0]  (6,0,0)[0.7]
    (3,1,0)[0] (4,1,.5)[1](5,1,0)[0]  (6,1,0)[0]
    (3,2,0)[0] (4,2,0)[0]  (5,2,0)[0]  (6,2,0)[0]
    (3,3,0)[0] (4,3,0)[0]  (5,3,0)[0]  (6,3,0)[0.1]
};
\end{axis}
\end{tikzpicture}
```

The previous example uses two patches of type `bicubic`. Note that the color data (`point meta`) has been provided explicitly – and its values are only used at the corners (the `[1]` value after the point `(4,1,.5)` is ignored). Color interpolation of `bicubic` patches uses only the color data at the patch's corners. The remaining color data values are ignored. Note that if you leave the default (which is `point meta=f(x)` instead of `point meta=explicit`), the second patch will be blue. This is because the four corner vertices of the second patch define the color shading – and their z value is 0.

Note that `bicubic` can easily be combined with `patch type sampling` in order to sample an arbitrary `surf`ace plot with smooth boundaries.

Just as described for `biquadratic`, a patch with type `bicubic` and `shader=interp` can have a bounding box which is slightly smaller than the region which is actually drawn (because the bounding box is computed from the input points).

The choice `coons` expects a sequence of one or more Coons patches, made up of $n = 12$ points each. A Coons patch is delimited by four cubic Bézier curves, with the end points attached to each other – and the n points provide the required control points for these curves in a specific ordering which is illustrated in the following example:
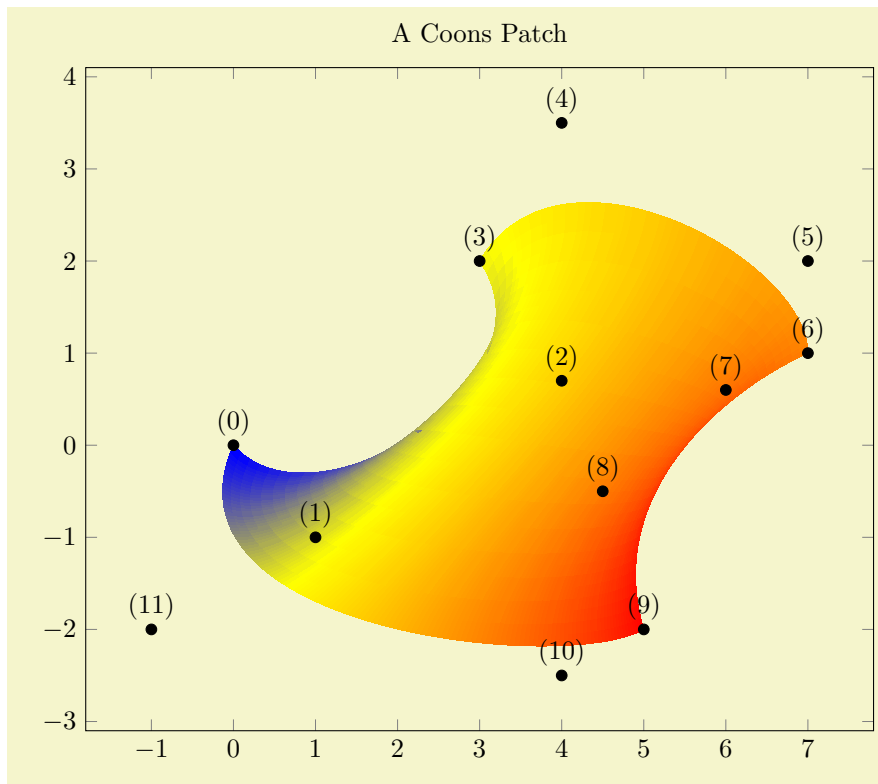
```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}\usepgfplotslibrary{patchplots}
\begin{tikzpicture}
\begin{axis}[nodes near coords={(\coordindex)},
    width=12cm,
    title=A Coons Patch]
\addplot[mark=*,patch,patch type=coons,
    shader=interp,point meta=explicit]
coordinates {
    (0,0)    [0] % first corner
    (1,-1)   [0] % Bezier control point between (0) and (3)
    (4,0.7)  [0] % Bezier control point between (0) and (3)
    %
    (3,2)    [1] % second corner
    (4,3.5)  [1] % Bezier control point between (3) and (6)
    (7,2)    [1] % Bezier control point between (3) and (6)
    %
    (7,1)       [2] % third corner
    (6,0.6)     [2] % Bezier control point between (6) and (9)
    (4.5,-0.5)  [2] % Bezier control point between (6) and (9)
    %
    (5,-2)    [3] % fourth corner
    (4,-2.5)  [3] % Bezier control point between (9) and (0)
    (-1,-2)   [3] % Bezier control point between (9) and (0)
};
\end{axis}
\end{tikzpicture}
```

The four cubic Bézier curves are *equivalent* to `curveto` paths of PGF, i.e. to a sequence of the form $(\langle corner\ 1\rangle)$.. `controls`$(\langle control\ point\ A\rangle)$ and $(\langle control\ point\ B\rangle)$ .. $(\langle corner\ 2\rangle)$. The interpolated shading is bilinear. More precisely, a bilinear shading in the unit cube $[0,1]^2$ is initialised which is then mapped into the Coons patch such that the corners match. The color interpolation uses only the color data of the four corners, color values of intermediate control points are ignored for the shading (although their value will be respected for the upper and lower limit of color data). In contrast to the finite element patches, a Coons patch is inherently two–dimensional. While you can still use three–dimensional coordinates, PGFPLOTS will draw the shading as you provide it, without checking for the depth information (as it does for the other `patch type`s). In other words: depending on the current `view` angle, the shading might fold over itself in unexpected ways.

Even for two dimensions, Coons patches may fold over themselves. To determine which part is foreground and which part is background, the following rule applies: the four corner points (0), (3), (6), (9) are associated to the unit cube points $(u,v) = (0,0)$, $(0,1)$, $(1,1)$ and $(1,0)$, respectively. The edge between corner (3) and (6) (i.e. the one with $v = 1$) is foreground, the edge between (1) and (9) is background. Thus, large values of v are drawn on top of small values of v. If v is constant, large values of u are drawn on top of small values of u. Thus, reordering the patch vertices (choosing a different first vertex and/or reversing the sequence) allows to get different foreground/background configurations[14].

Note that `patch type sampling` is unavailable for `patch type`=`coons` because the control points are no point evaluation of the same function.

The choice `tensor bezier` is similar to `patch type`=`coons`: it allows to define a bezier patch. However, it allows more freedom: it has 16 control points instead of the 12 of a `coons` patch. The four additional control points are situated in the center of each patch. This `patch type` generates `.pdf` shadings of type 7 (whereas `coons` patches are shadings of type 6). It has been added for reasons of completeness, although it has not been tested properly. Please refer to the specification of the `.pdf` format for details[15]. The choice `tensor bezier` is actually *the same* as `patch type`=`bicubic` – except that `bicubic` automatically respects the view depth (foreground/background) and is given in a different by means of function evaluations rather than control points.

Note that `patch type sampling` is unavailable for `patch type`=`tensor bezier` because the control points are no point evaluation of the same function.

The choice `polygon` expects polygons with a fixed number of vertices. This `patch type` requires the number of vertices as argument:

/pgfplots/`vertex count`=$\langle count\rangle$

---

[14]Internally, PGFPLOTS employs such mechanisms to map the higher order isoparametric patch types to Coons patches, sorting according to their corner's depth information.

[15]If someone is willing to test it and document it, feel free to email me!

The number of vertices to be used for `patch type`=`polygon`. The number can be arbitrary. All input patches are expected to have this many vertices – but it is acceptable if a patch uses the same vertex multiple times. This means that `patch type`=`polygon` accepts polygons with different numbers of vertices, but you need to apply some sort of "manual padding".

This parameter is (currently) mandatory.

A `patch` plot with `patch type`=`polygon` simply connects the n=`vertex count` vertices in their order of appearance and closes the resulting path:
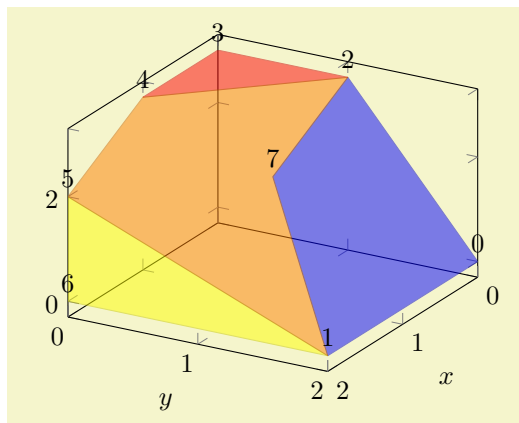
```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}\usepgfplotslibrary{patchplots}
\begin{tikzpicture}
    \begin{axis}[view/h=120,xlabel=$x$,ylabel=$y$]
    \addplot3[
        opacity=0.5,
        table/row sep=\\,
        patch,
        patch type=polygon,
        vertex count=5,
        patch table with point meta={%
            % pt1 pt2 pt3 pt4 pt5 cdata
            0 1 7 2 2 0\\
            1 6 5 5 5 1\\
            1 5 4 2 7 2\\
            2 4 3 3 3 3\\
    }]
    table {
        x y z\\
        0 2 0\\%0
        2 2 0\\%1
        0 1 3\\%2
        0 0 3\\%3
        1 0 3\\%4
        2 0 2\\%5
        2 0 0\\%6
        1 1 2\\%7
    };
% replicate the vertex list to show \coordindex:
\addplot3[only marks,nodes near coords=\coordindex]
table[row sep=\\] {
0 2 0\\ 2 2 0\\ 0 1 3\\ 0 0 3\\
1 0 3\\ 2 0 2\\ 2 0 0\\ 1 1 2\\
};
    \end{axis}
\end{tikzpicture}
```

The example above defines the `patch` by means of a connectivity table (`patch table with point meta`) and a vertex list (the normal input coordinates of the plot): there are 8 vertices and 4 polygons. Note that 2 of these polygons are triangles, one has 4 corners and only of them actually has all 5 allocated corners. This effect can be achieved by replicating one of the corners. The connectivity table in our example defines a unique color for each polygon: 0 for the first patch, 1 for the second, 2 for the third, and 3 for the last. These numbers map into the current `colormap`.

The `patch type`=`polygon` supports *neither* triangulation *nor* shading *nor* refinement. The order of appearance of the input points is supposed to be the order in which the line–to operations of the resulting path are generated.

5.9.2   Automatic Patch Refinement and Triangulation

PGFPLOTS supports automatic patch refinement for most of its `patch type`s. There are mainly two purposes for patch refinement: to increase the quality of `z buffer`=`sort` and/or to improve color interpolation for high–order patches.

/pgfplots/`patch refines`={⟨*levels*⟩}   (initially 0)

This key controls patch refinement. The initial choice `patch refines`=0 disables refinement and visualizes elements as they have been found in input files.

A positive ⟨*levels*⟩ enables (recursive) patch refinement: each patch is refined individually.

The following example illustrates the `patch refines` feature for a `triangle quadr` shape function on an edge. Note that since PGFPLOTS uses only first order shading which is based on the corner points (0), (1) and (2), the specified shape function of `patch refines`=0 has constant color. Higher ⟨*levels*⟩ approximate the patch with increasing quality:
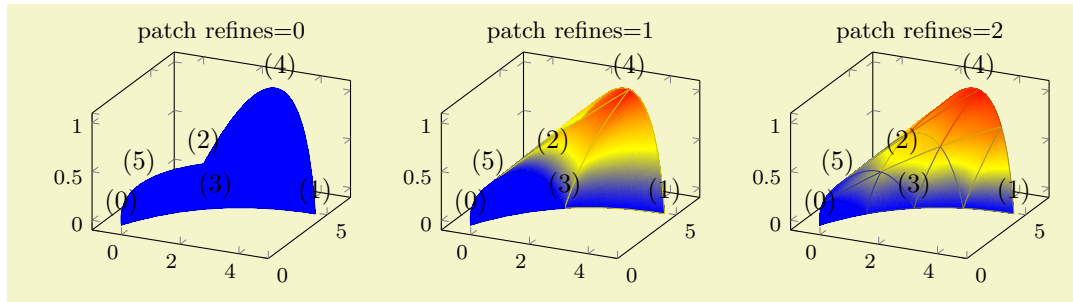

```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}\usepgfplotslibrary{patchplots}
\foreach \level in {0,1,2} {%
    \begin{tikzpicture}
    \begin{axis}[
        nodes near coords={(\coordindex)},
        footnotesize,
        title={patch refines=\level}]

    \addplot3[patch,patch type=triangle quadr,
        shader=faceted interp,patch refines=\level]
    coordinates {
        (0,0,0) (5,4,0) (0,7,0)
        (2,3,0) (3,6,1) (-1,4,0)
    };
    \end{axis}
    \end{tikzpicture}
}
```

In this example, patch refinement makes a huge difference since it is just one element with huge displacements. For practical examples, you probably won't need many refinement levels.

The refined patches reproduce the geometry's shape exactly. In addition, they improve color interpolation. Note that its purpose is just visualization, therefor hanging nodes are allowed (and will be generated by `patch refine` for most `patch type`s).

Patch refinement is implemented for all supported patches except for `patch type`=`coons`, `tensor bezier`, `bicubic` (might follow eventually) and `polygon`.

/pgfplots/`patch to triangles`=true|false   (initially `false`)

Occasionally, one has a complicated `patch type` on input and would like to visualize it as a `triangle` mesh. PGFPLOTS supports automatic triangulation of patches. Triangulation means to replace each individual input patch by one or more triangles. Triangulation can be combined with `patch refines` in which case `patch refines` is applied first and the resulting refined patches are then triangulated.
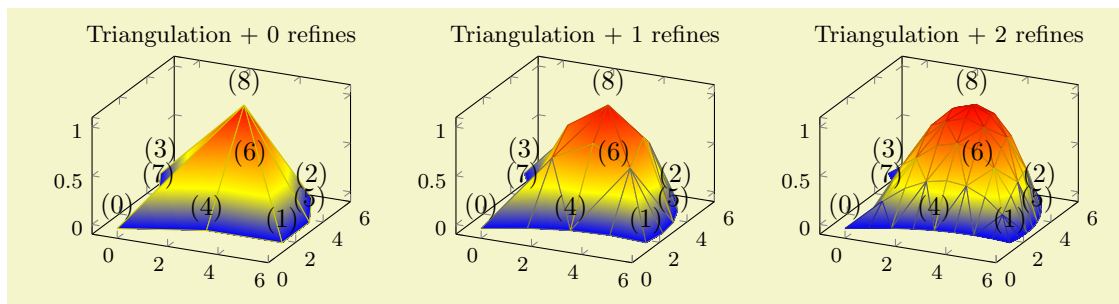
```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}\usepgfplotslibrary{patchplots}
\foreach \level in {0,1,2} {%
    \begin{tikzpicture}
    \begin{axis}[
        nodes near coords={(\coordindex)},
        footnotesize,
        title={Triangulation + \level\ refines}]

    \addplot3[patch,patch type=biquadratic,shader=faceted interp,
        patch to triangles,patch refines=\level]
    coordinates {
        (0,0,0) (6,1,0) (5,5,0) (-1,5,0)
        (3,1,0) (6,3,0) (2,6,0) (0,3,0)
        (3,3.75,1)
    };
    \end{axis}
    \end{tikzpicture}%
}
```

For one–dimensional `patch types` like `quadratic spline`, `patch to triangles` results in approximation by means of `patch type`=`line` instead of `triangle`.

The `patch to triangles` feature is implemented for all supported patches except for `patch type`=`coons`, `tensor bezier`, and `polygon`.

5.9.3 Peculiarities of Flat Shading and High Order Patches

The `patchplots` library has been optimized for use with interpolated shadings, i.e. for `shader`=`interp`: it allows the filled area to fold over itself or to be outside of the patch boundaries.

PGFPLOTS also supports `shader`=`flat` and `shader`=`faceted` by simply stroking and/or filling the patch boundaries. Naturally, such an approach works only if the enclosed patch boundary and the filled area are essentially the same! Consider using `shader`=`flat` or `shader`=`faceted` only if the *mesh width is small enough* such that patches do not fold over themselves.

The following example illustrates the effect: the coarse single element on the left folds over itsself, resulting in strange fill patterns. Refining the mesh reduces the effect.
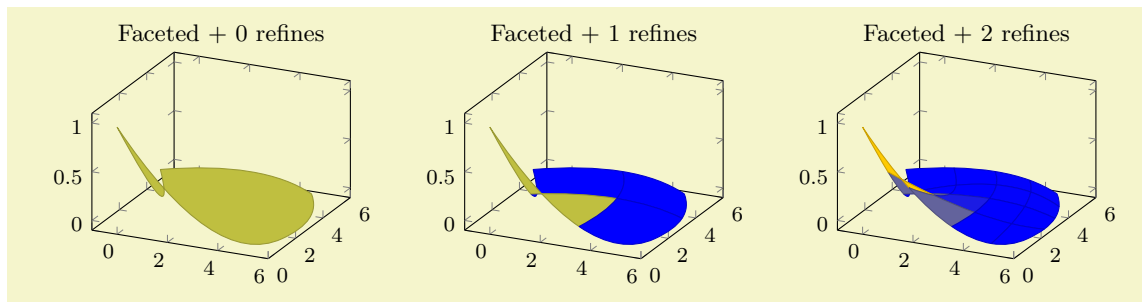

```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}\usepgfplotslibrary{patchplots}
\foreach \level in {0,1,2} {%
    \begin{tikzpicture}
    \begin{axis}[
        footnotesize,
        title={Faceted + \level\ refines}]

    \addplot3[patch,patch type=biquadratic,shader=faceted,
        patch refines=\level]
    coordinates {
        (0,0,1) (6,1,0) (5,5,0) (-1,5,0)
        (3,1,0) (6,3,0) (2,6,0) (0,3,0)
        (3,3.75,0)
    };
    \end{axis}
    \end{tikzpicture}
}
```

5.9.4   Drawing Grids

The `patchplots` library supports grid (`mesh`) visualization in the same way as for two/three–dimensional `mesh`- and `surf` plots. This includes four different approaches: the first is `shader=faceted`, which uses constant fill color and `faceted color` for stroke paths (as we already saw in Section 5.9.3). The second approach is to use `shader=faceted interp` which uses interpolated shadings for filling and issues stroke paths on top of each interpolated element. The third approach is to issue two `\addplot` commands, one with the filled `patch` plot, and one with a `patch,mesh` style which only draws (colored) grid lines on top of the previous plot. The three approaches are shown below.


```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}\usepgfplotslibrary{patchplots}
\begin{tikzpicture}
\begin{axis}[
    title={Grids with shader=faceted}]

\addplot3[patch,patch type=biquadratic,
    shader=faceted,patch refines=3]
coordinates {
    (0,0,1) (6,1,1.6) (5,5,1.3) (-1,5,0)
    (3,1,0) (6,3,0.4) (2,6,1.1) (0,3,0.9)
    (3,3.75,0.5)
};
\end{axis}
\end{tikzpicture}
```

As already discussed in Section 5.9.3, the approach with `shader=faceted` works well if the mesh width is small enough (such that single patches do not overlap and their fill area is within the patch boundaries).
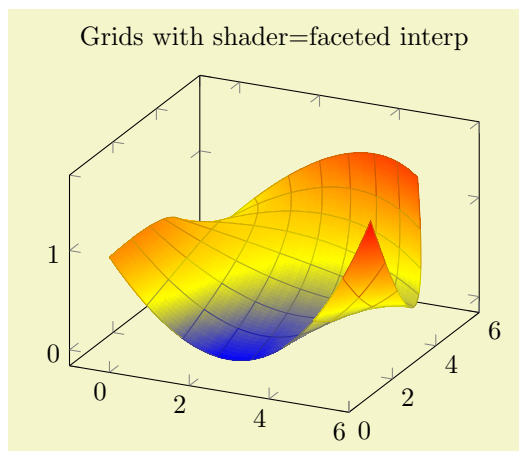

```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}\usepgfplotslibrary{patchplots}
\begin{tikzpicture}
\begin{axis}[
    title={Grids with shader=faceted interp}]

\addplot3[patch,patch type=biquadratic,
    shader=faceted interp,patch refines=3]
coordinates {
    (0,0,1) (6,1,1.6) (5,5,1.3) (-1,5,0)
    (3,1,0) (6,3,0.4) (2,6,1.1) (0,3,0.9)
    (3,3.75,0.5)
};
\end{axis}
\end{tikzpicture}
```

Here, grid lines are defined to be the patch boundary, so it may occasionally happen for coarse patches that grid lines cross the filled area. If you experience problems, consider using the `patch refines` key. The `shader=faceted interp` supports `z buffer` – at the cost of generating one shading for *each* patch element (the stroke path is drawn immediately after the patch element is shaded). This can become quite expensive[16] at display time and may lead to huge pdf files. However, `shader=faceted interp` provides smooth shadings and, at the same time, good grid lines which are drawn in the correct order.

---

[16]I would really like to hear any well–founded ideas how to improve this issue. In case you have an idea– let me know!
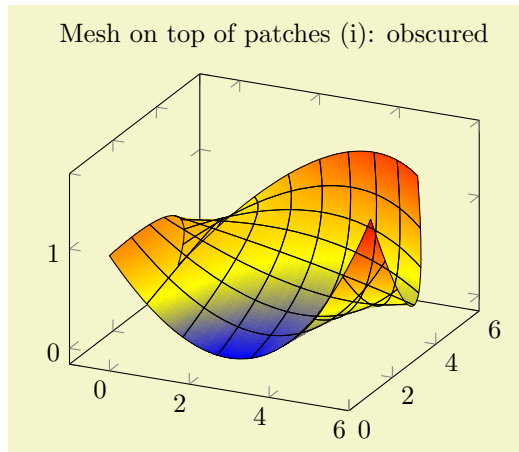
Mesh on top of patches (i): obscured

```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}\usepgfplotslibrary{patchplots}
\begin{tikzpicture}
\begin{axis}[
    title={Mesh on top of patches (i): obscured}]

\addplot3[patch,patch type=biquadratic,shader=interp,
    patch refines=3]
coordinates {
    (0,0,1) (6,1,1.6) (5,5,1.3) (-1,5,0)
    (3,1,0) (6,3,0.4) (2,6,1.1) (0,3,0.9)
    (3,3.75,0.5)
};
\addplot3[patch,patch type=biquadratic,mesh,black,
    patch refines=3]
coordinates {
    (0,0,1) (6,1,1.6) (5,5,1.3) (-1,5,0)
    (3,1,0) (6,3,0.4) (2,6,1.1) (0,3,0.9)
    (3,3.75,0.5)
};
\end{axis}
\end{tikzpicture}
```
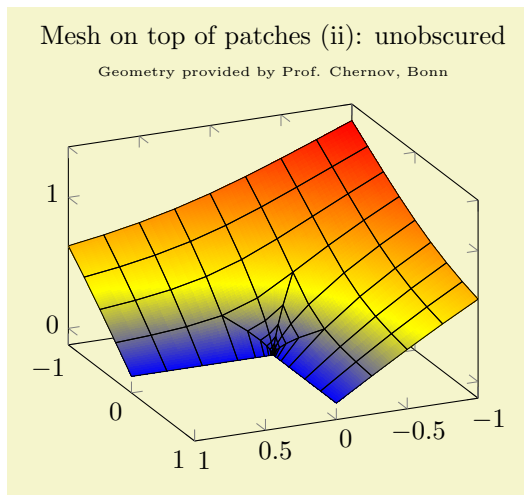
Mesh on top of patches (ii): unobscured

Geometry provided by Prof. Chernov, Bonn

```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}\usepgfplotslibrary{patchplots}
\begin{tikzpicture}
\begin{axis}[
    title={Mesh on top of patches (ii): unobscured\\
        \tiny Geometry provided by Prof. Chernov, Bonn},
    title style={align=center},
    view={156}{28}]
\addplot3[patch,patch type=bilinear,
    shader=interp,
    patch table=plotdata/patchexample_conn.dat]
    file {plotdata/patchexample_verts.dat};

\addplot3[patch,patch type=bilinear,
    mesh,black,
    patch table=plotdata/patchexample_conn.dat]
    file {plotdata/patchexample_verts.dat};
\end{axis}
\end{tikzpicture}
```

The approach to draw grids separately is done by means of two \addplot statements; the first using patch as before, the second using patch,mesh. This configures PGFPLOTS to visualize just the mesh. Make sure you provide 'mesh' after 'patch' since the latter activates filled surf visualization. The approach of meshes on top of patches implies to draw grid lines simply over any previous drawing operations. Thus, depth information is lost (as displayed in the first example above). Overlaying grid lines on top of the surface works in special cases (see bottom picture). An approach which always works is to provide the mesh at a fixed z position as displayed in the following example:
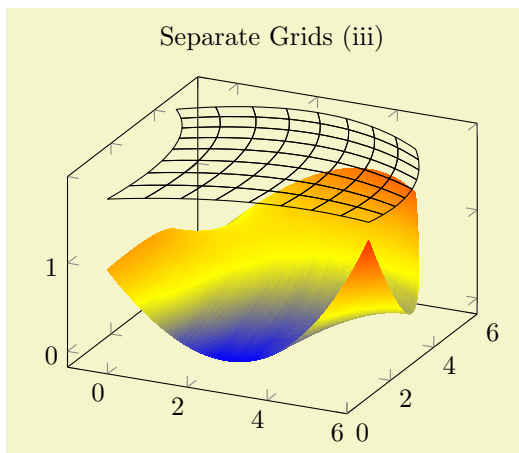
```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}\usepgfplotslibrary{patchplots}
\begin{tikzpicture}
\begin{axis}[
    title={Separate Grids (iii)}]

\addplot3[patch,patch type=biquadratic,shader=interp,
    patch refines=3]
coordinates {
    (0,0,1) (6,1,1.6) (5,5,1.3) (-1,5,0)
    (3,1,0) (6,3,0.4) (2,6,1.1) (0,3,0.9)
    (3,3.75,0.5)
};
\addplot3[patch,patch type=biquadratic,
    mesh,black,
    z filter/.code={\def\pgfmathresult{1.8}},
    patch refines=3]
coordinates {
    (0,0,1) (6,1,1.6) (5,5,1.3) (-1,5,0)
    (3,1,0) (6,3,0.4) (2,6,1.1) (0,3,0.9)
    (3,3.75,0.5)
};
\end{axis}
\end{tikzpicture}
```

Here, the first `\addplot3` command is the same as above, just with `shader=interp`. The second reproduces the same geometry, but uses a `z filter` to fix the z coordinate (in this case to $z = 1.8$). This effectively overrules all z coordinates.

Thus, grid lines can be drawn either by means of flat fill color with `shader=faceted` (efficient), by means of interpolated fill colors with `shader=faceted interp` (inefficient, see above) or, for special applications, using a separate `patch,mesh` plot which is drawn on top of the patches (efficient). In any case, the mesh visualization considers the `faceted color` which can depend on `mapped color`.

5.10   Polar Axes

```
\usepgfplotslibrary{polar} % LaTeX and plain TeX
\usepgfplotslibrary[polar] % ConTeXt
\usetikzlibrary{pgfplots.polar} % LaTeX and plain TeX
\usetikzlibrary[pgfplots.polar] % ConTeXt
```

A library to draw polar axes and plot types relying on polar coordinates, represented by angle (in degrees or, optionally, in radians) and radius.

5.10.1   Polar Axes

```
\begin{polaraxis}
  ⟨environment contents⟩
\end{polaraxis}
```

The `polar` library provides the `polaraxis` environment. Inside of such an environment, all coordinates are expected to be given in polar representation of the form ($\langle angle \rangle$, $\langle radius \rangle$), i.e. the x coordinate is always the angle and the y coordinate the radius:
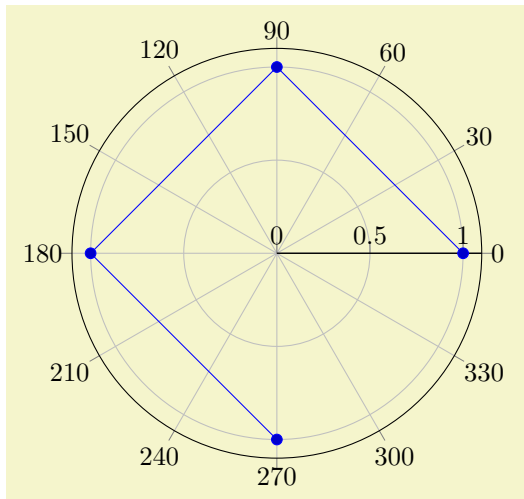
```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}\usepgfplotslibrary{polar}
\begin{tikzpicture}
    \begin{polaraxis}
    \addplot coordinates {(0,1) (90,1)
        (180,1) (270,1)};
    \end{polaraxis}
\end{tikzpicture}
```
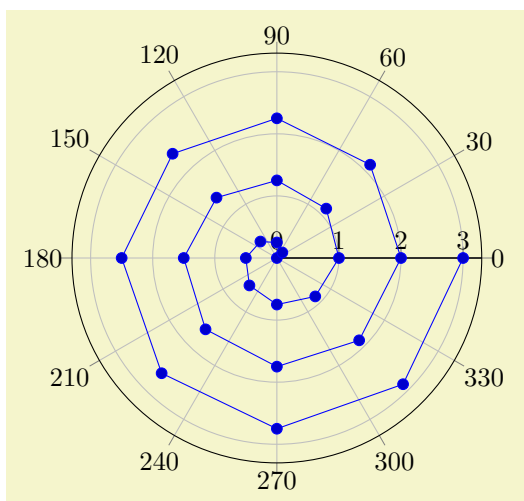


```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}\usepgfplotslibrary{polar}
\begin{tikzpicture}
    \begin{polaraxis}
    \addplot+[domain=0:3] (360*x,x); % (angle,radius)
    \end{polaraxis}
\end{tikzpicture}
```
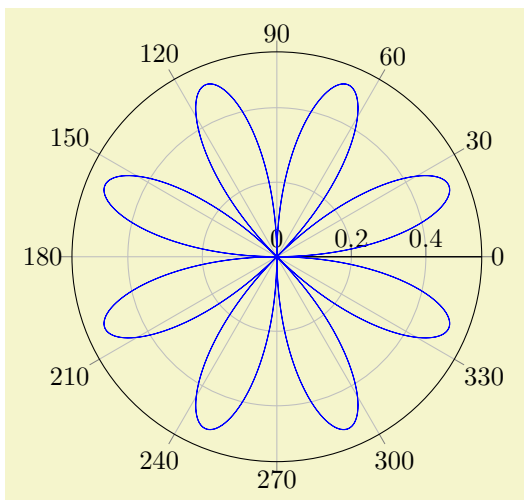


```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}\usepgfplotslibrary{polar}
\begin{tikzpicture}
    \begin{polaraxis}
    \addplot+[mark=none,domain=0:720,samples=600]
        {sin(2*x)*cos(2*x)};
    % equivalent to (x,{sin(..)cos(..)}), i.e.
    % the expression is the RADIUS
    \end{polaraxis}
\end{tikzpicture}
```

Polar axes support most of the PGFPLOTS user interface, i.e. legend entries, any axis descriptions, xtick/ytick and so on:
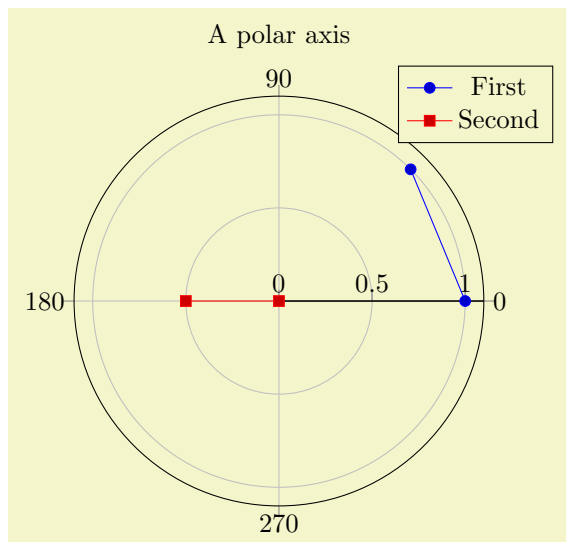
```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}\usepgfplotslibrary{polar}
\begin{tikzpicture}
    \begin{polaraxis}[
        xtick={0,90,180,270},
        title=A polar axis]

        \addplot coordinates {(0,1) (45,1)};
        \addlegendentry{First}

        \addplot coordinates {(180,0.5) (0,0)};
        \addlegendentry{Second}
    \end{polaraxis}
\end{tikzpicture}
```

Furthermore, you can use all of the supported input coordinate methods (like `\addplot coordinates`, `\addplot table`, `\addplot expression`). The only difference is that polar axes interpret the (first two) input coordinates as polar coordinates of the form ($\langle angle\ in\ degrees\rangle, \langle radius\rangle$).

It is also possible to provide `\addplot3`; in this case, the third coordinate will be ignored (although it can be used as color data using `point meta`=z). An example can be found below in Section 5.10.3.

5.10.2   Using Radians instead of Degrees

The initial configuration uses degrees for the angle (x component of every input coordinate). PGFPLOTS also supports to provide the angle in radians using the `data cs=polarrad` switch:
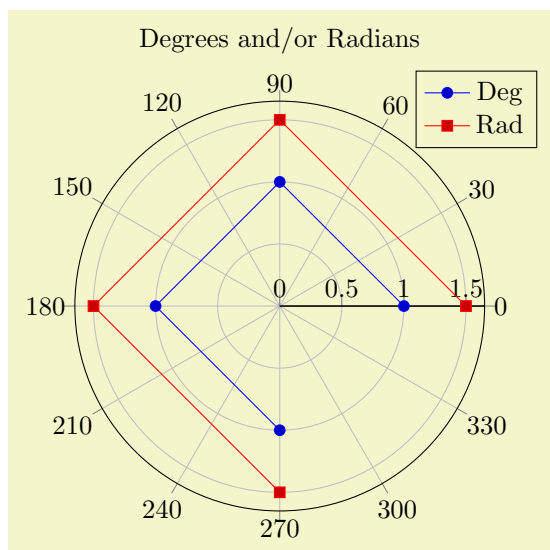

```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}\usepgfplotslibrary{polar}
\begin{tikzpicture}
    \begin{polaraxis}[title={Degrees and/or Radians}]
    \addplot
        coordinates {(0,1) (90,1) (180,1) (270,1)};
    \addlegendentry{Deg}

    \addplot+[data cs=polarrad]
        coordinates {(0,1.5) (pi/2,1.5)
            (pi,1.5) (pi*3/2,1.5)};
    \addlegendentry{Rad}
    \end{polaraxis}
\end{tikzpicture}
```

The `data cs` key is described in all detail on page 388; it tells PGFPLOTS the coordinate system of input data. PGFPLOTS will then take steps to automatically transform each coordinate into the required coordinate system (in our case, this is `data cs=polar`).

5.10.3   Mixing With Cartesian Coordinates

Similarly to the procedure described above, you can also provide Cartesian coordinates inside of a polar axis: simply tell PGFPLOTS that it should automatically transform them to polar representation by means of `data cs=cart`:
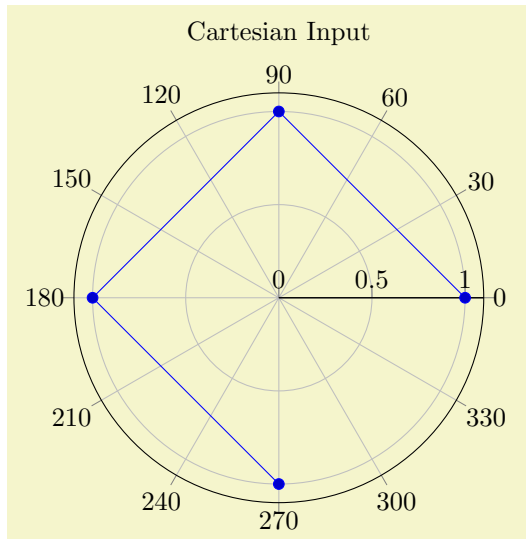
```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}\usepgfplotslibrary{polar}
\begin{tikzpicture}
    \begin{polaraxis}[title=Cartesian Input]
    \addplot+[data cs=cart]
        coordinates {(1,0) (0,1) (-1,0) (0,-1)};
    \end{polaraxis}
\end{tikzpicture}
```

More details about the `data cs` key can be found on page 388.

This does also allow more involved visualization techniques which may operate on Cartesian coordinates. The following example uses `\addplot3` to sample a function $f\colon \mathbb{R}^2 \to \mathbb{R}$, computes `contour` lines (with the help of `gnuplot`) and displays the result in a `polaraxis`:
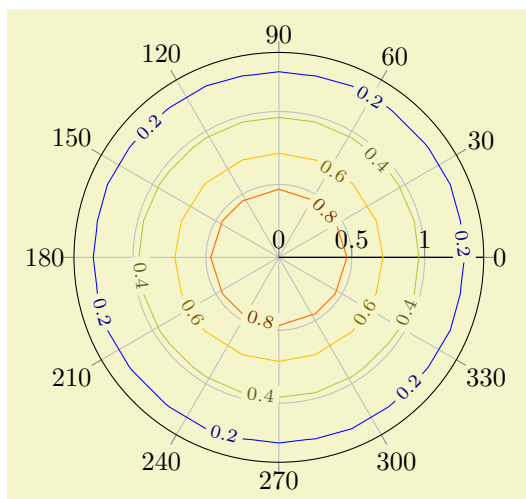

```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}\usepgfplotslibrary{polar}
\begin{tikzpicture}
    \begin{polaraxis}
    \addplot3[contour gnuplot,domain=-3:3,
      data cs=cart]
        {exp(-x^2-y^2)};
    \end{polaraxis}
\end{tikzpicture}
```

What happens is that $z = \exp(-x^2 - y^2)$ is sampled for $x, y \in [-3, 3]$, then contour lines are computed on (x, y, z), then the resulting triples (x, y, z) are transformed to polar coordinates (α, r, z) (leaving z intact). Finally, the z coordinate is used as `point meta` to determine the color.

Note that `\addplot3` allows to process three–dimensional input types, but the result will always be two–dimensional (the z coordinate is ignored for point placement in `polaraxis`). However, the z coordinate can be used to determine point colors (using `point meta`=z).

5.10.4 Polar Descriptions

Polar axes support axis labels just as other plot types.[17] In this case, `xticklabel cs` refers to a label position for the angles (x axis) and `yticklabel cs` refers to a label position for the radius (y axis).

The default axis label for the angles is placed at 45 degrees,

---

[17]Attention: support for polar axis labels is broken in versions before 1.13. Please upgrade to PGFPLOTS 1.13 and use `compat=1.13` or higher in order to use polar axis descriptions.
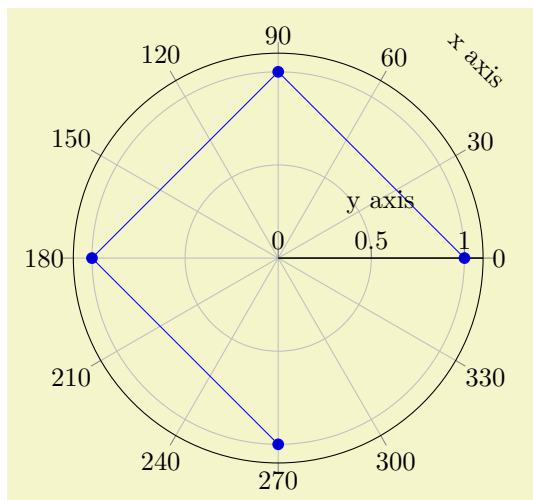
```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}\usepgfplotslibrary{polar}
\begin{tikzpicture}
\begin{polaraxis}[
    xlabel=x axis,
    ylabel=y axis,
]
\addplot coordinates {(0,1) (90,1)
    (180,1) (270,1)};
\end{polaraxis}
\end{tikzpicture}
```

and is configured as a `sloped` label using the default configuration

```
every axis x label/.style={
    at={(xticklabel cs:0.125)},
    sloped={at position=45},
    anchor=near ticklabel,
    near ticklabel at=45,
},
every axis y label/.style={
    at={(yticklabel cs:0.5)},
    anchor=near ticklabel,
},
```

This also allows sloped x labels as in the following example.[18]
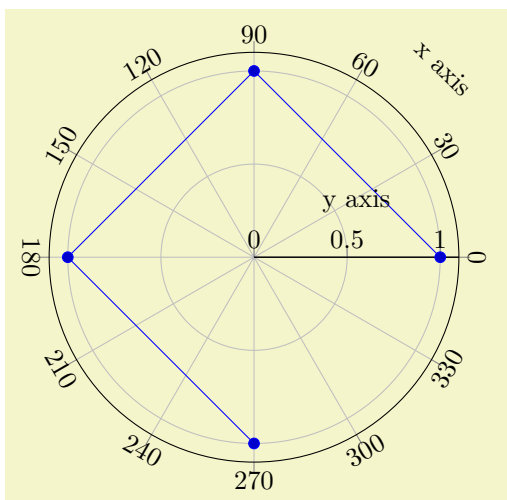

```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}\usepgfplotslibrary{polar}
\begin{tikzpicture}
\begin{polaraxis}[
    xlabel=x axis,
    ylabel=y axis,
    xticklabel style={sloped like x axis},
]
\addplot coordinates {(0,1) (90,1)
    (180,1) (270,1)};
\end{polaraxis}
\end{tikzpicture}
```

5.10.5   Special Polar Plot Types

/tikz/**polar comb**   (no value)

\addplot+[**polar comb**]

The `polar comb` plot handler is provided by TikZ; it draws paths from the origin to the designated position and places `mark`s at the positions (similar to the `comb` plot handler). Since the paths always start at the origin, it is particularly suited for `polaraxis`:

----

[18]Note that sloped polar labels also requires PGFPLOTS 1.13 and `compat=1.13` or newer.
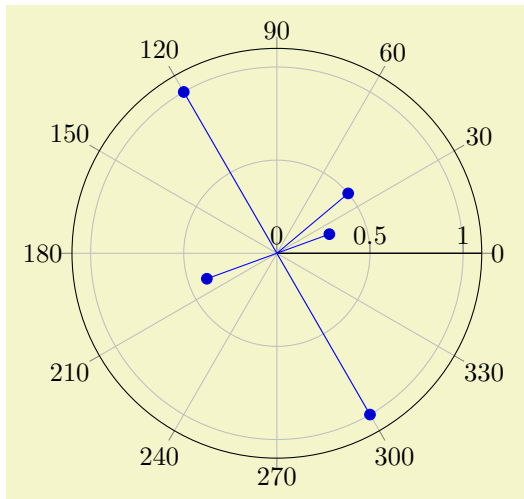
```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}\usepgfplotslibrary{polar}
\begin{tikzpicture}
    \begin{polaraxis}
    \addplot+[polar comb]
        coordinates {(300,1) (20,0.3) (40,0.5)
            (120,1) (200,0.4)};
    \end{polaraxis}
\end{tikzpicture}
```

5.10.6 Partial Polar Axes

The polar library also supports partial axes. If you provide xmin/xmax, you can restrict the angles used for the axis:
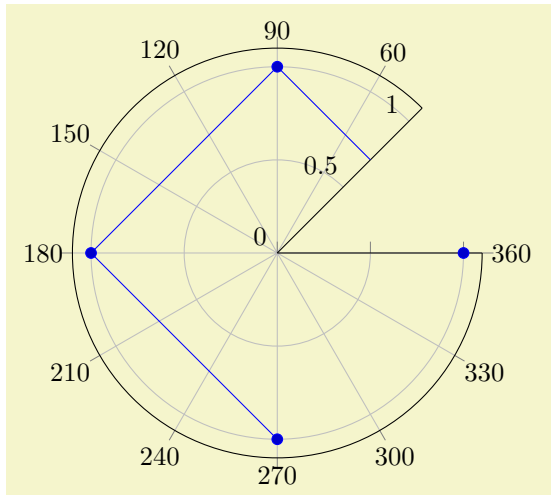

```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}\usepgfplotslibrary{polar}
\begin{tikzpicture}
    \begin{polaraxis}[xmin=45,xmax=360]
    \addplot coordinates {(0,1) (90,1) (180,1) (270,1)};
    \end{polaraxis}
\end{tikzpicture}
```

Currently, the first angle must be lower than the second one. But you can employ the periodicity to get pies as follows:
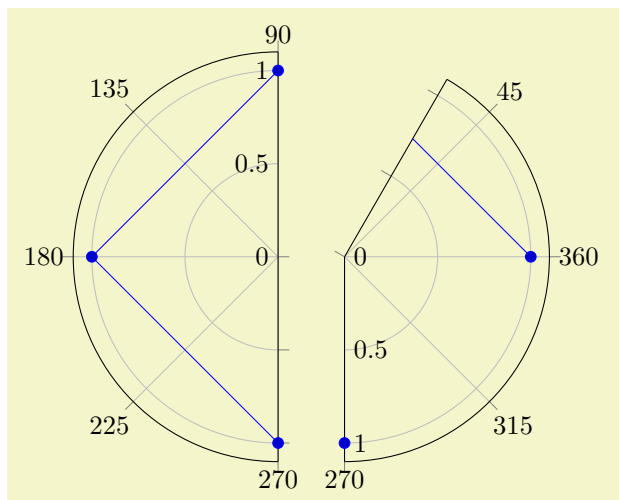
```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}\usepgfplotslibrary{polar}
\begin{tikzpicture}
    \begin{polaraxis}[xmin=90,xmax=270]
    \addplot coordinates {(0,1) (90,1) (180,1) (270,1)};
    \end{polaraxis}
\end{tikzpicture}~%
\begin{tikzpicture}
    \begin{polaraxis}[xmin=270,xmax=420]
    \addplot coordinates {(0,1) (90,1) (180,1) (270,1)};
    \end{polaraxis}
\end{tikzpicture}
```

Similarly, an explicitly provided value for `ymin` allows to reduce the displayed range away from 0:
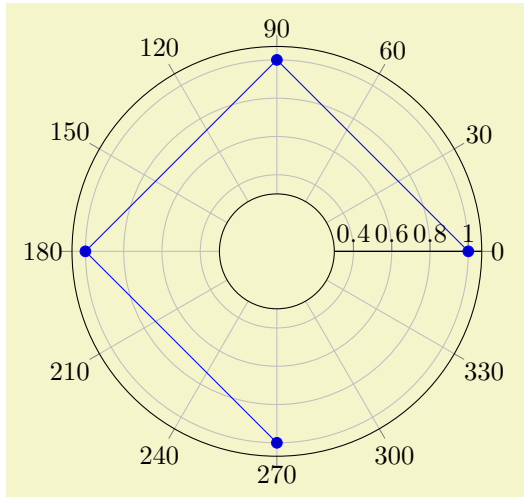

```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}\usepgfplotslibrary{polar}
\begin{tikzpicture}
    \begin{polaraxis}[ymin=0.3]
    \addplot coordinates {(0,1) (90,1)
      (180,1) (270,1)};
    \end{polaraxis}
\end{tikzpicture}
```

Modifying `xmin` and `xmax` manually can also be used to move the y axis line (the line with `ytick` and `yticklabels`):
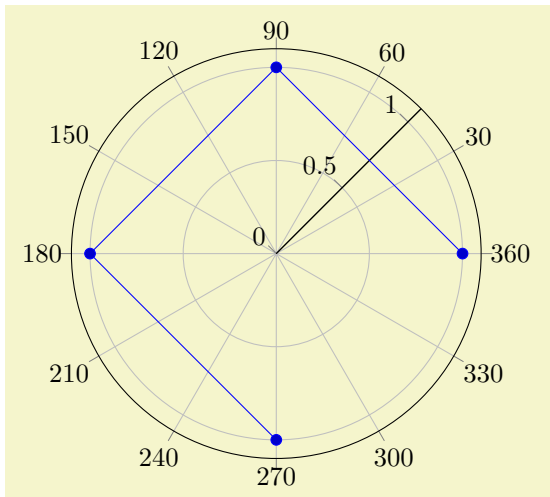

```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}\usepgfplotslibrary{polar}
\begin{tikzpicture}
    \begin{polaraxis}[xmin=45,xmax=405]
    \addplot coordinates {(0,1) (90,1) (180,1) (270,1)};
    \end{polaraxis}
\end{tikzpicture}
```

5.11 Smith Charts

```
\usepgfplotslibrary{smithchart} % LaTeX and plain TeX
\usepgfplotslibrary[smithchart] % ConTeXt
\usetikzlibrary{pgfplots.smithchart} % LaTeX and plain TeX
\usetikzlibrary[pgfplots.smithchart] % ConTeXt
```

A library to draw Smith Charts.

A Smith Chart maps the complex half plane with positive real parts to the unit circle. The `smithchart` library allows PGFPLOTS to visualize Smith Charts: it visualizes two–dimensional input coordinates

$z \in \mathbb{C}$ of the form $z = x + jy \in \mathbb{C}$ (j being the imaginary unit, $j^2 = -1$) with $x \geq 0$ using the map

$$r \colon [0, \infty] \times [-\infty, \infty] \to \{a + jb \mid a^2 + b^2 = 1\}, \quad r(z) = \frac{z - 1}{z + 1}$$

using complex number division. The result is always in the unit circle.

The main application for Smith Charts is in the area of electrical and electronics engineers specializing in radio frequency: to show the reflection coefficient $r(z)$ for normalised impedance z. It is beyond the scope of this manual to delve into the radio frequency techniques; for us, it is important to note that the `smithchart` library supports

- the data map $r(z)$ shown above,
- an axis class which interprets x as the real components and y as the imaginary components,
- a visualization of grid lines as arcs,
- the possibility to stop grid lines to allow uniform spacing in Smith Charts,
- a large set of the PGFPLOTS axis fine tuning parameters,
- input of already mapped coordinates $r(z)$ (i.e. Cartesian coordinates in the unit circle),
- many of the PGFPLOTS plot handlers.

5.11.1 Smith Chart Axes

`\begin{smithchart}[⟨options⟩]`
  ⟨environment contents⟩
`\end{smithchart}`

The `\begin{smithchart}` environment draws Smith Charts. It accepts the same *⟨options⟩* as `\begin{axis}`. In fact, it is equivalent to `\begin{axis}[⟨options⟩,axis type=smithchart]`.


```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}\usepgfplotslibrary{smithchart}
\begin{tikzpicture}
    \begin{smithchart}[title=Impedance Smith Chart]
        \addplot coordinates {(0.5,0.2) (1,0.8) (2,2)};
    \end{smithchart}
\end{tikzpicture}
```
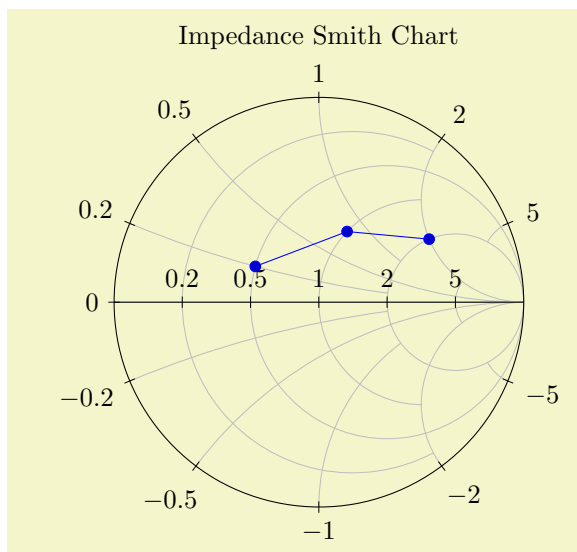
The example above visualizes three data points using the initial configuration of Smith Charts; the data points are interpreted as complex numbers $z = x + jy$ and are mapped using $r(z)$.

Here, the x coordinate refers to the cycles described by the horizontal line whereas the y coordinate refers to the cycles described by the tick labels on the outside.

`/pgfplots/smithchart mirrored`=true|false   (initially `false`)

PGFPLOTS also supports Admittance Smith Charts. Here, the origin is on the right side of the circle:

Admittance Smith Chart
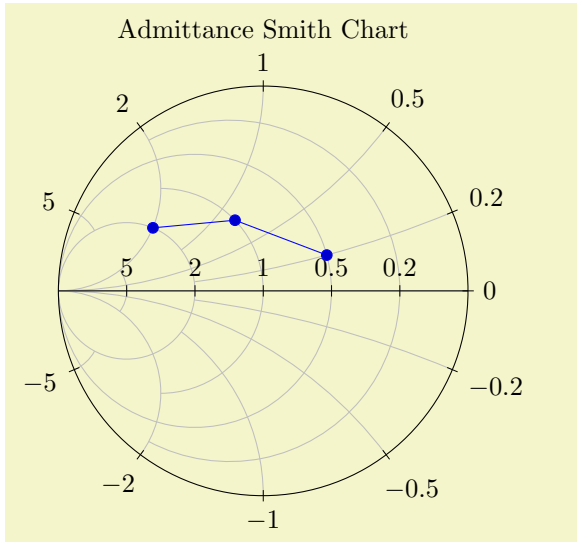
```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}\usepgfplotslibrary{smithchart}
\begin{tikzpicture}
    \begin{smithchart}[
        smithchart mirrored,
        title=Admittance Smith Chart]
    \addplot coordinates {(0.5,0.2) (1,0.8) (2,2)};
    \end{smithchart}
\end{tikzpicture}
```

Since PGFPLOTS can draw two axes on top of each other, a combined Impedance/Admittance Smith Chart is also possible.

Impedance and Admittance Smith Chart

```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}\usepgfplotslibrary{smithchart}
```
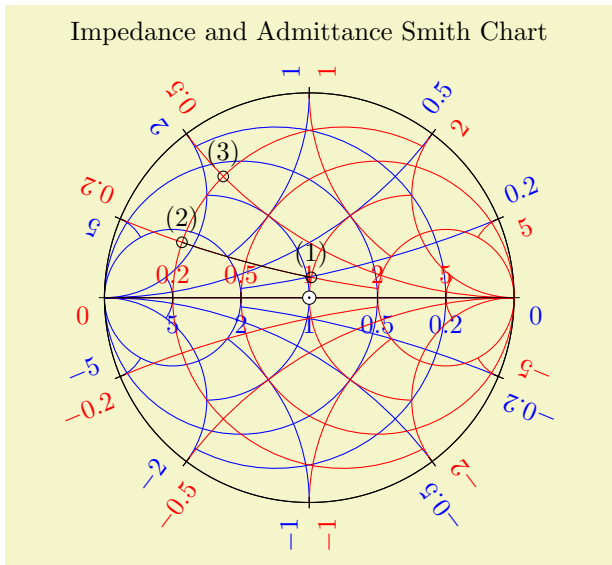
```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}\usepgfplotslibrary{smithchart}
\begin{tikzpicture}[]
% First, the Admittance chart:
\begin{smithchart}[
    title=Impedance and Admittance Smith Chart,
    smithchart mirrored,
    xticklabel shift=-19pt,
    grid style={blue},
    ticklabel style={blue},
    yticklabel around circle,
]
\end{smithchart}

% Second, overlay the impedance chart:
\begin{smithchart}[
    show origin,
    grid style={red},
    ticklabel style={red},
    yticklabel around circle*,
]
\addplot+[black,mark=o,only marks,point meta=explicit symbolic,nodes near coords]
coordinates {
    (0.2,0.2) [(2)]
    (1,0.2) [(1)]
    };

\addplot+[black,no marks,domain=0.2:1] {0.2};

\addplot+[black,mark=o,only marks,point meta=explicit symbolic,nodes near coords]
coordinates{
    (0.2,0.5) [(3)]
};
\end{smithchart}
\end{tikzpicture}
```

Since such a chart easily becomes crowded, it should be tuned manually by means of "suitable" appearance options (if you feel that there is a "suitable default", let me know).

Details for `show origin`, `yticklabel around circle`, and `yticklabel around circle*` can be found later in this section.

5.11.2 Size Control

A Smith Chart can be resized by providing either `width` or `height` as argument to the axis. If you provide both, the Chart is drawn as an ellipsis.

The tick and grid positions for `smithchart` axes are realized by means of three manually tuned sets of grid lines: one for small-sized plots, one for medium-sized plots and one for huge plots. The actual parameters for `width` or `height` are considered to select one of the following sets:

/pgfplots/**few smithchart ticks** (style, no value)

This produces the output of the example above – it constitutes the initial configuration for Smith Chart which has a width of less than `14cm`.

The `few smithchart ticks` style is defined by:

```
\pgfplotsset{
    few smithchart ticks/.style={
        default smithchart xtick/.style={
            xtick={0.2,0.5,1,2,5},
        },
        default smithchart ytick/.style={
            ytick={%
                0,%
                 0.2, 0.5, 1, 2, 5,%
                -0.2,-0.5,-1,-2,-5},
        },
        default smithchart xytick/.style={
            xgrid each nth passes y={2},
            ygrid each nth passes x={2},
        },
    },
}
```

Note that few smithchart ticks contains syntactical overhead to distinguish between "default ticks" and final tick positions: it does not assign xtick and ytick directly. Instead, it provides them as separate default xtick style arguments. The purpose of this distinction is to mark them as "default" arguments – the underlying styles smithchart/every default xtick is used if and only if there is no xtick value given.

In case you want to override this default, you can either

- copy–paste the definition above and adjust it or

- omit all the default smithchart xtick/.style stuff and write xtick={⟨your list⟩} directly.

As mentioned, the only purpose of the default smithchart xtick/.style overhead is to distinguish between \begin{smithchart}[xtick={⟨user defined⟩}] and default arguments (see the documentation of default smithchart xtick/.style for more about this technical detail).

For fine tuning of the scaling decisions, see the smith chart ticks by size key.

/pgfplots/many smithchart ticks   (style, no value)

The many smithchart ticks style is used for every Smith Chart whose width exceeds 14cm although it is less than 20cm:

Medium–Sized Smith Chart

```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}\usepgfplotslibrary{smithchart}
\begin{tikzpicture}
    \begin{smithchart}[
        title=Medium--Sized Smith Chart,
        width=14cm]
    \addplot coordinates {(0.5,0.2) (1,0.8) (2,2)};
    \end{smithchart}
\end{tikzpicture}
```
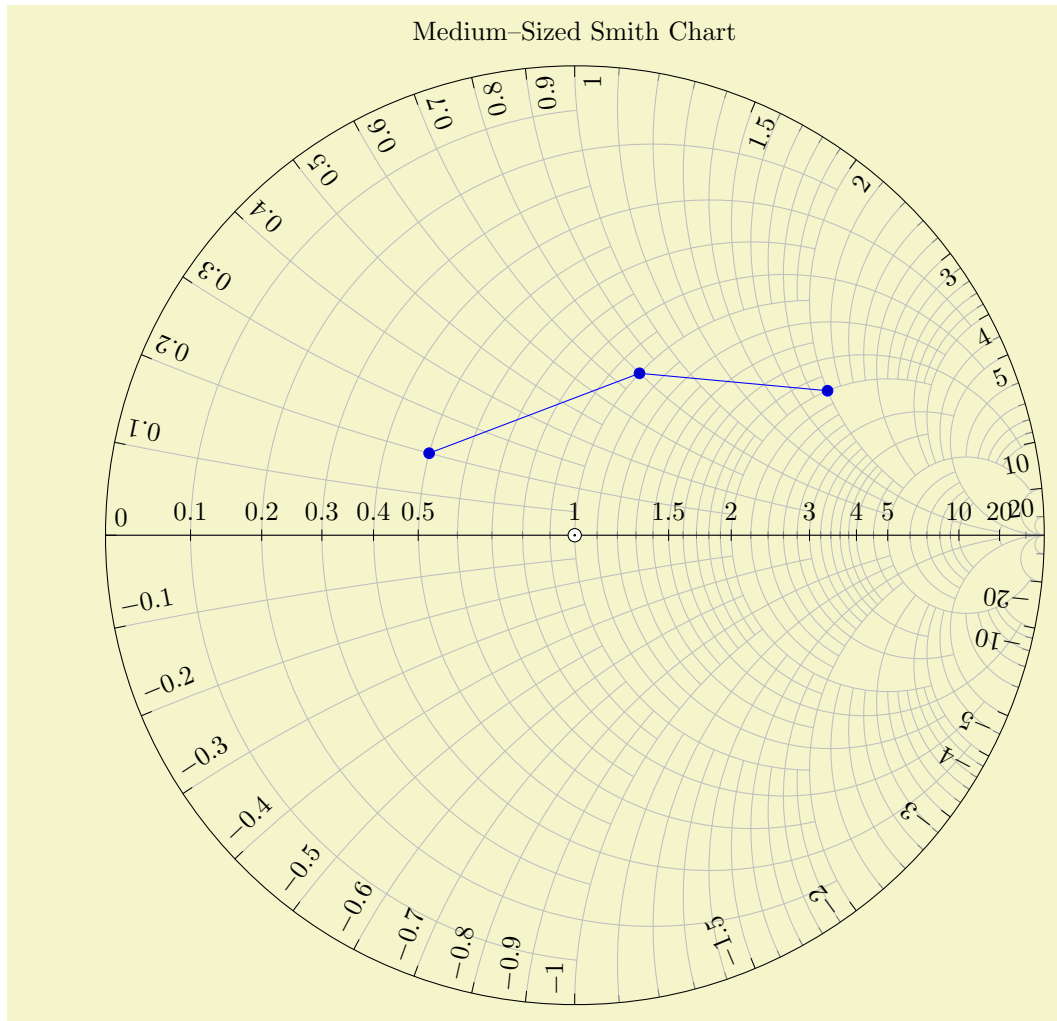
We see that `many smithchart ticks` has different placement and alignment options than `few smithchart ticks`: it uses sloped tick labels inside of the unit circle for the y descriptions (imaginary axis).

The initial configuration is realized by means of *two* separate styles: one which defines only the tick positions (the `many smithchart ticks*` style) and one which also changes placement and alignment options. The initial configuration can be changed individually (see the end of this section for examples). The initial configuration is:

```
\pgfplotsset{
    many smithchart ticks*/.style={
        default smithchart xtick/.style={
            xtick={
                0.1,0.2,0.3,0.4,0.5,1,1.5,2,3,4,5,10,20%
            },
            minor xtick={0.6,0.7,0.8,0.9,1.1,1.2,1.3,1.4,1.6,1.7,1.8,1.9,
                2.2,2.4,2.6,2.8,3.2,3.4,3.6,3.8,4.5,6,7,8,9,50},
        },
        default smithchart ytick/.style={
            ytick={%
                0,%
                0.1,0.2,...,1,1.5,2,3,4,5,10,20,%
                -0.1,-0.2,...,-1,-1.5,-2,-3,-4,-5,-10,-20%
            },
            minor ytick={%
                1.1,1.2,1.3,1.4,1.6,1.7,1.8,1.9,2.2,2.4,2.6,2.8,3.2,3.4,3.6,3.8,
                    4.5,6,7,8,9,50,%
                -1.1,-1.2,-1.3,-1.4,-1.6,-1.7,-1.8,-1.9,-2.2,-2.4,-2.6,-2.8,
                    -3.2,-3.4,-3.6,-3.8,-4.5,-6,-7,-8,-9,-50%
            },
        },
        default smithchart xytick/.style={
            xgrid each nth passes y={1,2,4,5,10,20},
            ygrid each nth passes x={1,2,3,5,10:3,20:3},
        },
    },
    /pgfplots/many smithchart ticks/.style={
        many smithchart ticks*,
        yticklabel in circle,
        show origin=true,
    },
}
```

See the documentation for `few smithchart ticks` for an explanation of the `default smithchart xtick`/.style overhead.

/pgfplots/dense smithchart ticks   (style, no value)

The `dense smithchart ticks` style assigns the set of tick positions for every Smith Chart whose width is at least 20cm:

Huge Smith Chart (rescaled)
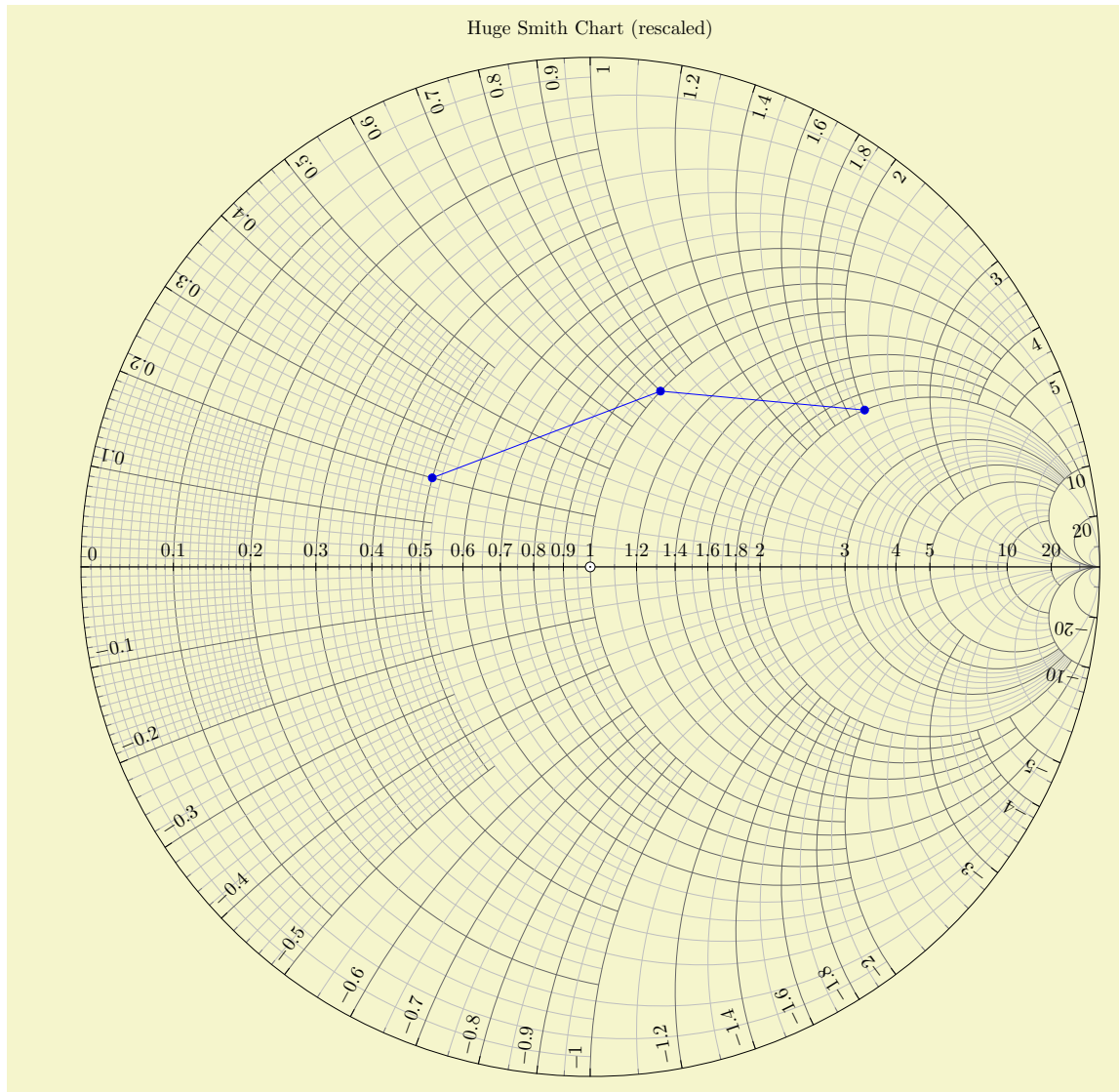
```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}\usepgfplotslibrary{smithchart}
\begin{tikzpicture}[scale=0.75]
    \begin{smithchart}[
        title=Huge Smith Chart (rescaled),
        width=20cm]
    \addplot coordinates {(0.5,0.2) (1,0.8) (2,2)};
    \end{smithchart}
\end{tikzpicture}
```

Attention: This style might change in future versions!

Similarly to `many smithchart ticks` (see above), the initial configuration is realized by means of *two* separate styles: one which defines only the tick positions (the `many smithchart ticks*` style) and one which also changes placement- and alignment options:

```
\pgfplotsset{
    dense smithchart ticks*/.style={
        default smithchart xtick/.style={
            xtick={
                0.1,0.2,0.3,0.4,0.5,0.6,0.7,0.8,0.9,1,1.2,1.4,1.6,1.8,2,3,4,5,10,20%
            },
            minor xtick={%
                0.01,0.02,0.03,0.04,0.05,0.06,0.07,0.08,0.09,0.11,0.12,0.13,0.14,0.15,0.16,0.17,
                0.18,0.19,0.22,0.24,0.26,0.28,0.32,0.34,0.36,0.38,0.42,0.44,0.46,0.48,%
                0.52,% This is sub-optimal and will (hopefully) be improved in the future.
                0.55,0.65,0.75,0.85,0.95,%
                %0.6,0.7,0.8,0.9,%
                1.1,1.3,1.5,1.7,1.9,%
                2.2,2.4,2.6,2.8,3.2,3.4,3.6,3.8,4.5,6,7,8,9,50},
        },
        default smithchart ytick/.style={
            ytick={%
                0,%
                0.1,0.2,...,1,1.2,1.4,1.6,1.8,2,3,4,5,10,20,%
                -0.1,-0.2,...,-1,-1.2,-1.4,-1.6,-1.8,-2,-3,-4,-5,-10,-20%
            },
            minor ytick={%
                0.01,0.02,0.03,0.04,0.05,0.06,0.07,0.08,0.09,0.11,0.12,0.13,0.14,0.15,0.16,0.17,
                0.18,0.19,0.22,0.24,0.26,0.28,0.32,0.34,0.36,0.38,0.42,0.44,0.46,0.48,%
                0.55,0.65,0.75,0.85,0.95,%
                1.1,1.3,1.5,1.7,1.9,2.2,2.4,2.6,2.8,3.2,3.4,3.6,3.8,4.5,6,7,8,9,50,%
                -0.01,-0.02,-0.03,-0.04,-0.05,-0.06,-0.07,-0.08,-0.09,-0.11,-0.12,-0.13,-0.14,
                -0.15,-0.16,-0.17,-0.18,-0.19,-0.22,-0.24,-0.26,-0.28,-0.32,-0.34,-0.36,-0.38,
                -0.42,-0.44,-0.46,-0.48,-0.55,-0.65,-0.75,-0.85,-0.95,%
                -1.1,-1.3,-1.5,-1.7,-1.9,-2.2,-2.4,-2.6,-2.8,-3.2,-3.4,-3.6,-3.8,-4.5,-6,-7,-8,
                -9,-50%
            },
        },
        default smithchart xytick/.style={
            xgrid each nth passes y={0.2 if < 0.2001,0.5 if < 0.50001,1 if < 1.001,2,4,5,10,20},
            ygrid each nth passes x={0.2 if < 0.2001,0.52 if < 0.52001,1 if < 1.001,2,3,5,10:3,20:3},
        },
    },
    dense smithchart ticks/.style={
        yticklabel in circle,
        dense smithchart ticks*,
        show origin=true,
        every major grid/.style={black!60},
    },
}
```

See the documentation for `few smithchart ticks` for an explanation of the `default smithchart xtick/.style` overhead.

/pgfplots/**default smithchart xtick**   (no value)
/pgfplots/**default smithchart ytick**   (no value)
/pgfplots/**default smithchart xytick**   (no value)

The `default smithchart xtick` style is installed if and only if you do not provide `xtick` manually.

Similarly, the `default smithchart ytick` style is installed if and only if you do not provide `ytick` manually.

Finally, the `default smithchart xytick` style is installed if and only if you provide neither `xtick` nor `ytick`.

These styles are usually defined in `few smithchart ticks` and its variants, see above.

5.11.3   Working with Prepared Data

/pgfplots/**is smithchart cs**=true|false   (initially `false`)

Occasionally, you may already have input data transformed into unit–circle Cartesian coordinate $r(z) = (x, y)$.

You can provide them to PGFPLOTS with the `is smithchart cs` key:
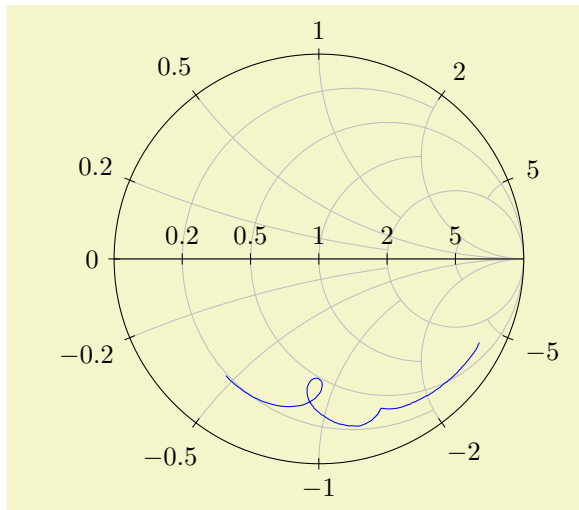
```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}\usepgfplotslibrary{smithchart}
\begin{tikzpicture}
    \begin{smithchart}
    % smithchart_data.dat contains
    % 0.78395 -0.40845
    % 0.78165 -0.41147
    % 0.77934 -0.41466
    % 0.77774 -0.41869
    % ...
    \addplot[blue,is smithchart cs]
        file {plotdata/smithchart_data.dat};
    \end{smithchart}
\end{tikzpicture}
```

Using `is smithchart cs` tells PGFPLOTS to skip the transformation $r(z)$.

5.11.4 Appearance Control and Styles

/pgfplots/show origin=true|false   (initially false)

Allows to place an extra description at the point $(0,0)$ to mark the origin.
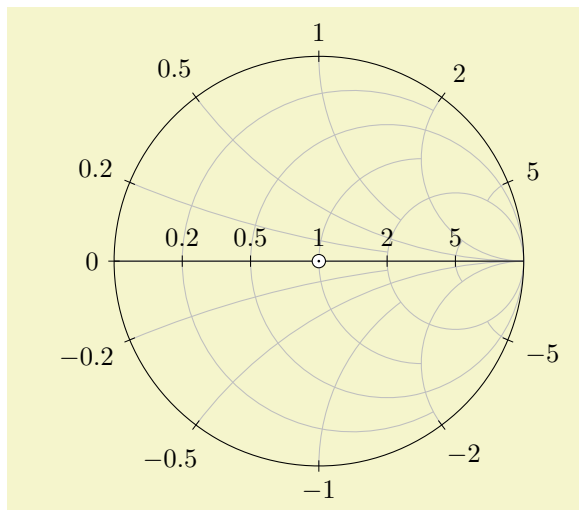

```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}\usepgfplotslibrary{smithchart}
\begin{tikzpicture}
    \begin{smithchart}[show origin]
    \end{smithchart}
\end{tikzpicture}
```

/pgfplots/show origin code/.code={⟨...⟩}

Allows to redefine the code to draw the origin marker. The initial configuration is

```
\pgfplotsset{
    show origin code/.code={%
        \path[draw=black,fill=white] (0pt,0pt) circle (2.5pt);
        \path[fill=black] (0pt,0pt) circle (0.5pt);
    }
}
```

/pgfplots/yticklabel in circle   (style, no value)

This style draws Smith Chart tick labels for imaginary components (the `ytick` arguments) inside of the circle.

It installs transformations to rotate and shift tick labels. See the `many smithchart ticks` style for an example.

The initial configuration for this style is

```
\pgfplotsset{
    yticklabel in circle/.style={
        ytick align=inside,
        yticklabel style={
            rotate=90,
            sloped like y axis={%
                execute for upside down={\tikzset{anchor=north east}},
                %allow upside down,
                reset nontranslations=false},
            anchor=south west,
            %font=\tiny,
        }
    }
}
```

/pgfplots/**yticklabel around circle**   (style, no value)

This style draws Smith Chart tick labels for imaginary components (the `ytick` arguments) outside of the circle, but rotated to fit the slope of the circle.


```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}\usepgfplotslibrary{smithchart}
\begin{tikzpicture}
    \begin{smithchart}[yticklabel around circle]
    \end{smithchart}
\end{tikzpicture}
```

The initial configuration for this style is

```
\pgfplotsset{
    yticklabel around circle/.style={
        ytick align=center,
        yticklabel style={
            rotate=90,
            sloped like y axis={%
                execute for upside down={\tikzset{anchor=south west}},
                %allow upside down,
                reset nontranslations=false},
            anchor=south east,
        }
    },
}
```

/pgfplots/**yticklabel around circle***   (style, no value)

A variant of `yticklabel around circle` which exchanges the anchors:

```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}\usepgfplotslibrary{smithchart}
\begin{tikzpicture}
    \begin{smithchart}[yticklabel around circle*]
    \end{smithchart}
\end{tikzpicture}
```

If you have two Smith Charts in the same figure, you can overlay them if the first uses `yticklabel around circle` and the second uses `yticklabel around circle*` (see the beginning of this section for an example).

The initial configuration for this style is

```
\pgfplotsset{
    yticklabel around circle*/.style={
        ytick align=center,
        yticklabel style={
            rotate=90,
            sloped like y axis={%
                execute for upside down={\tikzset{anchor=north west}},
                %allow upside down,
                reset nontranslations=false},
            anchor=north east,
        }
    }
}
```

/pgfplots/**every smithchart axis**   (style, no value)

This style is installed for every Smith Chart. It is defined as

```
\pgfplotsset{
    every smithchart axis/.style={
        grid=both,
        xmin=0,
        scaled ticks=false, % never draw the \cdot 10^4 labels
        major tick style={draw=black},
        xtick align=center,
        ytick align=center,
    },
}
```

5.11.5 Controlling Arcs and Their Stop Points

This section allows advanced control over Smith Chart arcs (grid lines). The two features `xgrid each nth passes y` and `xgrid stop at y` (and their counterparts for y) allow to draw only partial arcs in order to get a more uniform appearance.

/pgfplots/**xgrid each nth passes y**={⟨*list of stop entries*⟩}   (initially `empty`)

This key constitutes the main idea to draw only partial arcs: you provide a couple of y tick coordinates which constitute "boundaries". Then, only each (say) second x grid line is allowed to pass these boundaries:
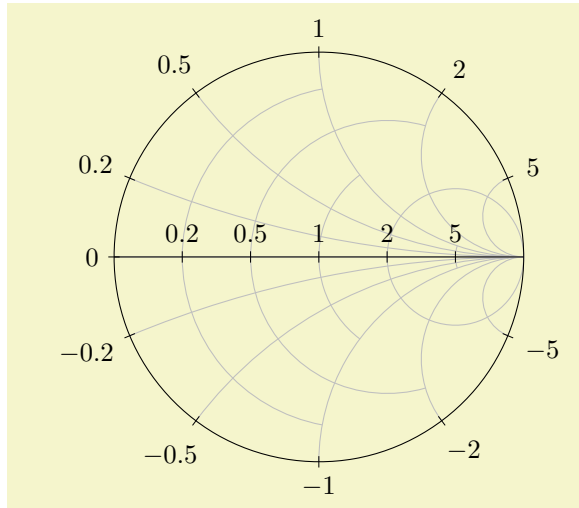
```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}\usepgfplotslibrary{smithchart}
\begin{tikzpicture}
    \begin{smithchart}[
        xtick={0.2,0.5,1,2,5},
        ytick={
            0,
             0.2, 0.5, 1, 2, 5,
             -0.2,-0.5,-1,-2,-5},
        xgrid each nth passes y={1,2},
    ]
    \end{smithchart}
\end{tikzpicture}
```

The example overwrites the `default smithchart ticks` to define a new layout: now, every `ytick` uses the complete arc, but some of the grid lines for `xtick` stop at $y = 1$ and, if they pass, they may stop at $y = 2$.

The argument ⟨*list of stop entries*⟩ is a comma–separated list of entries. Each entry is, in the simplest case, a y coordinate (it should be a coordinate which appears in the `ytick` list). This simplest case means "only each second x grid line may pass the grid line for this y". The second syntax allows to provide a natural number, using ⟨*y coord*⟩:⟨*number*⟩. This means to let only each ⟨*number*⟩'s x grid line pass the designated y grid line. The third syntax also allows to write `if < `⟨*x value*⟩. It means the entry is considered only for x grid lines which are less than ⟨*x value*⟩. To summarize: there are the three possible forms of entries

1. single y coordinates, for example `xgrid each nth passes y={1,2}` or

2. the same as above, followed by an integer, for example `xgrid each nth passes y={1:3,2:2}` or

3. an additional restriction clause like `xgrid each nth passes y={0.2 if <0.3}`.

    In this case, the all x grid lines which fulfill $x \leq 0.3$ will be checked if they are allowed to pass $y = 0.2$. All x grid lines with $x > 0.3$ are not affected by the constraint. See the `dense smithchart ticks` style for an application example.

Note that `xgrid each nth passes y` always employs symmetry; you do not need to provide y and $-y$ (if you want to, you may use the `xgrid stop at y` key to overrule the "each nth"-strategy).

In order to check if a given `xtick` argument is the "nth" grid line, PGFPLOTS collects all `xtick` and `minor xtick` arguments into *one* large array and sorts it. Then, it uses the resulting sequence to assign the indices. Consequently, you can freely intermix minor and major ticks; it will still work. The only way to affect the counting is the `xgrid each nth passes y start` key, see below.

/pgfplots/ygrid each nth passes x={⟨*list of stop entries*⟩}   (initially `empty`)

As you may already have guessed, this is the y counterpart of `xgrid each nth passes y`. It restricts the arcs for y grid lines by provided x ticks:
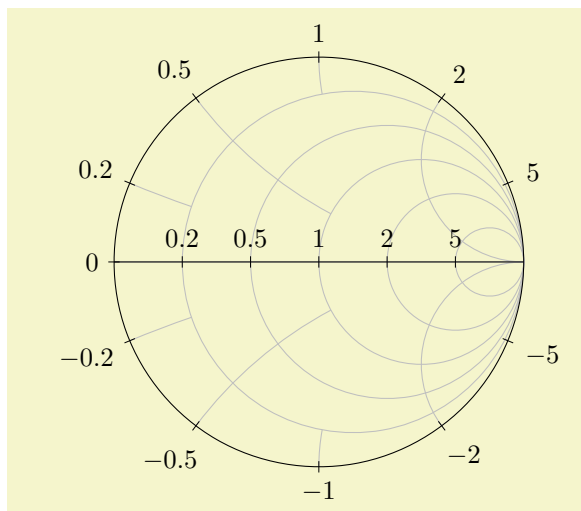
```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}\usepgfplotslibrary{smithchart}
\begin{tikzpicture}
    \begin{smithchart}[
        xtick={0.2,0.5,1,2,5},
        ytick={
            0,
             0.2, 0.5, 1, 2, 5,
            -0.2,-0.5,-1,-2,-5},
        ygrid each nth passes x={0.2,1:2},
    ]
    \end{smithchart}
\end{tikzpicture}
```

The syntax is exactly the same as explained for xgrid each nth passes y. The only difference is that the if < syntax uses absolute values y (to maintain symmetry).

Now, we know how to use xgrid each nth passes y and the corresponding ygrid each nth passes x *separately*. Can we use both keys at the same time? Yes – but it may happen that lines end in white space! PGFPLOTS applies some logic to avoid arcs ending in white space by extending them to the next feasible stopping point. The result of mixing both of these keys is thus corrected automatically.

/pgfplots/xgrid each nth passes y start={⟨*integer*⟩}   (initially 0)
/pgfplots/ygrid each nth passes x start={⟨*integer*⟩}   (initially 0)

Allows to modify where the "each nth" counting starts. The argument can be considered as a shift. I consider this key to be more or less experimental – in the hope it may be useful. Try it out.

/pgfplots/xgrid stop at y={⟨*list*⟩}   (initially empty)
/pgfplots/ygrid stop at x={⟨*list*⟩}   (initially empty)

These keys allow to provide *individual* stop points for explicitly chosen tick positions. These explicit stop points have higher precedence over the each nth features described above.

The ygrid stop at x key accepts a comma–separated list of entries ⟨*y coord*⟩:⟨*x stop point*⟩:
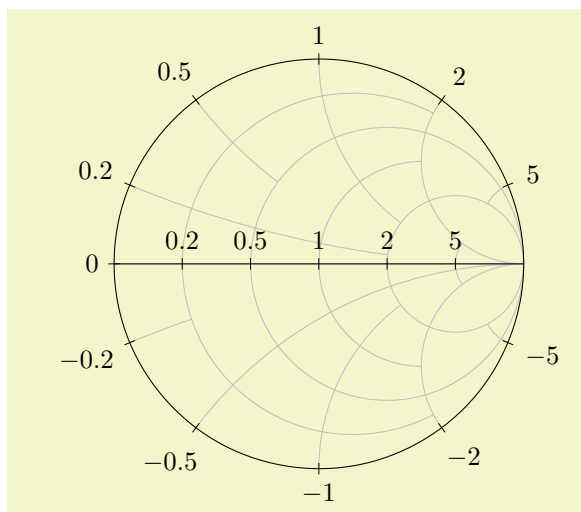

```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}\usepgfplotslibrary{smithchart}
\begin{tikzpicture}
    \begin{smithchart}[
        ygrid stop at x={0.5:0.5,-0.2:0.2}
    ]
    \end{smithchart}
\end{tikzpicture}
```

In this example, the $y = 0.5$ arc stops at the $x = 0.5$ arc whereas the $y = -0.2$ arc stops at $x = 0.2$.

The ygrid stop at x key allows unsymmetric layouts (different stop points for y and $-y$).

5.12 Statistics

\usepgfplotslibrary{statistics} % LaTeX and plain TeX

```
\usepgfplotslibrary[statistics] % ConTeXt
\usetikzlibrary{pgfplots.statistics} % LaTeX and plain TeX
\usetikzlibrary[pgfplots.statistics] % ConTeXt
```

A library which provides plot handlers for statistics.

5.12.1 Box Plots

Box plots are visualizations for one–dimensional distributions. They provide a fast overview over characteristics of the distribution. Box plots are inherently one–dimensional; they only use a second axis to place multiple box plots next to each other.

PGFPLOTS supports two related plot handlers: boxplot and boxplot prepared. The boxplot handler takes a one–dimensional sample as input, computes the median, the lower quartile, the upper quartile, the lower whisker and the upper whisker, and visualizes the result using the boxplot prepared handler. The boxplot prepared handler expects all required values on input and visualizes them.

Prepared Box Plots and Common Options

The boxplot prepared handler is discussed first; all its customizations apply to boxplot as well.

/pgfplots/**boxplot prepared**={⟨*options with* boxplot/ *prefix*⟩}

\addplot+[**boxplot prepared**={⟨*options with* boxplot/ *prefix*⟩}]

A boxplot prepared takes a couple of key–value pairs which describe the required statistics and a coordinate stream of outliers on input and draws a box plot.
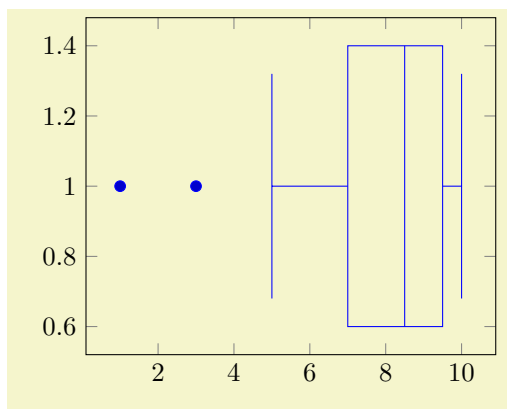

```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}\usepgfplotslibrary{statistics}
\begin{tikzpicture}
\begin{axis}
    \addplot+[
        boxplot prepared={
            lower whisker=5,
            lower quartile=7,
            median=8.5,
            upper quartile=9.5,
            upper whisker=10,
        },
    ]
        table[row sep=\\,y index=0] {
        data\\ 1\\ 3\\
    };
\end{axis}
\end{tikzpicture}
```

The previous example shows the main idea of boxplot prepared: each required quantity has to be provided explicitly using a key-value syntax. The following coordinate stream can be empty; all coordinates inside of it are considered to be outliers. They are drawn as scatter plot.

A box plot produces two coordinates: one which belongs to the input data (for example median) and one which is only used for drawing purposes. Limits will be updated for both of them. While this is clear for the axis which shows the input data (x in this example, see also draw direction), it should be noted that limits and scaling parameters for the other axis will be chosen just as for any other plot. The box's extend is a little bit less than one unit by default (compare box extend). As a consequence, would might need to adjust either the limits or the scaling parameters for the remaining axis:
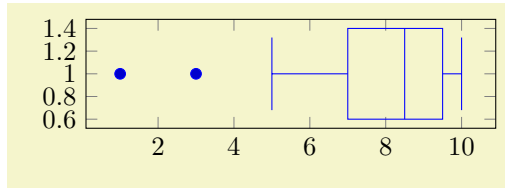
```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}\usepgfplotslibrary{statistics}
\begin{tikzpicture}
\begin{axis}[
        y=1.5cm,
    ]
\addplot+[
    boxplot prepared={
        lower whisker=5,
        lower quartile=7,
        median=8.5,
        upper quartile=9.5,
        upper whisker=10,
    },
]
    table[row sep=\\,y index=0] {
    data\\ 1\\ 3\\
};
\end{axis}
\end{tikzpicture}
```

If you place multiple blots with handler `boxplot prepared` into the same axis, they will automatically be placed next to each other by means of the default value of `draw position`:

`/pgfplots/boxplot/draw position={⟨axis unit to place box⟩}`   (initially 1+\plotnumofactualtype)

The `draw position` key determines how to choose the position of the box plot, i.e. the axis unit which is free to choose.

The initial configuration places the first box plot at $y = 1$ and all following ones at the next integer numbers.
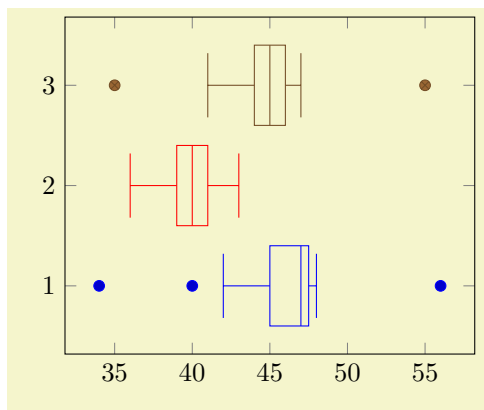

```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}\usepgfplotslibrary{statistics}
\begin{tikzpicture}
\begin{axis}
\addplot+[
    boxplot prepared={
        lower whisker=42, lower quartile=45,
        median=47,
        upper quartile=47.5, upper whisker=48,
    },
]
    table[row sep=\\,y index=0] { 40\\ 34\\ 56\\ };

\addplot+[
    boxplot prepared={
        lower whisker=36, lower quartile=39,
        median=40,
        upper quartile=41, upper whisker=43,
    },
]
    % no outliers:
    coordinates {};

\addplot+[
    boxplot prepared={
        lower whisker=41, lower quartile=44,
        median=45,
        upper quartile=46, upper whisker=47,
    },
]
    coordinates {(0,35) (0,55)};
\end{axis}
\end{tikzpicture}
```

The preceding example shows three box plots in the same axis. Note that they have been aligned using the default setting.

The fact that the first N `boxplot` (or the equivalent `boxplot prepared`) are placed at the coordinates $1, 2, 3, \ldots, N$ makes it simple to assign tick labels: either use `ytick`=data or `ytick`=1,2,3 combined with `yticklabels`:

```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}\usepgfplotslibrary{statistics}
\begin{tikzpicture}
\begin{axis}[
    ytick={1,2,3},
    yticklabels={Group A, Group B, Group C},
]
    \addplot+[
        boxplot prepared={
            lower whisker=42, lower quartile=45,
            median=47,
            upper quartile=47.5, upper whisker=48,
        },
    ]
    table[row sep=\\,y index=0] { 40\\ 34\\ 56\\ };

    \addplot+[
        boxplot prepared={
            lower whisker=36, lower quartile=39,
            median=40,
            upper quartile=41, upper whisker=43,
        },
    ]
    coordinates {};

    \addplot+[
        boxplot prepared={
            lower whisker=41, lower quartile=44,
            median=45,
            upper quartile=46, upper whisker=47,
        },
    ]
    coordinates {(0,35) (0,55)};
\end{axis}
\end{tikzpicture}
```

The draw position may be read from some input table using draw position=\thisrow⟨colname⟩. In this case, the last encountered data row will be used (this remark is, of course, only useful if a data stream is present).

While the default choice of draw position hopefully covers the most common use-cases, one can also assign a custom value to it if specific box plots should be placed individually:
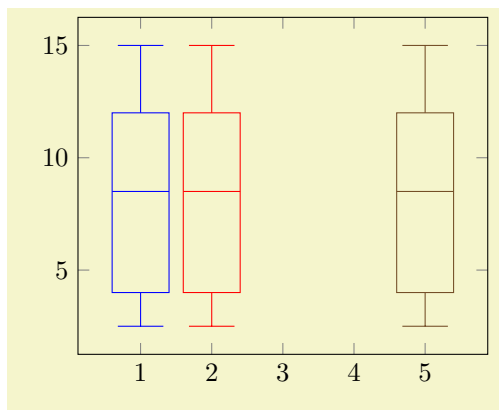

```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}\usepgfplotslibrary{statistics}
  \begin{tikzpicture}
    \begin{axis}[
        boxplot/draw direction=y,
      ]
      \addplot+[boxplot prepared={
          lower whisker=2.5, lower quartile=4,
          median=8.5, upper quartile=12,
          upper whisker=15}]
          coordinates {};
      \addplot+[boxplot prepared={
          lower whisker=2.5, lower quartile=4,
          median=8.5, upper quartile=12,
          upper whisker=15}]
          coordinates {};
      \addplot+[boxplot prepared={draw position=5,
          lower whisker=2.5, lower quartile=4,
          median=8.5, upper quartile=12,
          upper whisker=15}]
          coordinates {};
    \end{axis}
  \end{tikzpicture}
```

The example shows the first two plots using the default draw position. As this uses the plot index +1, they are placed at $x = 1$ and $x = 2$, respectively (using x due to draw direction=y). The third plot has draw position=5 and is drawn at $x = 5$.

Note that if you assign draw position for one plot, you may also need to adopt all followings ones as PGFPLOTS does not automatically detect collisions.

The preceeding examples read their outlier data streams from the y coordinate of the input streams: for `\addplot table`, we have explicitly said `y index=0` and for `\addplot coordinates`, we have used `(0,35)` `(0,55)` where the x components are ignored. This default can be changed using the `boxplot/data` key.

/pgfplots/boxplot/**data**={⟨*expression*⟩}   (initially `y`)

> Tells `boxplot` how to get its data. The common idea is to provide a mathematical ⟨*expression*⟩ which depends on data supplied by the `\addplot` statement. For example, if you have `\addplot expression`, the ⟨*expression*⟩ may depend upon `x`, `y` or `z`. In case of an `\addplot table` input routine, the ⟨*expression*⟩ can employ `\thisrow{`⟨*colname*⟩`}` to access the currently active table row in the designated column.
>
> It is also possible to avoid invocations of the math parser. Use `boxplot/data value`={⟨*value*⟩} instead to do so. Here, ⟨*value*⟩ should be of a numeric constant.
>
> The initial configuration employs what would usually become the final `y` coordinate as input (to be more precise, the initial value is `data value=\pgfkeysvalueof{/data point/y}`).

/pgfplots/boxplot/**lower whisker**={⟨*value*⟩}   (initially `auto`)
/pgfplots/boxplot/**lower quartile**={⟨*value*⟩}   (initially `auto`)
/pgfplots/boxplot/**median**={⟨*value*⟩}   (initially `auto`)
/pgfplots/boxplot/**upper quartile**={⟨*value*⟩}   (initially `auto`)
/pgfplots/boxplot/**upper whisker**={⟨*value*⟩}   (initially `auto`)
/pgfplots/boxplot/**average**={⟨*value*⟩}   (initially `empty`)

> These keys constitute the supported statistics. Typically, a box plot uses each of them except for `average`.
>
> Any numeric value for ⟨*value*⟩ will be used as-is. This holds for both `boxplot prepared` and `boxplot`.
>
> An empty ⟨*value*⟩ disables the respective key: its associated visualization will be omitted. This is the default for `average`.
>
> The value `auto` tells PGFPLOTS to include the statistics in the automatic computation applied by `boxplot`. It is irrelevant for `boxplot prepared` (where it is essentially the same as an empty ⟨*value*⟩).
>
> The definition of the values is as follows. Assume that we have a given sample of a distribution, say $x_1, \ldots, x_N$, and assume that the values are sorted, $x_1 < \cdots < x_N$ (which is not a requirement for `boxplot`, by the way). For any real number p with $0 \le p \le 1$, the "p–quantile" (or p–percentage) is defined as
>
> $$x_p := \begin{cases} x_{N \cdot p} & \text{if } N \cdot p \text{ is an integer number} \\ \frac{1}{2}(x_{\lfloor Np \rfloor} + x_{\lceil N \cdot p \rceil}) & \text{if } N \cdot p \text{ is not an integer.} \end{cases}$$
>
> `median` is the 0.5–quantile of the input data: half of the points are less and half of the points are larger than the median.
>
> `lower quartile` is the 0.25–quantile of the input data.
>
> `upper quartile` is the 0.75–quantile of the input data.
>
> `lower whisker` is the smallest data value which is larger than `lower quartile`$-1.5 \cdot$ IQR where IQR is the "inter–quartile–range", i.e. the difference between `upper quartile` and `lower quartile`.
>
> `upper whisker` is the largest data value which is smaller than `upper quartile`$+1.5 \cdot$ IQR.
>
> `average` is the sample average. It is omitted by `boxplot` in its default configuration. Set it to `auto` to enable its auto-computation.

/pgfplots/boxplot/**draw direction**=x|y   (initially `x`)

> Since `boxplot` is inherently one–dimensional, it can be visualized along the x or the y axis.
>
> The default configuration uses the x direction as seen above.
>
> The alternative choice y lets the boxes and their whiskers extend along the y axis and stacks multiple box plots along the x axis:
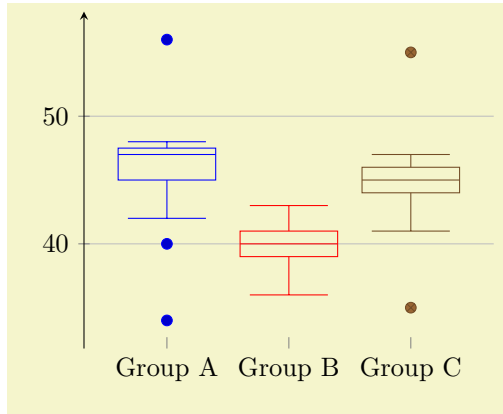
```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}\usepgfplotslibrary{statistics}
\begin{tikzpicture}
\begin{axis}[
    boxplot/draw direction=y,
    x axis line style={opacity=0},
    axis x line*=bottom,
    axis y line=left,
    enlarge y limits,
    ymajorgrids,
    xtick={1,2,3},
    xticklabels={Group A, Group B, Group C},
]
\addplot+[
    boxplot prepared={
        lower whisker=42, lower quartile=45,
        median=47,
        upper quartile=47.5, upper whisker=48,
    },
]
    table[row sep=\\,y index=0] { 40\\ 34\\ 56\\ };
\addplot+[
    boxplot prepared={
        lower whisker=36, lower quartile=39,
        median=40,
        upper quartile=41, upper whisker=43,
    },
]
    coordinates {};
\addplot+[
    boxplot prepared={
        lower whisker=41, lower quartile=44,
        median=45,
        upper quartile=46, upper whisker=47,
    },
]
    coordinates {(0,35) (0,55)};
\end{axis}
\end{tikzpicture}
```

/pgfplots/boxplot/variable width=true|false   (initially false)

If enabled, the box extend will be scaled according to the sample size relative to all other boxplot or boxplot prepared within the same axis.

The key variable width only has an effect if sample size is available. For boxplot prepared, one needs to provide sample size explicitly.
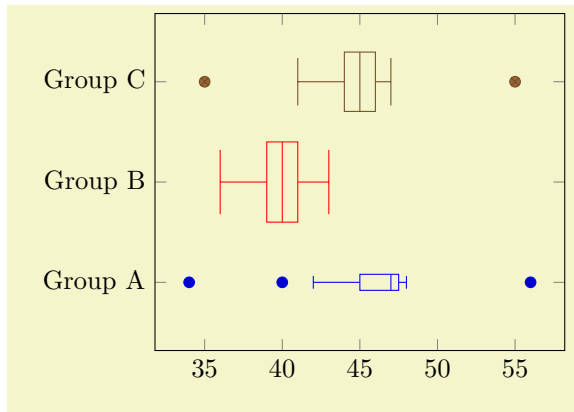
```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}\usepgfplotslibrary{statistics}
\begin{tikzpicture}
\begin{axis}[
    ytick={1,2,3},
    yticklabels={Group A, Group B, Group C},
    boxplot/variable width,
]
    \addplot+[% Group A:
        boxplot prepared={
            lower whisker=42, lower quartile=45,
            median=47,
            upper quartile=47.5, upper whisker=48,
            sample size=1000,
        },
    ]
    table[row sep=\\,y index=0] { 40\\ 34\\ 56\\ };

    \addplot+[% Group B:
        boxplot prepared={
            lower whisker=36, lower quartile=39,
            median=40,
            upper quartile=41, upper whisker=43,
            sample size=100000,
        },
    ]
    coordinates {};

    \addplot+[% Group C:
        boxplot prepared={
            lower whisker=41, lower quartile=44,
            median=45,
            upper quartile=46, upper whisker=47,
            sample size=50000,
        },
    ]
    coordinates {(0,35) (0,55)};
\end{axis}
\end{tikzpicture}
```

The `variable width` computation computes the largest and smallest value of `sample size`, chosen among all box plots in the same axis. If a single plot has no `sample size`, it will be omitted from the computation (and it will not be scaled). If a single box plot has `variable width`=false, its `sample size` will not contribute either. The box plot with largest value of `sample size` will be drawn with 100% of `box extend`. The box plot with smallest value will be drawn with `variable width min target` times `box extend` as size (i.e. it will receive the smallest configured size). All box plots in-between are scaled linearly.

Note that the previous paragraph is not entirely true: `sample size` is only indirectly related to the scaling factor. Instead, the `variable width expr` is evaluated with the `sample size` as argument (see below for details).

/pgfplots/boxplot/**sample size**={⟨*number*⟩}   (initially `auto`)

The number of samples used to derive the statistics. This number is used if `variable width`=true.

The value `auto` means to "use it whenever it can be acquired somewhere". For a `boxplot`, it means that the size of the input sample is taken as-is. For a `boxplot prepared`, it means that the data is unavailable.

The empty string means that the value is unavailable.

Otherwise, a number is expected.

/pgfplots/boxplot/**variable width expr**={⟨*math expression*⟩}   (initially `sqrt(#1)`)

A math expression which is used to evaluate the scaling factors of `variable width`. The argument is the current value of `sample size`. This key is used to implement common (nonlinear) transformations which are to be applied to the `sample size` before the result is used to scale down box sizes.

Typically, the argument should be a monotonically increasing function.

/pgfplots/boxplot/**sample size min**={⟨*min sample size of group*⟩}   (initially `empty`)

/pgfplots/boxplot/**sample size max**={⟨*max sample size of group*⟩}   (initially `empty`)

This is part of the `variable width` scaling: it is used to determine the `box extend` relative to all other box plots of the same group. It fixes the range.

/pgfplots/boxplot/**variable width min target**={⟨*factor for the box width minimal size*⟩}   (initially `0.2`)

Used for the `variable width` feature to determine the size for the box plot with smallest value of `sample size`. The argument is interpreted to be a scaling factor in the range $[0, 1]$.

It is to be understood as percentage of `box extend`: a value of 1 means 100% of `box extend`. The initial configuration is `0.2`, meaning 20% of `box extend`.

The box plot with largest value of `sample size` has 100% of `box extend`.

/pgfplots/boxplot/**box extend**={⟨*axis unit for box extension*⟩}   (initially `0.8`)

A parameter which controls the size of the boxes with respect to the axis orthogonal to the data axis.

The `box extend` is used as follows: if a box is centered at say, $y = 1$ with `box extend`=1, the box will start at $1/2$ and will end at $11/2$. In other words: the box size is 1 y unit.

It is interpreted as coordinate in the axis, and it affects the automatic computation of `ymin` and `ymax` values for a `boxplot`.
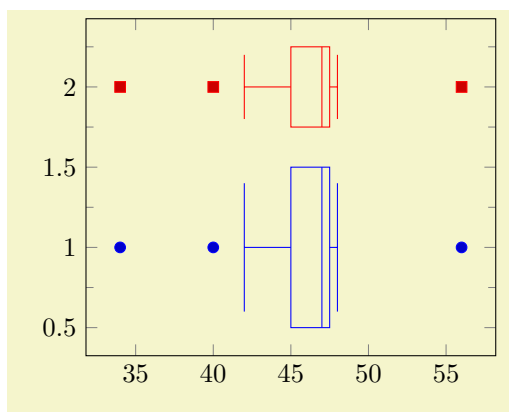
```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}\usepgfplotslibrary{statistics}
\begin{tikzpicture}
\begin{axis}[minor y tick num=1]
    \addplot+[
        boxplot prepared={
            lower whisker=42, lower quartile=45,
            median=47,
            upper quartile=47.5, upper whisker=48,
            box extend=1, }, ]
    table[row sep=\\,y index=0] { 40\\ 34\\ 56\\ };

    \addplot+[
        boxplot prepared={
            lower whisker=42, lower quartile=45,
            median=47,
            upper quartile=47.5, upper whisker=48,
            box extend=0.5, }, ]
    table[row sep=\\,y index=0] { 40\\ 34\\ 56\\ };
\end{axis}
\end{tikzpicture}
```

The `box extend` controls the size of the box and the length of the median line. It also controls the size of whiskers, although they have a separate parameter `whisker extend`.

It is supposed to be the low–level size of a box plot, although it can be interpreted and used as a "low–level–variant" of `variable width`.

/pgfplots/boxplot/**whisker extend**={⟨*axis unit for whisker extension*⟩}   (initially `\pgfkeysvalueof{/pgfplots/boxplot/box extend}*0.8`)

A parameter which configures how large whisker lines are with respect to the non–data axis.

It is used in the same way as `box extend`, and it also affects axis limits.

The initial configuration couples its value to `box extend` (it is 80% of `box extend`, to be more precise).

/pgfplots/boxplot/**draw relative anchor**={⟨*number between* 0 *and* 1⟩}   (initially `0.5`)

A key which customizes the anchor inside of the box where the whiskers are attached.
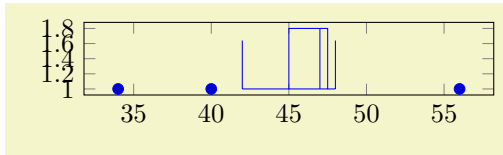
```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}\usepgfplotslibrary{statistics}
\begin{tikzpicture}
\begin{axis}[y=1cm]
    \addplot+[
        boxplot prepared={
            lower whisker=42, lower quartile=45,
            median=47,
            upper quartile=47.5, upper whisker=48,
            draw relative anchor=0, }, ]
    table[row sep=\\,y index=0] { 40\\ 34\\ 56\\ };
\end{axis}
\end{tikzpicture}
```
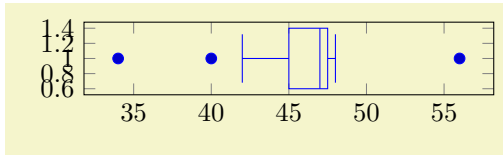
```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}\usepgfplotslibrary{statistics}
\begin{tikzpicture}
\begin{axis}[y=1cm]
    \addplot+[
        boxplot prepared={
            lower whisker=42, lower quartile=45,
            median=47,
            upper quartile=47.5, upper whisker=48,
            draw relative anchor=0.5, }, ]
    table[row sep=\\,y index=0] { 40\\ 34\\ 56\\ };
\end{axis}
\end{tikzpicture}
```
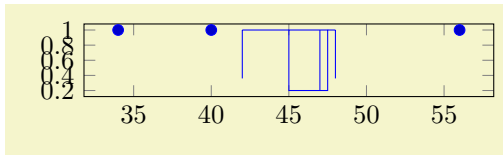
```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}\usepgfplotslibrary{statistics}
\begin{tikzpicture}
\begin{axis}[y=1cm]
    \addplot+[
        boxplot prepared={
            lower whisker=42, lower quartile=45,
            median=47,
            upper quartile=47.5, upper whisker=48,
            draw relative anchor=1, }, ]
    table[row sep=\\,y index=0] { 40\\ 34\\ 56\\ };
\end{axis}
\end{tikzpicture}
```

The value 0 means that whisker lines are attached to the bottom of the box (0% of `box extend`). The value 1 means that whisker lines are attached to the top edge of the box. Any value in-between is scaled linearly. The initial configuration is 0.5 which means that whiskers are attached to the middle of the box.

Analyzing Samples Automatically

/pgfplots/boxplot={⟨*options with* boxplot/ *prefix*⟩}

\addplot+[boxplot={⟨*options with* boxplot/ *prefix*⟩}]

The `boxplot` handler takes a one–dimensional sample as input, computes the `median`, the `lower quartile`, the `upper quartile`, the `lower whisker` and the `upper whisker`, and visualizes the result using the `boxplot prepared` handler.

Attention: Computing the statistics automatically is considerably faster if you use `compat`=1.12 combined with `lualatex`: this library has a special LUA backend which allows scalability, speed, and accuracy beyond TeX's capabilities.
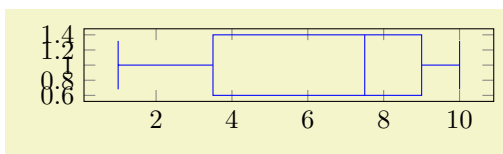
```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}\usepgfplotslibrary{statistics}
\begin{tikzpicture}
\begin{axis}[y=1cm]
    \addplot+[boxplot]
        table[row sep=\\,y index=0] {
        data\\
        1\\ 2\\ 1\\ 5\\ 4\\ 10\\
        7\\ 10\\ 9\\ 8\\ 9\\ 9\\
    };
\end{axis}
\end{tikzpicture}
```

The values do not need to be sorted. However, *if* they are sorted in ascending order, PGFPLOTS might need less time to analyze them.

Data points can be given by means of any supported input stream, although the most useful ones are probably `\addplot table` and `\addplot coordinates`. In any case, `boxplot` acquires only one–dimensional data. To this end, it uses the current value of the `boxplot/data` key to see which input coordinate is to be used. In the default configuration, this is the y coordinate of the input stream. All other input items are ignored (except for `point meta`, which is handed down to the outlier stream).

/pgfplots/boxplot/estimator=value   (initially `Excel`)

Selects one of 10 available boxplot value estimators.

The default estimator is `R7` alias `Excel` if PGFPLOTS is configured to use `compat=1.12` or higher. For all older compatibility levels, it is `legacy`.

The choice `R1` resembles the estimator type 1 used by R. It has aliases `SAS3` and `Maple1`. This choice is currently limited to the `lua backend`.

The choice `R2` resembles the estimator type 2 used by R. It has aliases `SAS5` and `Maple2`. This choice is currently limited to the `lua backend`.

The choice `R3` resembles the estimator type 3 used by R. It has aliases `SAS2`.

The choice `R4` resembles the estimator type 4 used by R. It has aliases `SAS1`, `SciPy0-1`, and `Maple3`.

The choice `R5` resembles the estimator type 5 used by R. It has aliases `SciPy12-12` and `Maple4`.

The choice `R6` resembles the estimator type 6 used by R. It has aliases `SAS4`, `SciPy0-0`, and `Maple5`.

The choice `R7` resembles the estimator type 7 used by R. It has aliases `Excel`, `SciPy1-1` and `Maple6`.

The choice `R8` resembles the estimator type 8 used by R. It has aliases `ScuPy13-13` and `Maple7`.

The choice `R9` resembles the estimator type 9 used by R. It has aliases `SciPy38-38` and `Maple8`.

The choice `legacy` is a minimally repaired variant of the estimator which was shipped with the first version of the `statistics` library. It is merely kept for reasons of backwards compatibility[19].

/pgfplots/boxplot/whisker range={⟨number⟩}   (initially `1.5`)

Defines how to determine `lower whisker` and `upper whisker`. In the default configuration, the lower whisker is placed at the smallest data point which is larger than `lower quartile` $-1.5 \cdot$ IQR. The upper whisker is placed at the largest data point which is smaller than `upper quartile` $+1.5 \cdot$ IQR. Here, IQR is the inter–quartile–range, defined as

IQR := `upper quartile` $-$ `lower quartile`.

Everything outside of the whisker range is supposed to be an outlier.

Styles

/pgfplots/boxplot/every boxplot   (style, no value)

A style which is immediately installed whenever `boxplot` or `boxplot prepared` are set.

The initial value is empty.

/pgfplots/boxplot/every whisker   (style, no value)

A style which is installed whenever a whisker is drawn. It is empty initially.

/pgfplots/boxplot/every box   (style, no value)

A style which is installed whenever a box is drawn. It is empty initially. Note that this does not apply to the path for the `median`.

/pgfplots/boxplot/every median   (style, no value)

A style which is installed whenever a median is drawn. It is empty initially.

/pgfplots/boxplot/every average   (style, no value)

A style which is installed whenever an average is drawn. The initial configuration is

---

[19]There is also an estimator called `legacy*`. This is the original one shipped with the first version of this library. It is discouraged but kept in case someone really needs it.

```
\pgfplotsset{
    boxplot/every average/.style={%
        /tikz/mark=diamond*,
    },
}
```

Placing Annotations

\pgfplotsboxplotvalue{⟨*key name*⟩}

    Same as

    \pgfkeysvalueof{/pgfplots/boxplot/⟨*key name*⟩}.

\boxplotvalue{⟨*key name*⟩}

    Same as \pgfplotsboxplotvalue{⟨*key name*⟩} (just shorted).

Coordinate system `boxplot box`

    The `boxplot box cs` accepts two arguments specified a tuple of the form `boxplot box cs=(`⟨*data coordinate, box–relative offset*⟩`)` where the first is a value of the box plot's data (it is expressed in the same space as `median` or `upper whisker`).

    The second argument is an offset expressed as signed multiple of `box extend`. An offset of 0 means to place the point exactly on the bottom line of the box. An offset of 1 places the point on the top line of the box. An offset of 0.5 places the point in the middle.
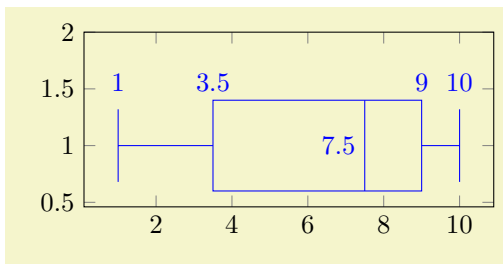

```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}\usepgfplotslibrary{statistics}
\begin{tikzpicture}
\begin{axis}[y=1.5cm, ymax=2]
\addplot+[boxplot]
table[row sep=\\,y index=0] {
    data\\
    1\\ 2\\ 1\\ 5\\ 4\\ 10\\
    7\\ 10\\ 9\\ 8\\ 9\\ 9\\
}
[above]
node at
  (boxplot box cs: \boxplotvalue{lower whisker},1)
  {\pgfmathprintnumber{\boxplotvalue{lower whisker}}}
node at
  (boxplot box cs: \boxplotvalue{lower quartile},1)
  {\pgfmathprintnumber{\boxplotvalue{lower quartile}}}
node[left] at
  (boxplot box cs: \boxplotvalue{median},0.5)
  {\pgfmathprintnumber{\boxplotvalue{median}}}
node at
  (boxplot box cs: \boxplotvalue{upper quartile},1)
  {\pgfmathprintnumber{\boxplotvalue{upper quartile}}}
node at
  (boxplot box cs: \boxplotvalue{upper whisker},1)
  {\pgfmathprintnumber{\boxplotvalue{upper whisker}}}
;
\end{axis}
\end{tikzpicture}
```

Coordinate system `boxplot whisker`

    A coordinate system which is almost the same as `boxplot box cs`, except that it aligns at `whisker extend` instead of `box extend`.

    The `boxplot whisker cs` accepts two arguments of the form `boxplot whisker cs=(`⟨*data coordinate, whisker–relative offset*⟩`)` where the first is a value of the box plot's data (it is expressed in the same space as `median` or `upper whisker`).

    The second argument is an offset expressed as signed multiple of `whisker extend`. An offset of 0 means to place the point exactly on the lower end of the whisker line. An offset of 1 places the point on the upper end of the whisker line. An offset of 0.5 places the point in the middle of the whisker line.
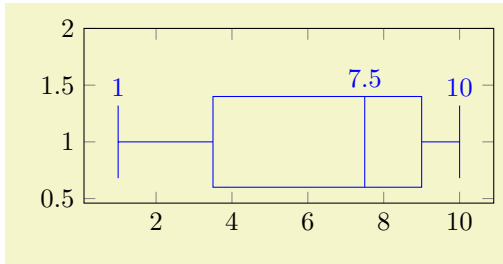
```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}\usepgfplotslibrary{statistics}
\begin{tikzpicture}
\begin{axis}[y=1.5cm, ymax=2]
\addplot+[boxplot]
table[row sep=\\,y index=0] {
    data\\
    1\\ 2\\ 1\\ 5\\ 4\\ 10\\
    7\\ 10\\ 9\\ 8\\ 9\\ 9\\
}
[above]
node at
  (boxplot whisker cs:\boxplotvalue{lower whisker},1)
  {\pgfmathprintnumber{\boxplotvalue{lower whisker}}}
node at
  (boxplot box cs: \boxplotvalue{median},1)
  {\pgfmathprintnumber{\boxplotvalue{median}}}
node at
  (boxplot whisker cs:\boxplotvalue{upper whisker},1)
  {\pgfmathprintnumber{\boxplotvalue{upper whisker}}}
;
\end{axis}
\end{tikzpicture}
```

Customizing Visualization Paths

The following keys are of interest if you want to redefine the shape of a box, of a median, or of the whiskers.
Note that you should customize styles like `boxplot/every box` if you merely wish to change fill colors.

/pgfplots/boxplot/**draw/lower whisker**/.code={⟨...⟩}
/pgfplots/boxplot/**draw/upper whisker**/.code={⟨...⟩}
/pgfplots/boxplot/**draw/whisker**/.code={⟨...⟩}

A couple of code keys which customize the stroke paths for whiskers.

The initial configuration is

```
\pgfplotsset{
    boxplot/draw/lower whisker/.style={%
        /pgfplots/boxplot/draw/whisker=%
            {\pgfplotsboxplotvalue{lower quartile}}
            {\pgfplotsboxplotvalue{lower whisker}}
    },
    boxplot/draw/upper whisker/.style={%
        /pgfplots/boxplot/draw/whisker=%
            {\pgfplotsboxplotvalue{upper quartile}}
            {\pgfplotsboxplotvalue{upper whisker}}%
    },
    boxplot/draw/whisker/.code 2 args={%
        \draw[/pgfplots/boxplot/every whisker/.try]
            (boxplot cs:#1) -- (boxplot cs:#2)
            (boxplot whisker cs:#2,0)
            --
            (boxplot whisker cs:#2,1)
        ;
    },%
}
```

The key `draw/lower whisker` key is used if and only if `lower whisker` has a numeric value. The key
`draw/upper whisker` is used if and only if `upper whisker` has a value.

If one of `lower quartile` or `upper quartile` is empty, both are replaced by the following values:

`lower quartile` := `upper whisker` and

`upper quartile` := `lower whisker`.

Thus, if the box cannot be drawn but you only have whiskers, the two whiskers will be connected with
each other.

/pgfplots/boxplot/**draw/box**/.code={⟨...⟩}

A path which is used for `every box`.

```
\pgfplotsset{
    boxplot/draw/box/.code={%
        \draw[/pgfplots/boxplot/every box/.try]
            (boxplot box cs:\pgfplotsboxplotvalue{lower quartile},0)
            rectangle
            (boxplot box cs:\pgfplotsboxplotvalue{upper quartile},1)
        ;
    },%
}
```

It either `lower quartile` or `upper quartile` is empty, this key will not be invoked.

Note that `draw/median` will be invoked after this key.

/pgfplots/boxplot/**draw/median**/**.code**={⟨...⟩}

A path which is used for every `median`. Its initial configuration is

```
\pgfplotsset{
    boxplot/draw/median/.code={%
        \draw[/pgfplots/boxplot/every median/.try]
            (boxplot box cs:\pgfplotsboxplotvalue{median},0)
            --
            (boxplot box cs:\pgfplotsboxplotvalue{median},1)
        ;
    },%
}
```

This key will be omitted if `median` is empty.

/pgfplots/boxplot/**draw/average**/**.code**={⟨...⟩}

The path which is used to visualize an `average`. The initial configuration is

```
\pgfplotsset{
    boxplot/draw/average/.code={%
        \draw[/pgfplots/boxplot/every average/.try]
            \pgfextra
            % do NOT use \draw[mark=*] plot coordinates because
            % boxplots uses the same plot handler to draw its
            % outliers.
            \pgftransformshift{%
                % basic level access to 'boxplot box cs':
                \pgfplotsboxplotpointabbox
                    {\pgfplotsboxplotvalue{average}}
                    {0.5}%
            }%
            \pgfuseplotmark{\tikz@plot@mark}%
            \endpgfextra
        ;
    },
}
```

This key will be omitted if `average` has an empty value (the default).

The key `draw/average` will be evaluated after `draw/median` and after `draw/box`.

5.12.2 Histograms

/pgfplots/**hist**={⟨*options with* `hist/` *prefix*⟩}

\addplot+[**hist**={⟨*options with* `hist/` *prefix*⟩}]

A histogram plot takes one-dimensional input data and counts the occurrence of values: it determines the data range $[m, \overline{m}]$ and subdivides it into N equally sized bins with $(N + 1)$ end–points. Then, it counts the number of points falling into each bin. More precisely, it computes the $N + 1$ points $m =: x_0 < x_1 < \cdots < x_N := \overline{m}$ using $x_i := m + i \cdot (\overline{m} - m)/N$. Then, it creates the $N + 1$ coordinates (x_i, y_i), $i = 0, \ldots, N - 1$ by means of

$$y_i := \begin{cases} \text{bincount}\big([x_i, x_{i+1})\big)\big) & i < N \\ y_{N-1} & i = N, \end{cases}$$

i.e. the value of the last coordinate is replicated. This set of $(N+1)$ interval boundaries is then visualized by an `ybar interval` plot handler.
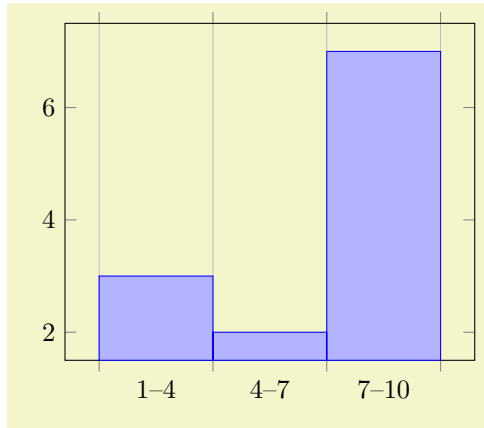

```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}\usepgfplotslibrary{statistics}
\begin{tikzpicture}
\begin{axis}[
  ybar interval,
  xticklabel=
\pgfmathprintnumber\tick--\pgfmathprintnumber\nexttick
]
    \addplot+[hist={bins=3}]
        table[row sep=\\,y index=0] {
        data\\
        1\\ 2\\ 1\\ 5\\ 4\\ 10\\
        7\\ 10\\ 9\\ 8\\ 9\\ 9\\
    };
\end{axis}
\end{tikzpicture}
```

We see that `hist={bins=3}` takes a table with one column as input. The data values fall into the range $[1, 10]$ which is partitioned into 3 intervals (of equal lengths). Finally, the number of points falling into each of the three bins is plotted. The `xticklabel` key shows the range (note that it works only in conjunction with `x tick label as interval` which has been enabled by `ybar interval` before). We see that there are 3 elements in the range $[1, 4)$, 2 elements in the range $[4, 7)$ and finally 7 elements in the range $[7, 10]$.

The bins are half–open intervals, i.e. the end–point does not belong to the bin. Only the last bin contains its right end point.
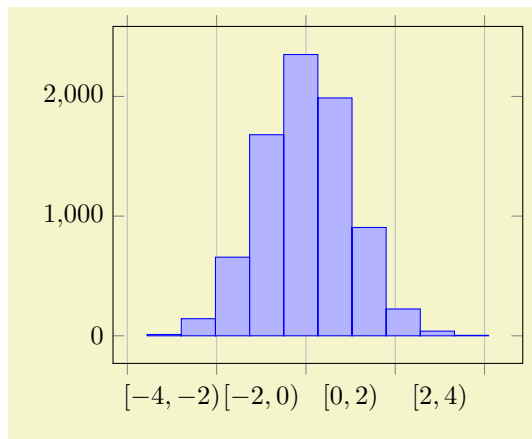

```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}\usepgfplotslibrary{statistics}
\begin{tikzpicture}
\begin{axis}[
  ybar interval,
  xtick=,% reset from ybar interval
  xticklabel=
    {$[\pgfmathprintnumber\tick,%
        \pgfmathprintnumber\nexttick)$}
]]
% a data file containing 8000 normally distributed
% random numbers of mean 0 and variance 1
\addplot+[hist={data=x}]
    file {plotdata/pgfplots.randn.dat};

\end{axis}
\end{tikzpicture}
```

The `hist` plot type can be combined with `plot expression` as well: provide the usual ⟨*expression*⟩ as you would for a line plot. Then, configure the value for `data=`⟨*expression*⟩ in dependence of `x`, `y`, or `z`:
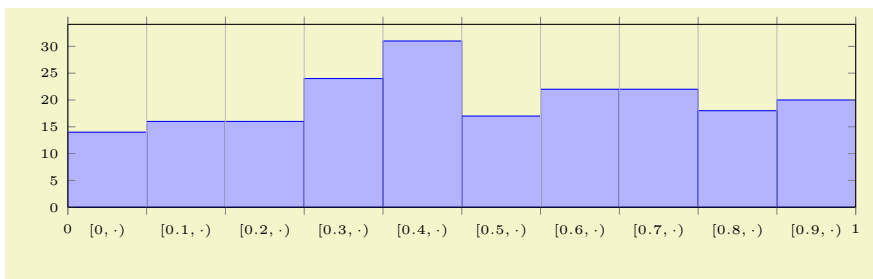
```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}\usepgfplotslibrary{statistics}
\begin{tikzpicture}
\begin{axis}[
  tiny,
  height=4cm,width=12cm,
  ybar interval,
  ymin=0,
  xmin=0,xmax=1,
  axis on top,
  extra x ticks={0,1},
  extra x tick style={
    grid=none,
    x tick label as interval=false,
    xticklabel=$\pgfmathprintnumber\tick$
  },
  xticklabel={$[\pgfmathprintnumber[fixed]\tick,\cdot)$}
]
    \addplot+[samples=200,hist] {rnd};
\end{axis}
\end{tikzpicture}
```

The example uses the `rnd` method of PGF which defines `y` to contain uniform random numbers in the range $[0, 1]$. Then, it configures `hist`. Note that `hist` has the default `data=y` such that it uses the `y` coordinate as input. Note furthermore that the `x` value is effectively ignored here. The options after `\begin{axis}[...]` are mainly to scale the graphics and to insert the right limits. The `extra x ticks` method is inserted to demonstrate how to add further tick marks without affecting the overall layout. Note that the `extra x tick style` sets `x tick label as interval`=false to disable the special tick handling which is active for the rest of the plot.

The following keys configure `hist`. If they are provided inside of ⟨*options*⟩, the common key prefix `hist/` can be omitted.

/pgfplots/hist/data={⟨*expression*⟩}   (initially y)

> Tells `hist` how to get its data. The common idea is to provide a mathematical ⟨*expression*⟩ which depends on data supplied by the `\addplot` statement. For example, if you have `\addplot expression`, the ⟨*expression*⟩ may depend upon `x`, `y` or `z`. In case of an `\addplot table` input routine, the ⟨*expression*⟩ can employ `\thisrow{`⟨*colname*⟩`}` to access the currently active table row in the designated column.
>
> It is also possible to avoid invocations of the math parser. Use `hist/data value`={⟨*value*⟩} instead to do so. Here, ⟨*value*⟩ should be of a numeric constant.
>
> The initial configuration employs what would usually become the final `y` coordinate as input (to be more precise, the initial value is `data value=\pgfkeysvalueof{/data point/y}`).

/pgfplots/hist/data min={⟨*min value*⟩}   (initially /pgfplots/xmin)
/pgfplots/hist/data max={⟨*max value*⟩}   (initially /pgfplots/xmax)

> Allows to provide the min/max values (the $\underline{m}$ and $\overline{m}$) values manually.
>
> If empty, these values will be deduced from the input data range.
>
> The resulting interval will be splitted into `hist/bins` intervals.
>
> The initial configuration uses any provided data limits, i.e. the (natural) choices `hist/data min`=xmin and `hist/data max`=xmax.

/pgfplots/hist/bins={⟨*number of intervals*⟩}   (initially 10)

> Specifies the number of intervals to use.

/pgfplots/hist/intervals={⟨*true,false*⟩}   (initially true)

> If `intervals=true` (the initial configuration), `hist` will generate $N + 1$ coordinates, with

$$\underline{m} = x_0 < x_1 < \cdots < x_N = \overline{m}$$

> where $[\underline{m}, \overline{m}]$ is the data range. In this case, the data points for x_{N-1} and x_N will get the same value, namely the number of elements in the last bin. This is (only) useful in conjunction with `const plot` or `ybar interval`.

If `intervals=false`, the last data point will be omitted and exactly N coordinates will be generated. In this case, the right end point is not returned explicitly.

/pgfplots/**hist/cumulative**={⟨*true,false*⟩}   (initially `false`)

Allows to compute a cumulative histogram.

A cumulative histogram uses the sum of all previous bins and the current one as final value.

Here is the example from above, this time with **hist/cumulative**:


```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}\usepgfplotslibrary{statistics}
\begin{tikzpicture}
\begin{axis}[
  ybar interval,
  xtick=,% reset from ybar interval
  xticklabel=
    {$[\pgfmathprintnumber\tick,
      \pgfmathprintnumber\nexttick)$}
]]
% a data file containing 8000 normally distributed
% random numbers of mean 0 and variance 1
\addplot+[hist={
      data=x,
      cumulative}]
  file {plotdata/pgfplots.randn.dat};

\end{axis}
\end{tikzpicture}
```
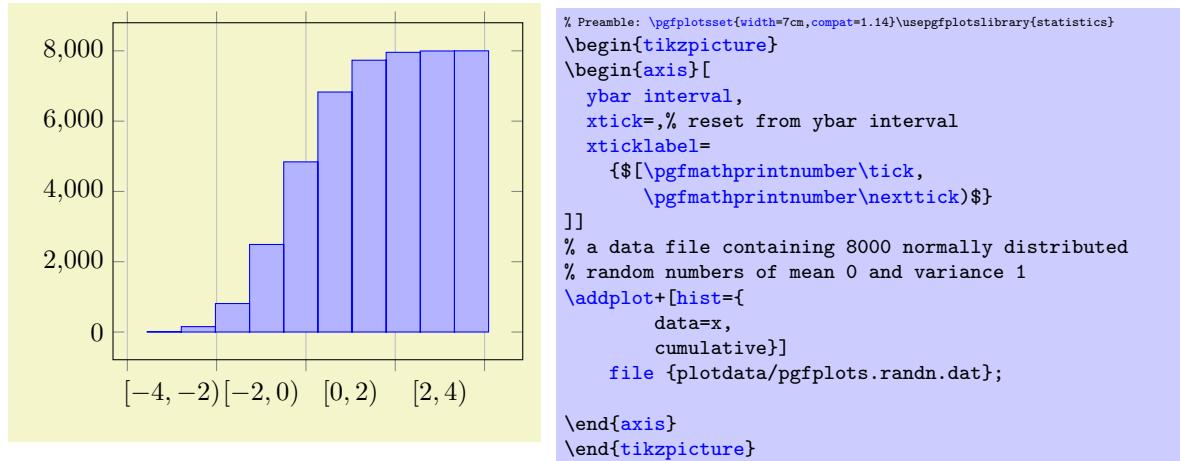
/pgfplots/**hist/density**={⟨*true,false*⟩}   (initially `false`)

An extension by Jürnjakob Dugge

Enables density estimation mode. If **hist/density** is active, the resulting data points will be renormalized such that the overall "mass" equals 1.
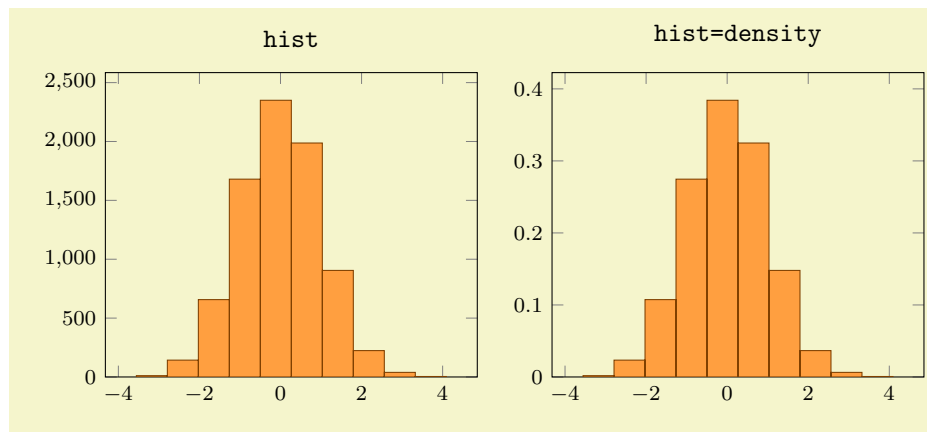
```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}\usepgfplotslibrary{statistics}
\begin{tikzpicture}
\begin{axis}[small,ymin=0,title=\texttt{hist}]
\addplot [
    hist,
    fill=orange!75,
    draw=orange!50!black]
    table [y index=0] {plotdata/pgfplots.randn.dat};
\end{axis}
\end{tikzpicture}
%
\pgfplotsexpensiveexample
\begin{tikzpicture}
\begin{axis}[small,ymin=0, title=\texttt{hist=density}]
\addplot [
    hist=density,
    fill=orange!75,
    draw=orange!50!black]
    table [y index=0] {plotdata/pgfplots.randn.dat};
\end{axis}
\end{tikzpicture}
```

The keys `hist/density` and `hist/cumulative` can be combined as well:
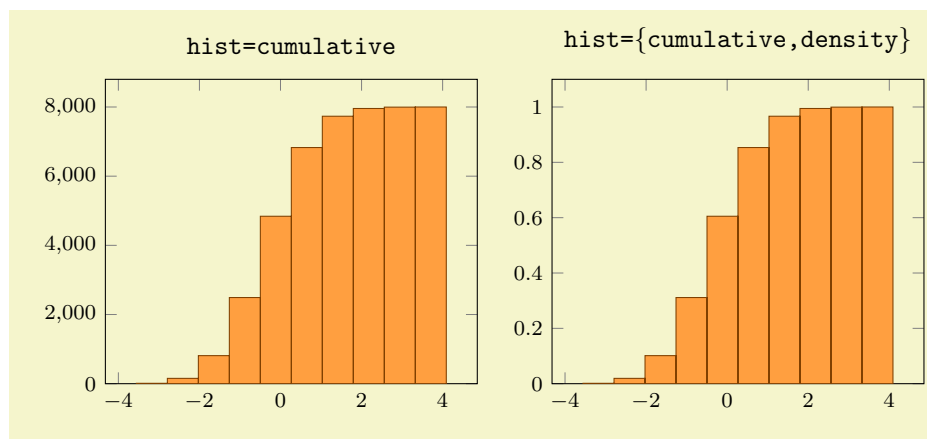

```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}\usepgfplotslibrary{statistics}
\begin{tikzpicture}
\begin{axis}[small,ymin=0, title=\texttt{hist=cumulative}]
\addplot [
    hist=cumulative,
    fill=orange!75,
    draw=orange!50!black]
    table [y index=0] {plotdata/pgfplots.randn.dat};
\end{axis}
\end{tikzpicture}
%
\pgfplotsexpensiveexample
\begin{tikzpicture}
\begin{axis}[small,ymin=0, title=\texttt{hist=\{cumulative,density\}}]
\addplot [
    hist={cumulative,density},
    fill=orange!75,
    draw=orange!50!black]
    table [y index=0] {plotdata/pgfplots.randn.dat};
\end{axis}
\end{tikzpicture}
```

/pgfplots/**hist/handler**   (style, initially `ybar interval`)

Allows to change the way the generated coordinates are visualized. The `hist/handler` key is a style, so use `hist/handler/.style`={`const plot`} to change it.
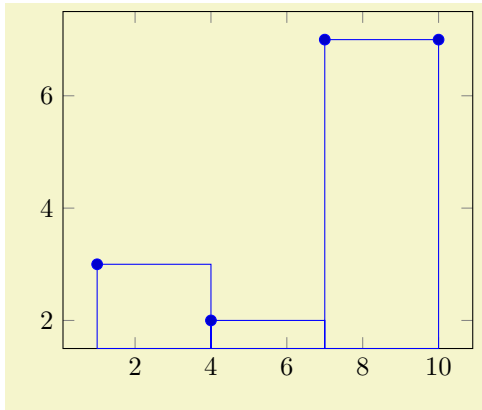
```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}\usepgfplotslibrary{statistics}
\begin{tikzpicture}
\begin{axis}

    \addplot+[hist={bins=3}]
        table[row sep=\\,y index=0] {
        data\\
        1\\ 2\\ 1\\ 5\\ 4\\ 10\\
        7\\ 10\\ 9\\ 8\\ 9\\ 9\\
    };
\end{axis}
\end{tikzpicture}
```
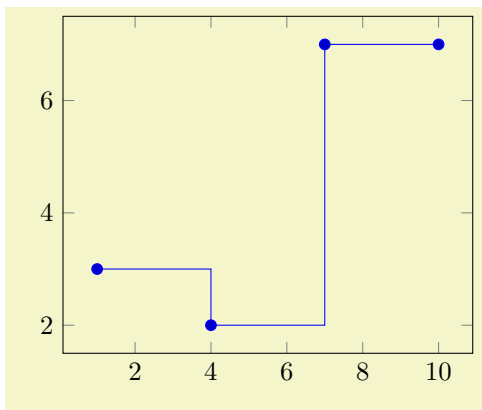
```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}\usepgfplotslibrary{statistics}
\begin{tikzpicture}
\begin{axis}

    \addplot+[hist={bins=3,
        handler/.style={const plot}}
    ]
        table[row sep=\\,y index=0] {
        data\\
        1\\ 2\\ 1\\ 5\\ 4\\ 10\\
        7\\ 10\\ 9\\ 8\\ 9\\ 9\\
    };
\end{axis}
\end{tikzpicture}
```
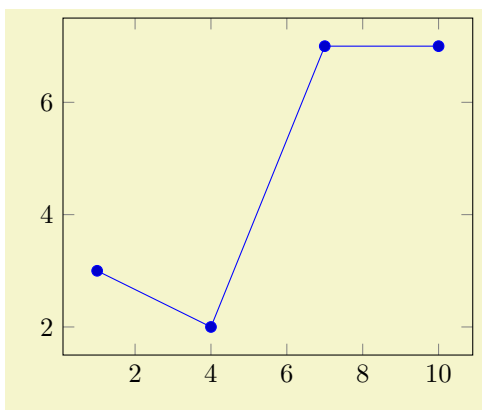
```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}\usepgfplotslibrary{statistics}
\begin{tikzpicture}
\begin{axis}

    \addplot+[hist={bins=3,
        handler/.style={sharp plot}}
    ]
        table[row sep=\\,y index=0] {
        data\\
        1\\ 2\\ 1\\ 5\\ 4\\ 10\\
        7\\ 10\\ 9\\ 8\\ 9\\ 9\\
    };
\end{axis}
\end{tikzpicture}
```

Note that sharp plot might benefit from intervals=false:
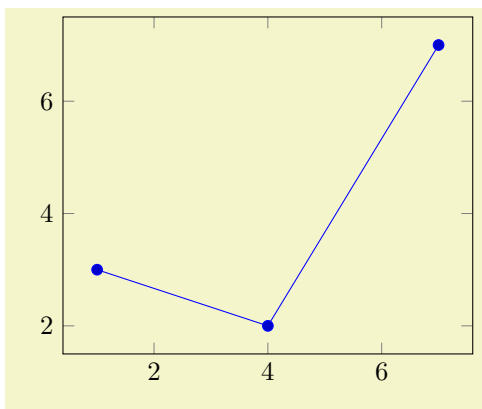
```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}\usepgfplotslibrary{statistics}
\begin{tikzpicture}
\begin{axis}

    \addplot+[hist={bins=3,
        handler/.style={sharp plot},
        intervals=false}
    ]
        table[row sep=\\,y index=0] {
        data\\
        1\\ 2\\ 1\\ 5\\ 4\\ 10\\
        7\\ 10\\ 9\\ 8\\ 9\\ 9\\
    };
\end{axis}
\end{tikzpicture}
```

/pgfplots/hist/data filter/.code={⟨...⟩}

Allows to define coordinate filters, similar to the coordinate filter key `x filter` described in Section 4.22. The argument `#1` is the coordinate as it has been found after processing `hist/data`. The code is supposed to assign `\pgfmathresult` to contain the result. If `\pgfmathresult` is empty afterwards, it will be skipped. Otherwise, it is supposed to contain a number.

This filter is applied *before* the histogram is computed. Note that `x filter` and `y filter` are applied *after* the histogram is computed.

Note that predefined styles like `each nth point` can also be applied to `hist/data` if

1. an asterisk '`*`' is appended to the predefined style's name and
2. the first argument to the style is `hist/data`.

For example, `each nth point*={hist/data}{2}` will skip each second input value of `hist/data` (try it out).

`/pgfplots/hist/data coord trafo/.code={⟨...⟩}`
`/pgfplots/hist/data coord inv trafo/.code={⟨...⟩}`

These keys work in the same way as for `x coord trafo` and `x coord inv trafo`. They are applied to the `hist/data` value before the histogram is evaluated and after the result value is assigned, respectively.

Note that `hist` will apply the `hist/data coord inv trafo` before it visualizes its results. Consequently, it may be necessary to assign a similar transformation to `x coord trafo` as well.

See the documentation of `x coord trafo` for more information about custom transformations.

`/pgfplots/hist/symbolic coords={⟨list⟩}`

A style which enables `symbolic x coords` for an axis containing `hist` plots:
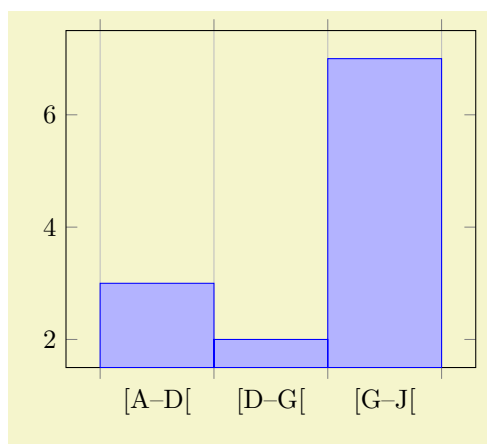
```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}\usepgfplotslibrary{statistics}
\begin{tikzpicture}
\begin{axis}[
  ybar interval,
  hist/symbolic coords={A,B,C,D,E,F,G,H,I,J},
  xticklabel={[\tick--\nexttick[}],
]
    \addplot+[hist={bins=3}]
        table[row sep=\\,y index=0] {
        data\\
        A\\ B\\ A\\ D\\ F\\ J\\
        G\\ J\\ I\\ H\\ I\\ I\\
    };
\end{axis}
\end{tikzpicture}
```

The style does two things: first, it defines `hist/data coord trafo` and `hist/data coord inv trafo`, then, it calls `symbolic x coords` with the same argument.

Attention : do not use `hist/data`=x or other symbolic values as input when you have `symbolic coords`. Rather than symbolic values, you need to provide *expandable* values like `\pgfkeysvalueof{/data point/x}` (which has the same effect, but directly expands to the correct value).

Please refer to the documentation of `symbolic x coords` for further details about symbolic coordinates.

5.13 Ternary Diagrams

```
\usepgfplotslibrary{ternary} % LaTeX and plain TeX
\usepgfplotslibrary[ternary] % ConTeXt
\usetikzlibrary{pgfplots.ternary} % LaTeX and plain TeX
\usetikzlibrary[pgfplots.ternary] % ConTeXt
```

A library to draw ternary diagrams.

A ternary diagram visualizes three–component systems such that the sum of them yields 100%. Ternary diagrams are triangular axes.

5.13.1 Ternary Axis

\begin{ternaryaxis}[⟨options⟩]
  ⟨environment contents⟩
\end{ternaryaxis}

The axis environment for ternary axes.
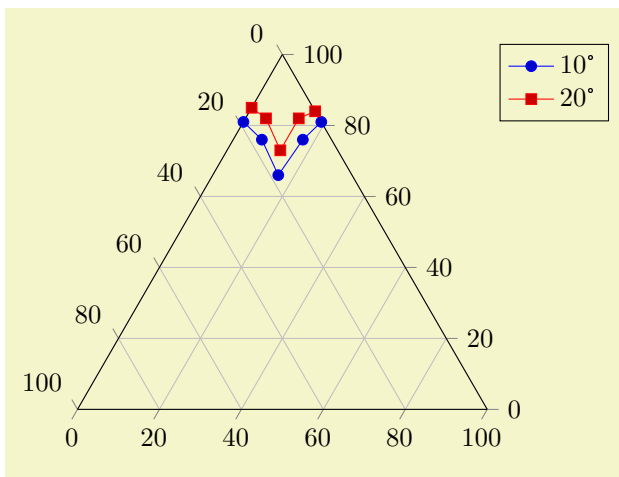

```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}\usepgfplotslibrary{ternary}
\begin{tikzpicture}
\begin{ternaryaxis}
    \addplot3 coordinates {
        (0.81,    0.19,    0.00)
        (0.76,    0.17,    0.07)
        (0.66,    0.16,    0.16)
        (0.76,    0.07,    0.17)
        (0.81,    0.00,    0.19)
    };

    \addplot3 coordinates {
        (0.85,    0.15,    0.00)
        (0.82,    0.13,    0.05)
        (0.73,    0.14,    0.13)
        (0.82,    0.06,    0.13)
        (0.84,    0.00,    0.16)
    };
    \legend{$10$\textdegree, $20$\textdegree}
\end{ternaryaxis}
\end{tikzpicture}
```

A `ternaryaxis` works with *relative coordinates*: each data point consists of three components x, y, z. Their sum forms a compound entity which has 100% (of whatever). In the standard configuration, we have $x, y, z \in [0, 1]$. The unit interval is not necessary: you can as well choose *absolute data ranges* $x \in [x_{\min}, x_{\max}]$, $y \in [y_{\min}, y_{\max}]$ and $z \in [z_{\min}, z_{\max}]$. The important thing is that the relative values

$$\tilde{x} := \frac{x - x_{\min}}{x_{\max} - x_{\min}}, \ \tilde{y} := \frac{y - y_{\min}}{y_{\max} - y_{\min}}, \ \tilde{z} := \frac{z - z_{\min}}{z_{\max} - z_{\min}}$$

sum up to 100%, i.e. $\tilde{x} + \tilde{y} + \tilde{z} = 1$. Thus, PGFPLOTS computes $\tilde{x}$, $\tilde{y}$ and $\tilde{z}$ and interpretes them as barycentric (triangular) coordinates.

For this to work, it is **crucial to provide** `xmin`, `xmax`, `ymin`, `ymax` and `zmin`, `zmax` precisely! The initial configuration fixes them to the unit interval.

What happens behind the scenes is that a data point (x, y, z) is placed at X, Y determined by

$$\begin{bmatrix} X(x, y, z) \\ Y(x, y, z) \end{bmatrix} = \tilde{x}A + \tilde{y}B + \tilde{z}C = \begin{bmatrix} \frac{1}{2}\tilde{x} + 2\tilde{z} \\ \frac{\sqrt{3}}{2}\tilde{x} \end{bmatrix}$$

where $A = (^1/_2, \sqrt{3}/_2)$ is top corner of the triangle, $B = (0,0)$ the lower left and $C = (1,0)$ the lower right one. The $\tilde{y}$ component is not really necessary due to the linear dependency $\tilde{x} + \tilde{y} + \tilde{z} = 1$.

The input coordinate $(100\%, 0\%, 0\%)$ is mapped to A, the input coordinate $(0\%, 100\%, 0\%)$ to B and $(0\%, 0\%, 100\%)$ to C (Acrobat Reader: click into the axis to verify it).
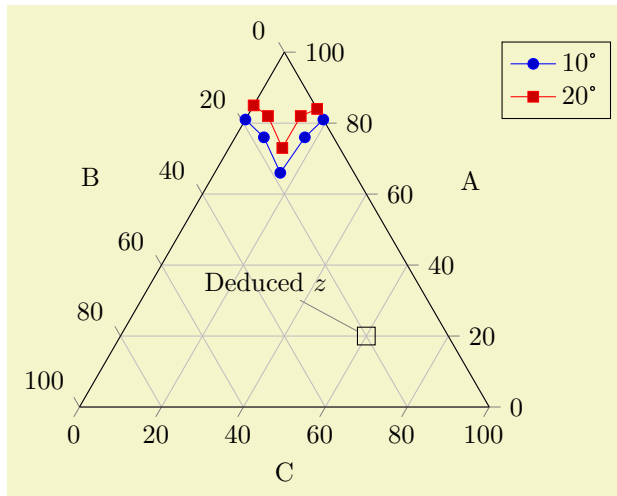

```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}\usepgfplotslibrary{ternary}
\begin{tikzpicture}
\begin{ternaryaxis}[xlabel=A,ylabel=B,zlabel=C]
    \addplot3 coordinates {
        (0.81,  0.19,  0.00)
        (0.76,  0.17,  0.07)
        (0.66,  0.16,  0.16)
        (0.76,  0.07,  0.17)
        (0.81,  0.00,  0.19)
    };

    \addplot3 coordinates {
        (0.85,  0.15,  0.00)
        (0.82,  0.13,  0.05)
        (0.73,  0.14,  0.13)
        (0.82,  0.06,  0.13)
        (0.84,  0.00,  0.16)
    };

    \node[pin=130:Deduced $z$,draw=black] at (0.2,0.2) {};

    \legend{$10$\textdegree, $20$\textdegree}
\end{ternaryaxis}
\end{tikzpicture}
```

A `ternaryaxis` can contain zero, one or more `\addplot3` commands, just as a usual `axis`. In case you provide only two–dimensional coordinates (for example using `\addplot` or `axis cs`), the third component is deduced automatically such that components sum to 100%. The `\addplot3` command can use any of the accepted input formats, for example using `coordinates`, `table`, `expression` or whatever – but the input is always interpreted as barycentric coordinates (three components summing up to 100%).
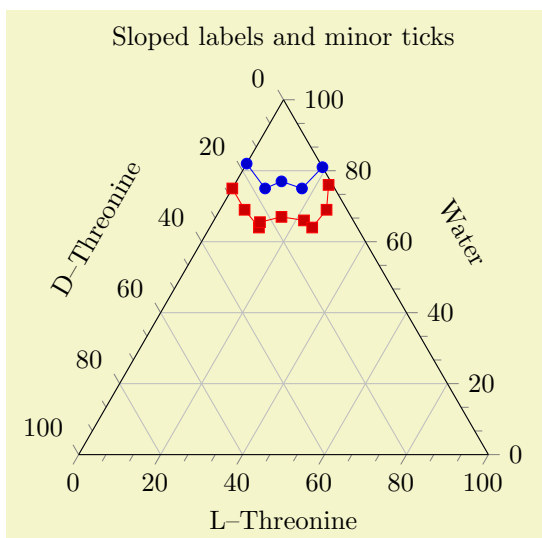
```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}\usepgfplotslibrary{ternary}
\begin{tikzpicture}
\begin{ternaryaxis}[
    title=Sloped labels and minor ticks,
    xlabel=Water,
    ylabel=D--Threonine,
    zlabel=L--Threonine,
    label style={sloped},
    minor tick num=2,
]
    \addplot3 coordinates {
        (0.82,  0.18,  0.00)
        (0.75,  0.17,  0.08)
        (0.77,  0.12,  0.11)
        (0.75,  0.08,  0.17)
        (0.81,  0.00,  0.19)
    };
    \addplot3 coordinates {
        (0.75,  0.25,  0.00)
        (0.69,  0.25,  0.06)
        (0.64,  0.24,  0.12)
        (0.655, 0.23,  0.115)
        (0.67,  0.17,  0.16)
        (0.66,  0.12,  0.22)
        (0.64,  0.11,  0.25)
        (0.69,  0.05,  0.26)
        (0.76,  0.01,  0.23)
    };
\end{ternaryaxis}
\end{tikzpicture}
```
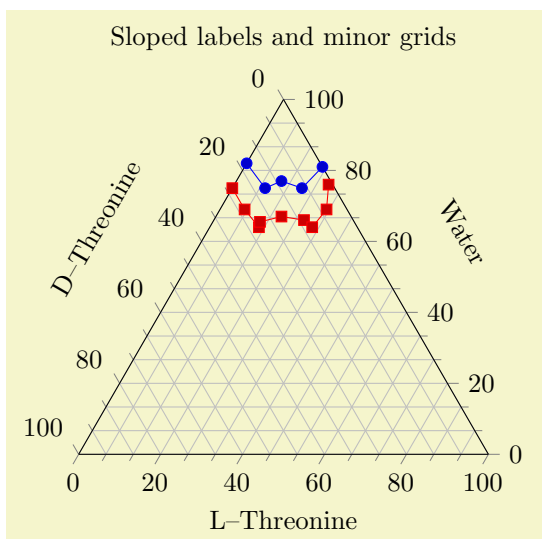


```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}\usepgfplotslibrary{ternary}
\begin{tikzpicture}
\begin{ternaryaxis}[
    title=Sloped labels and minor grids,
    xlabel=Water,
    ylabel=D--Threonine,
    zlabel=L--Threonine,
    label style={sloped},
    minor tick num=2,
    grid=both,
]
    \addplot3 coordinates {
        (0.82,  0.18,  0.00)
        (0.75,  0.17,  0.08)
        (0.77,  0.12,  0.11)
        (0.75,  0.08,  0.17)
        (0.81,  0.00,  0.19)
    };
    \addplot3 coordinates {
        (0.75,  0.25,  0.00)
        (0.69,  0.25,  0.06)
        (0.64,  0.24,  0.12)
        (0.655, 0.23,  0.115)
        (0.67,  0.17,  0.16)
        (0.66,  0.12,  0.22)
        (0.64,  0.11,  0.25)
        (0.69,  0.05,  0.26)
        (0.76,  0.01,  0.23)
    };
\end{ternaryaxis}
\end{tikzpicture}
```

A `ternaryaxis` supports (most of) the PGFPLOTS axis interface, among them the `grid` option, the `xtick`={⟨positions⟩} way to provide ticks, including `extra x ticks` and its variants. Of course, it can also contain any of the `mark`, `color` and `cycle list` options of a normal axis.

The following example is a (crude) copy of an example of

    http://www.sv.vt.edu/classes/MSE2094_NoteBook/96ClassProj/experimental/ternary2.html

and uses `area style` to change `cycle list` and the legend appearance.
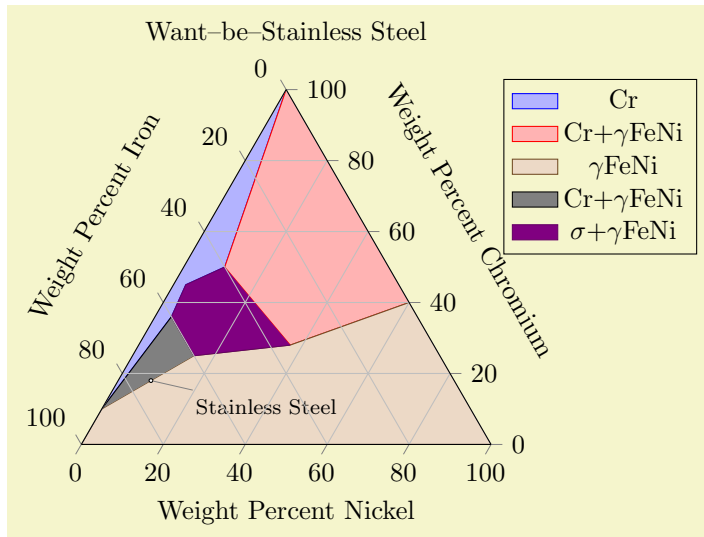
```latex
% Preamble: \pgfplotsset{width=7cm,compat=1.14}\usepgfplotslibrary{ternary}
\begin{tikzpicture}
\begin{ternaryaxis}[
    title=Want--be--Stainless Steel,
    xlabel=Weight Percent Chromium,
    ylabel=Weight Percent Iron,
    zlabel=Weight Percent Nickel,
    label style=sloped,
    area style,
]
    \addplot3 table {
    A B C
    1 0 0
    0.5 0.4 0.1
    0.45 0.52 0.03
    0.36 0.6 0.04
    0.1 0.9 0
    };
    \addlegendentry{Cr}

    \addplot3 table {
    A B C
    1 0 0
    0.5 0.4 0.1
    0.28 0.35 0.37
    0.4 0 0.6
    };
    \addlegendentry{Cr+$\gamma$FeNi}

    \addplot3 table {
    0.4 0 0.6
    0.28 0.35 0.37
    0.25 0.6 0.15
    0.1 0.9 0
    0 1 0
    0 0 1
    };
    \addlegendentry{$\gamma$FeNi}

    \addplot3 table {
    0.1 0.9 0
    0.36 0.6 0.04
    0.25 0.6 0.15
    };
    \addlegendentry{Cr+$\gamma$FeNi}

    \addplot3 table {
    0.5 0.4 0.1
    0.45 0.52 0.03
    0.36 0.6 0.04
    0.25 0.6 0.15
    0.28 0.35 0.37
    };
    \addlegendentry{$\sigma$+$\gamma$FeNi}

    \node[inner sep=0.5pt,circle,draw,fill=white,pin=-15:\footnotesize Stainless Steel]
      at (0.18,0.74,0.08) {};

\end{ternaryaxis}
\end{tikzpicture}
```

Ternary plots can also use `contour prepared` to plot contour lines. The following example is a (crude) copy of an example of

http://www.sv.vt.edu/classes/MSE2094_NoteBook/96ClassProj/experimental/ternary2.html:

```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}\usepgfplotslibrary{ternary}
\begin{tikzpicture}
\begin{ternaryaxis}[
    title=Want--be--Stainless Steel,
    xlabel=Weight Percent Chromium,
    ylabel=Weight Percent Iron,
    zlabel=Weight Percent Nickel,
    label style=sloped,
]

% plotdata/pgfplotsternary.example1.dat:
%
% Chromium Iron Nickel Temperature
% 0.90     0.0      0.10    1700
% 0.85     0.14     0.00    1700
%
% 0.85     0.00     0.15    1600
% 0.78     0.22     0.00    1600
% 0.71     0.29     0.00    1600
% ....
\addplot3[contour prepared={labels over line},
        point meta=\thisrow{Temperature}]
    table[x=Chromium,y=Iron,z=Nickel]
        {plotdata/pgfplotsternary.example1.dat};
\end{ternaryaxis}
\end{tikzpicture}
```

The `contour prepared`={labels over line} installs the display style `contour/labels over line` and expects precomputed contour lines from the input stream. Here, the input stream is a table, consisting of the three relative components for Chromium, Iron and Nickel – and the `point meta` is set to be the Temperature column. The `contour prepared` style uses the (x, y, z) coordinate to plot the data point and the `point meta` to determine contour labels (the initial configuration of `contour prepared` is to use `point meta`=z). The output thus allows to use both barycentric coordinates (ternary components) *and* contour labels.

/pgfplots/**ternary limits relative**=true|false   (initially true)

/pgfplots/**ternary relative limits**=true|false   (initially true)

Allows to switch tick labels between relative numbers in the range $[0, 100]$ or absolute numbers.

The choice `ternary limits relative`=true accepts data in any input number range, for example $(x, y, z) \in [0, 1]^3$, or $(x, y, z) \in [0, 100]^3$ or in any absolute scala of the form $x_i \in [\underline{x}_i, \overline{x}_i]$ for $x_i \in \{x, y, z\}$ (remember that it is crucial to communicate these limits to PGFPLOTS explicitly using `xmin`, `xmax`, `ymin`, `ymax` and `zmin`, `zmax` such that relative coordinates can be computed, see the description above for details). In every case, relative tick labels are drawn, i.e. tick labels in the range $[0, 100]$.
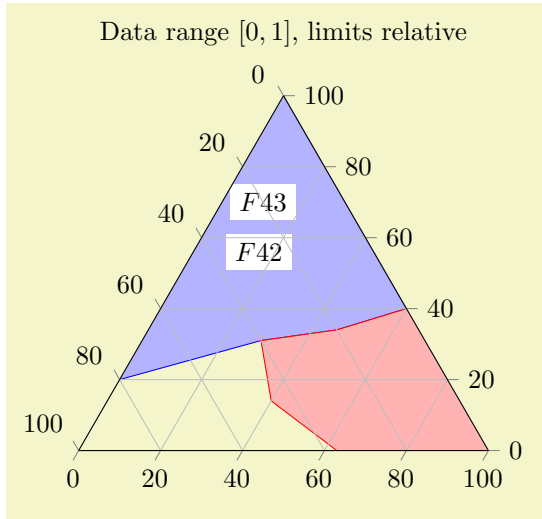
```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}\usepgfplotslibrary{ternary}
\begin{tikzpicture}
\begin{ternaryaxis}[
    ternary limits relative,
    title={Data range $[0,1]$, limits relative},
    area style]
\addplot3 coordinates {
    (0.2,0.8,0)
    (0.31,0.4,0.29)
    (0.34,0.2,0.46)
    (0.4,0,0.6)
    (1,0,0)
};
\addplot3 coordinates {
    (0.4,0,0.6)
    (0.34,0.2,0.46)
    (0.31,0.4,0.29)
    (0.14,0.46,0.4)
    (0,0.37,0.63)
    (0,0,1)
};
\node[fill=white]
    at (axis cs:0.56,0.28,0.16) {$F 42$};
\node[fill=white]
    at (0.7,0.2) {$F 43$};
\end{ternaryaxis}
\end{tikzpicture}
```

```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}\usepgfplotslibrary{ternary}
\begin{tikzpicture}
\begin{ternaryaxis}[
    xmax=500,ymin=1,ymax=2,
    ternary limits relative,
    title={Data range $x\in[0,500]$,
        $y\in[1,2]$, $z\in[0,1]$ limits relative},
    area style]
\addplot3 coordinates {
    (100,1.8,0)
    (155,1.4,0.29)
    (170,1.2,0.46)
    (200,1,0.6)
    (500,1,0)
};
\addplot3 coordinates {
    (200,1,0.6)
    (170,1.2,0.46)
    (155,1.4,0.29)
    (70,1.46,0.4)
    (0,1.37,0.63)
    (0,1,1)
};
\node[fill=white]
    at (axis cs:280,1.28,0.16) {$F 42$};
\node[fill=white]
    at (0.7,0.2) {$F 43$};
\end{ternaryaxis}
\end{tikzpicture}
```

The choice `ternary limits relative`=false accepts the same data ranges, but it draws tick labels in the very same data ranges.

Data range $x \in [0, 500]$, $y \in [1, 2]$, $z \in [0, 1]$ limits absolute
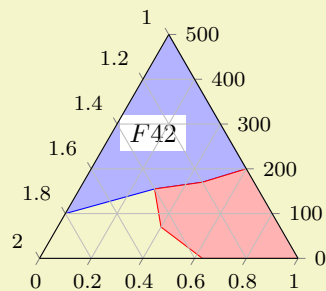
```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}\usepgfplotslibrary{ternary}
\begin{tikzpicture}
\begin{ternaryaxis}[
    ternary limits relative=false,
    xmax=500,ymin=1,ymax=2,
    title={Data range $x\in[0,500]$,
        $y\in[1,2]$, $z\in[0,1]$ limits absolute},
    footnotesize, % just for the sake of demonstration...
    area style]
\addplot3 coordinates {
    (100,1.8,0)
    (155,1.4,0.29)
    (170,1.2,0.46)
    (200,1,0.6)
    (500,1,0)
};
\addplot3 coordinates {
    (200,1,0.6)
    (170,1.2,0.46)
    (155,1.4,0.29)
    (70,1.46,0.4)
    (0,1.37,0.63)
    (0,1,1)
};
\node[fill=white]
    at (axis cs:280,1.28,0.16) {$F 42$};
\node[fill=white]
    at (0.7,0.2) {$F 43$};
\end{ternaryaxis}
\end{tikzpicture}
```

Coordinate system `cartesian cs`

A coordinate system which allows Cartesian coordinates. The lower left point has coordinate $(0,0)$, the lower right point has $(1,0)$ and the upper point of the triangle is at $(1/2, \sqrt{3}/2)$.

If you use the standard point syntax (x, y) in path commands inside of the axis, you'll get Cartesian coordinates. If you want to use it for axis descriptions (like `xlabel`), you'll have to write `cartesian cs:0,0` explicitly (axis labels have the default coordinate system `axis description cs`).
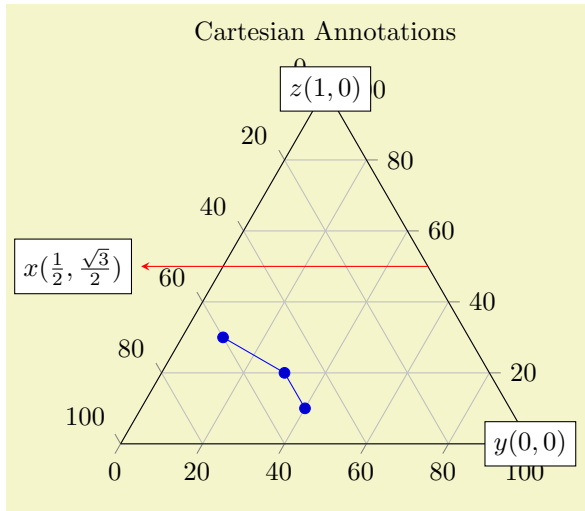

```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}\usepgfplotslibrary{ternary}
\begin{tikzpicture}
    \begin{ternaryaxis}[
        title=Cartesian Annotations,
        clip=false]

    \addplot3 coordinates {
        (0.1,0.5,0.4)
        (0.2,0.5,0.3)
        (0.3,0.6,0.1)
    };

    \node[fill=white,draw] at (0,0) {$y (0,0)$};
    \node[fill=white,draw] at (1,0) {$z (1,0)$};
    \node[fill=white,draw] at (0.5,{sqrt(3)/2})
        {$x (\frac12,\frac{\sqrt3}{2})$};

    \draw[red,-stealth] (0.5,0) -- (0.5,0.7);
    \end{ternaryaxis}
\end{tikzpicture}
```

/pgfplots/`every ternary axis`   (style, no value)

A style which is installed at the beginning of every ternary axis. It is used to adjust some of the PGFPLOTS keys to fit the triangular shape.

The initial configuration is

```
\pgfplotsset{
    every ternary axis/.style={
        tick align=outside,
        grid=major,
        xticklabel style={anchor=west},
        every 3d description/.style={},
        every axis x label/.style={at={(ticklabel cs:0.5)},anchor=near ticklabel},
        every axis y label/.style={at={(ticklabel cs:0.5)},anchor=near ticklabel},
        every axis z label/.style={at={(ticklabel cs:0.5)},anchor=near ticklabel},
        every x tick scale label/.style=
          {at={(xticklabel cs:0.95,5pt)},anchor=near xticklabel,inner sep=0pt},
        every y tick scale label/.style=
          {at={(yticklabel cs:0.95,5pt)},anchor=near yticklabel,inner sep=0pt},
        every z tick scale label/.style=
          {at={(yticklabel cs:0.95,5pt)},anchor=near yticklabel,inner sep=0pt},
        every axis title shift=15pt,
        every axis legend/.style={
            cells={anchor=center},
            inner xsep=3pt,inner ysep=2pt,nodes={inner sep=2pt,text depth=0.15em},
            shape=rectangle,
            fill=white,
            draw=black,
            at={(1.03,1.03)},
            anchor=north west,
        },
        annot/point format 3d/.initial={(\%.2f, \%.2f, \%.2f)},
    },
}
```

5.13.2 Tieline Plots

/tikz/**tieline**={⟨*options with* tieline/ *prefix*⟩}

\addplot+[**tieline**={⟨*options with* tieline/ *prefix*⟩}]

A plot handler for use in ternary diagrams which plots tie lines and binodal curves.

On input, it accepts *pairs* of coordinates, $A^{(i)} = (A_x^{(i)}, A_y^{(i)}, A_z^{(i)})$ and $B^{(i)} = (B_x^{(1)}, B_y^{(2)}, B_z^{(3)})$, for $i = 1, \ldots, N$ (i.e. it requires a total of six coordinates, perhaps plus additional color data).

On output, it connects the pairs, i.e. for every fixed $i = 1, \ldots, N$, it connects $A^{(i)} - B^{(i)}$ (the so-called "tie lines"). In addition, it also draws the binodal curve, which is made up by connecting all $A^{(i)}$ and then, in reverse ordering, all $B^{(i)}$: $A^{(1)} - A^{(2)} - \cdots - A^{(N)} - B^{(N)} - B^{(N-1)} - \cdots - B^{(1)}$:
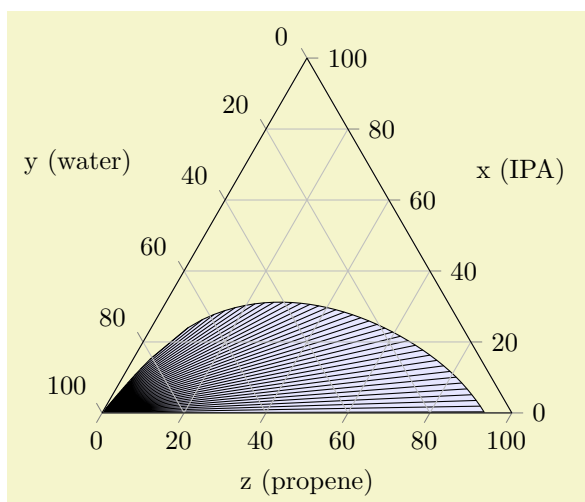

```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}\usepgfplotslibrary{ternary}
\begin{tikzpicture}
\begin{ternaryaxis}[
    xlabel=x (IPA),
    ylabel=y (water),
    zlabel=z (propene),
    axis on top,
]
% plotdata/ternary_data.txt is a table of the form
%A_propene A_water A_IPA   B_propene B_water B_IPA
% 0.0009    0.9990  0       0.9333    0.0667  0
% 0.0009    0.9988  0.0002  0.9303    0.0665  0.0032
% 0.0011    0.9975  0.0013  0.9135    0.0673  0.0191
% 0.0013    0.9962  0.0024  0.8956    0.0693  0.0351
%...
    \addplot3[tieline,fill=blue!10]
    table [x=A_IPA,y=A_water,z=A_propene]
        {plotdata/ternary_data.txt};
\end{ternaryaxis}
\end{tikzpicture}
```

We see that each input line has six columns, and each six columns are taken into account (this is different from other plot handlers!). The six columns make up the three components of the A and B points, respectively. In the example above, we used explicit column names and provided A_x using **x**=A_IPA, A_y using **y**=A_water and A_z using **z**=A_propene. Note that these keys are the common input method for \addplot table; they are nothing special (that means we could also use x index instead). The three columns for B can be provided manually (see below), or deduced automatically: in our case, the value

for B_x has been found in the third column after `x=A_IPA` (which is `B_IPA`); the value for B_y has been found in the third column after `y=A_water` and B_z is made up from the third column after `z=A_propene`. In other words, the B value is searched (by default) by adding 3 to the column index of the respective A coordinate.

You do not need to provide *any* column names; in this case, the first three columns make up A (in the order of appearance) and the following three make up B.

The only supported input type for `tieline` plots is table input. It is optimized to use `\addplot3 table` (as described above). To use the two–dimensional variant `\addplot table`, you need to tell PGFPLOTS explicitly which columns make up A_x, A_y, B_x, B_y; the z coordinates are deduced automatically such that the result sums to 100%.

/pgfplots/**table/tie end x**={⟨*colname*⟩}	(initially **empty**)
/pgfplots/**table/tie end y**={⟨*colname*⟩}	(initially **empty**)
/pgfplots/**table/tie end z**={⟨*colname*⟩}	(initially **empty**)
/pgfplots/**table/tie end x index**={⟨*col index*⟩}	(initially **empty**)
/pgfplots/**table/tie end y index**={⟨*col index*⟩}	(initially **empty**)
/pgfplots/**table/tie end z index**={⟨*col index*⟩}	(initially **empty**)

These keys can be used to provide column names or column indices for B_x, B_y and B_z, respectively. They can be provided like

`\addplot3[tieline] table[tie end y=B_water] ....`

Note that the `tie end x` keys are *only* available if the `tieline` option has been used before.

The values for A are provided with `table/x`, `table/x index` and its variants as for any other plot type.

The `tieline` plot handler accepts several options to customize the appearance. You can provide them as argument after `tieline`, using `tieline={⟨options⟩}`. In this case, the `tieline/` prefix can be omitted. The keys are described in the following:

/pgfplots/**tieline/each nth tie**={⟨*number*⟩}   (initially **empty**)

Allows to draw only each nth tie line, even though the binodal curve uses all provided coordinates:
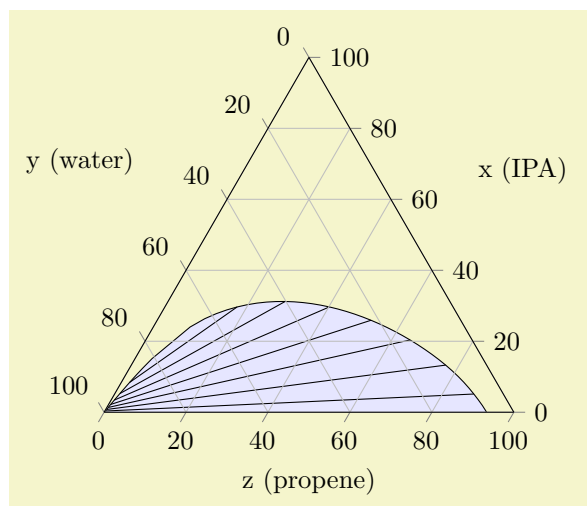

```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}\usepgfplotslibrary{ternary}
\begin{tikzpicture}
\begin{ternaryaxis}[
    xlabel=x (IPA),
    ylabel=y (water),
    zlabel=z (propene),
    axis on top,
]
% plotdata/ternary_data.txt is a table of the form
%A_propene A_water A_IPA  B_propene B_water B_IPA
% 0.0009    0.9990  0       0.9333    0.0667  0
% 0.0009    0.9988  0.0002 0.9303    0.0665  0.0032
% 0.0011    0.9975  0.0013 0.9135    0.0673  0.0191
% 0.0013    0.9962  0.0024 0.8956    0.0693  0.0351
%...
    \addplot3[
        tieline={each nth tie=5},
        fill=blue!10,
    ]
    table [x=A_IPA,y=A_water,z=A_propene]
        {plotdata/ternary_data.txt};
\end{ternaryaxis}
\end{tikzpicture}
```

Note that plot `mark`s (if any) are drawn on every input position, use the `mark repeat` option to change that.

/pgfplots/**tieline/tieline style**={⟨*options*⟩}

Appends ⟨*options*⟩ to the style `tieline/every tieline`.

Useful ⟨*options*⟩ are, for example, other plot handlers to adjust the appearance of tie lines. Suppose that you have additional color data for every tie line (which might have been provided as further

input column). In our case, we provide random color data using `point meta`=rand, and visualize the single tielines as with `contour prepared`:
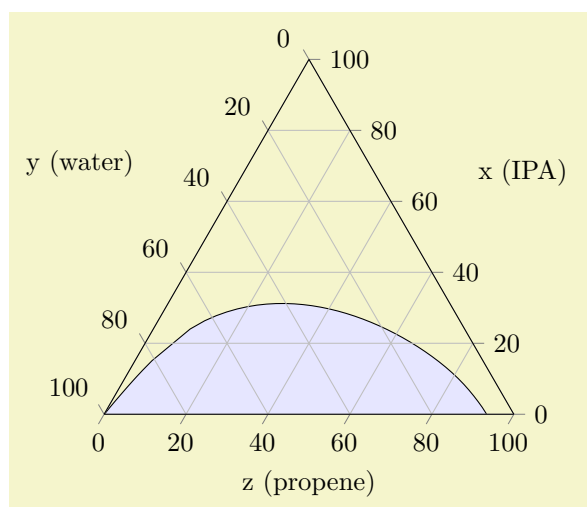
```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}\usepgfplotslibrary{ternary}
\begin{tikzpicture}
\begin{ternaryaxis}[
    xlabel=x (IPA),
    ylabel=y (water),
    zlabel=z (propene),
    axis on top,
]
% plotdata/ternary_data.txt is a table of the form
%A_propene A_water A_IPA  B_propene B_water B_IPA
% 0.0009   0.9990  0       0.9333    0.0667  0
% 0.0009   0.9988  0.0002 0.9303    0.0665  0.0032
% 0.0011   0.9975  0.0013 0.9135    0.0673  0.0191
% 0.0013   0.9962  0.0024 0.8956    0.0693  0.0351
%...
    \addplot3[
        point meta=rand,
        tieline={
            each nth tie=8,
            tieline style={contour prepared}
        },
        fill=blue!10,
    ]
    table [x=A_IPA,y=A_water,z=A_propene]
        {plotdata/ternary_data.txt};
\end{ternaryaxis}
\end{tikzpicture}
```

The effect here is that contour labels and line colors are chosen for every tie line, where the actual color is determined using `point meta` and `colormap`. Other choices for plot handlers in `tieline style` might be the `mesh`.

/pgfplots/tieline/curve style={⟨*options*⟩}

Appends ⟨*options*⟩ to the style `tieline/every curve`.

The `curve style` allows to customize the plot handler for the curve. A possible choice might be `curve style`={`smooth`} or a separate fill/draw color.

5.14 Units in Labels

by Nick Papior Andersen

```
\usepgfplotslibrary{units} % LaTeX and plain TeX
\usepgfplotslibrary[units] % ConTeXt
\usetikzlibrary{pgfplots.units} % LaTeX and plain TeX
\usetikzlibrary[pgfplots.units] % ConTeXt
```

A library which allows to use automatic typesetting of units in labels. The library utilizes different keys to typeset the final output in a consistent way. Calling one of the commands automatically sets the key '`use units`=true' so one does not have to worry about this.

PGFPLOTS has the capability of supporting units. This provides quick customization of the plot as well as the addition of units in labels.

Loading the library automatically enables the typesetting of units in labels. Currently it only supports predefined SI units but a per-user customization is also implemented such that it can be used in any way you like.

First the key which enables you to switch on/off the unit system.

/pgfplots/use units={⟨*boolean*⟩}   (initially `true`)

This key simply enables PGFPLOTS to use what is described next. This key will be set to true if you load the library. You can use this to temporarily determine whether the unit library should be used in plots.

/pgfplots/x unit={⟨*unit*⟩}   (initially `empty`)
/pgfplots/y unit={⟨*unit*⟩}   (initially `empty`)
/pgfplots/z unit={⟨*unit*⟩}   (initially `empty`)

These keys set the unit in their respective axis. In SI units you could for instance set the `x unit` in Newton as `x unit`=N.

/pgfplots/x unit prefix={⟨*prefix*⟩}   (initially `empty`)
/pgfplots/y unit prefix={⟨*prefix*⟩}   (initially `empty`)
/pgfplots/z unit prefix={⟨*prefix*⟩}   (initially `empty`)

These keys set the prefix of the unit. If a value on the `y axis` is in kilo you would set the `y unit prefix`=k. Prefix will be typeset in front of the unit.

This command will not intervene with the basis of the axis system. I.e. a prefix as just mentioned will not divide every `y axis` number by 1000. In order to do this, see key ⟨*axis*⟩ `SI prefix`, see Section 5.14.1.

Notice that if the ⟨*axis*⟩ `unit` isn't set the entire unit will not be typeset.

Remarks: Remember that all typesetting of labels occur within math mode (i.e. within $$ delimiters). Therefore one can use `\frac` and other mathematics commands.

Often one just has to utilize the above mentioned keys. It is the basis of the unit typesetting system provided by PGFPLOTS.


```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}\usepgfplotslibrary{units}
\begin{tikzpicture}
  \begin{axis}[use units,
    x unit=m,x unit prefix=k,
    y unit=N,y unit prefix=m,
    xlabel=Distance,ylabel=Force]
    \addplot coordinates {
      (1,2.3)
      (2,2.7)
      (3,2.1)
      (4,1.8)
      (5,1.5)
      (6,1.1)
    };
  \end{axis}
\end{tikzpicture}
```

Below is an example of what would be obtained according to the styles

```
% x label becomes ``Temperature [T]'', y label becomes ``Nothing''
\pgfplotsset{use units,x unit=T,xlabel=Temperature,ylabel=Nothing}
% x label becomes ``Temperature'', y label becomes ``Nothing''
\pgfplotsset{use units,x unit prefix=m,xlabel=Temperature,ylabel=Nothing}
```

Notice the second example. Only setting the prefix will not activate the unit typesetting. Therefore one should ensure to use the `x unit` key if the typesetting of the labels should be done.

For typesetting the units one can also change the appearance. For instance one might not like the square brackets which surround the unit. These can luckily be changed using the below keys.

/pgfplots/unit marking pre={⟨*pre*⟩}   (initially `\left[`)
/pgfplots/unit marking post={⟨*post*⟩}   (initially `\right]`)
/pgfplots/unit markings=parenthesis|square brackets|slash space   (initially `square brackets`)

These keys set the surroundings of the unit. The initial yields $\left[\frac{1}{2}\right]$ such that you can typeset fractions in units. Be aware that you can only obtain large fractions if you use `\dfrac`. These can easily be set using the option key `unit markings` where the options typesets as the following

```
\pgfplotsset{x unit=T,unit markings=parenthesis} % x unit becomes `` \left(T\right)''
\pgfplotsset{x unit=T,unit markings=square brackets} % x unit becomes `` \left[T\right]''
\pgfplotsset{x unit=T,unit markings=slash space} % x unit becomes `` / T''
```

Notice that all typesetting of units first inserts a space and then the `unit marking pre` code.

Of course you can just manually set each of them with the `unit marking pre` and `unit marking post` keys. Just remember that they are typeset within a $$.

One will typically typeset the unit with a specific font. To do so an option of changing the typesetting command is supplied.

/pgfplots/unit code/.code 2 args={⟨...⟩}

This can be utilized to great extent. By default, units are typeset as \mathrm{⟨*unit prefix*⟩⟨*unit*⟩}. But if one for instance wishes to utilize the package `siunitx`, which has great capabilities in typesetting both units, numbers and angles, one can just set the key as

```
\pgfplotsset{unit code/.code 2 args={\si{#1#2}}}
```

which would yield the unit as \si{⟨*unit prefix*⟩⟨*unit*⟩}.

The first argument is typeset as ⟨*unit prefix*⟩ and the second argument is ⟨*unit*⟩.

The most important thing is that the command needs exactly two arguments. So if you would like a command that typesets the prefix in bold face and the unit in normal roman font you should call

```
\pgfplotsset{unit code/.code 2 args={\mathbf{#1}\mathrm{#2}}
```

5.14.1 Preset SI prefixes

To support the SI system a number of preset keys are defined. This should yield a more intuitive way of supplying the prefix as well as add some more functionality. For instance it provides an easy scaling mechanism.

/pgfplots/x SI prefix=yocto|...|milli|centi|deci|deca|hecto|kilo|...|yotta	(initially **none**)
/pgfplots/y SI prefix=yocto|...|milli|centi|deci|deca|hecto|kilo|...|yotta	(initially **none**)
/pgfplots/z SI prefix=yocto|...|milli|centi|deci|deca|hecto|kilo|...|yotta	(initially **none**)
/pgfplots/change x base=true|false	(initially **false**)
/pgfplots/change y base=true|false	(initially **false**)
/pgfplots/change z base=true|false	(initially **false**)

These keys sets the prefix of the unit. The allowed prefixes are:

Prefix	Power		Prefix	Power
yocto	-24		deca	1
zepto	-21		hecto	2
atto	-18		kilo	3
femto	-15		mega	6
pico	-12		giga	9
nano	-9		tera	12
micro	-6		peta	15
milli	-3		exa	18
centi	-2		zetta	21
deci	-1		yotta	24

As well as resetting the base of the axis if the key `change` ⟨*axis*⟩ `base=true`. Just **remember** to set the `change` ⟨*axis*⟩ `base` before using the ⟨*axis*⟩ `SI prefix` key.

See the utilization as in the example below.
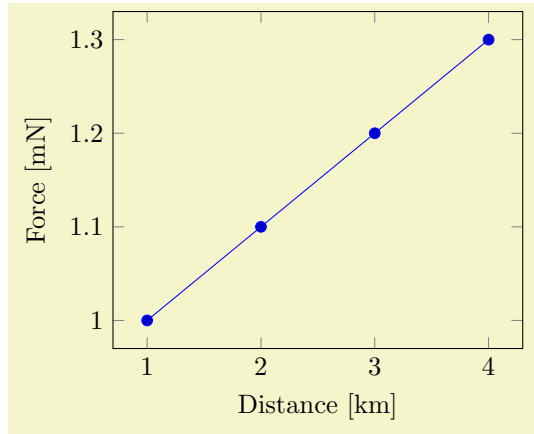
```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}\usepgfplotslibrary{units}
\begin{tikzpicture}
  \begin{axis}[change x base,
    x SI prefix=kilo,x unit=m,
    y SI prefix=milli,y unit=N,
    xlabel=Distance,ylabel=Force]
    \addplot coordinates {
        (1000,1)
        (2000,1.1)
        (3000,1.2)
        (4000,1.3)
    };
  \end{axis}
\end{tikzpicture}
```

Notice that the `x axis` has changed base without displaying the $\cdot 10^3$. This is done by using the key `change x base`. Even though you have used the key `y SI prefix`=milli the base isn't changed on the `y axis`. Try adding `change y base` just after `change x base` and see the result!

The above keys are the easy implementation of the base change. Below is a further customization of the base change. It makes it easy to implement a prefix with a custom base change.

`/pgfplots/axis base prefix`=axis {⟨*axis*⟩} base {⟨*base*⟩} prefix {⟨*prefix*⟩}   (initially `empty`)

One can utilize this key to customize further of the base and setting the prefix.

```
\pgfplotsset{change x base,axis base prefix={axis x base -3 prefix k}}
\pgfplotsset{change x base,x SI prefix=kilo}
```

The above two commands are thus equivalent. Remember that the base should operate in opposite of prefix!

Chapter 6

Memory and Speed considerations

6.1 Memory Limits of TEX

PGFPLOTS can typeset plots with several thousand points if memory limits of TEX are configured properly. Its runtime is roughly proportional to the number of input points[1].
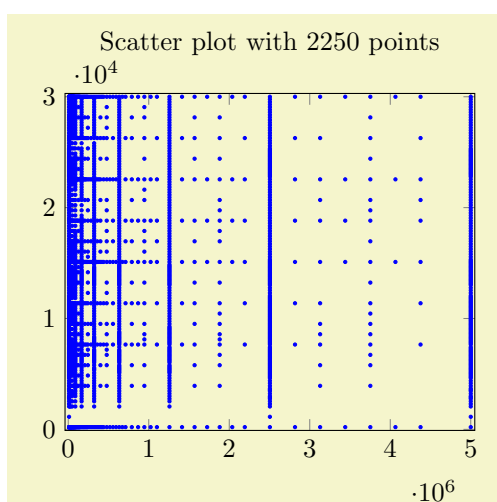

```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
\begin{axis}[
    enlargelimits=0.01,
    title style={yshift=5pt},
    title=Scatter plot with $2250$ points]

\addplot[blue,
    mark=*,only marks,mark options={scale=0.3}]
    file[skip first]
    {plotdata/pgfplots_scatterdata3.dat};

\end{axis}
\end{tikzpicture}
```
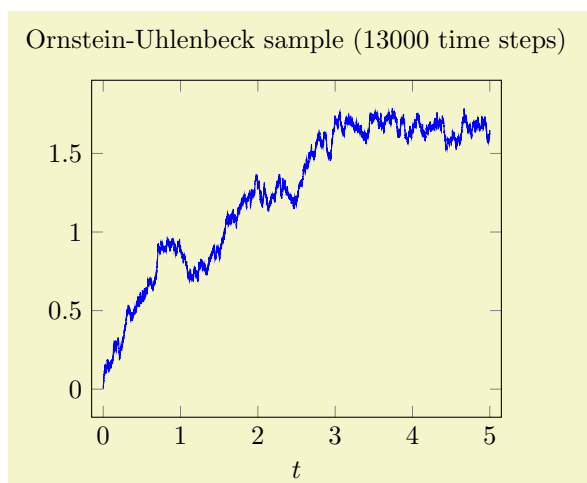


```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
\begin{axis}[
    enlarge x limits=0.03,
    title=Ornstein-Uhlenbeck sample
        ($13000$ time steps),
    xlabel=$t$]

\addplot[blue] file {plotdata/ou.dat};
\end{axis}
\end{tikzpicture}
```

---

[1]In fact, the runtime is pseudo–linear: starting with about 100,000 points, it will become quadratic. This limitation applies to the path length of PGF paths as well. Furthermore, the linear runtime is not possible yet for stacked plots.
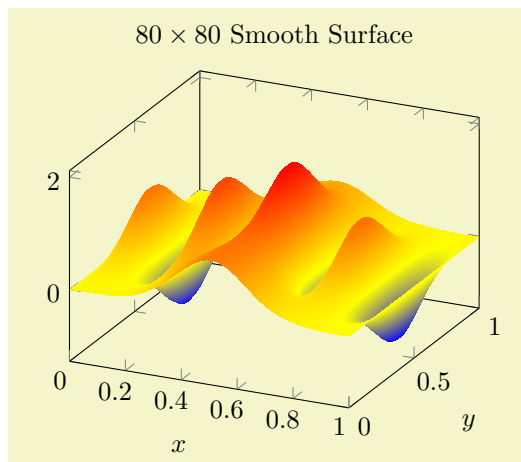
```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
% huger graphs are possible; consider lualatex
\begin{tikzpicture}
\begin{axis}[
    title=$80 \times 80$ Smooth Surface,
    xlabel=$x$,
    ylabel=$y$]
\addplot3[surf,samples=80,shader=interp,domain=0:1]
    {sin(deg(8*pi*x))* exp(-20*(y-0.5)^2)
    + exp(-(x-0.5)^2*30
        - (y-0.25)^2 - (x-0.5)*(y-0.25))};
\end{axis}
\end{tikzpicture}
```

PGFPLOTS relies completely on TEX to do all typesetting. It uses the front-end-layer and basic layer of PGF to perform all drawing operations. For complicated plots, this may take some time, and you may want to read Section 7 for how to write single figures to external graphics files. Externalization is the best way to reduce typesetting time.

However, for large scale plots with a lot of points, limitations of TEX's capacities are reached easily.

6.2   Memory Limitations

The default settings of most TEX-distributions are quite restrictive, so it may be necessary to adjust them.

Usually, the log–file or the final error message contains a summary about the used resources, giving a hint which parameter needs to be increased.

6.2.1   LuaLaTEX

One solution which works quite well is to switch the LaTEX executable: if you have a decent TEX distribution, you will have the `lualatex` executable as well. This, in turn, uses dynamic memory allocation such that it usually has enough memory for any PGFPLOTS axis.

The LuaLaTEX executable `lualatex` is supposed to be almost compatible with `pdflatex`.

This approach works for any platform.

6.2.2   MikTEX

If you are running MikTEX and you do not want to (or cannot switch) to `lualatex`, you can proceed as follows.

For MikTEX, memory limits can be increased in two ways. The first is to use command line switches:

```
pdflatex
    --stack-size=n --save-size=n
    --main-memory=n --extra-mem-top=n --extra-mem-bot=n
    --pool-size=n --max-strings=n
```

Experiment with these settings if MikTEX runs out of memory. Usually, one doesn't invoke `pdflatex` manually: there is a development aid which does all the invocations, so this one needs to be adjusted.

Sometimes it might be better to adjust the MikTEX configuration file permanently, for example to avoid reconfiguring the TEX development program. This can be implemented using the command

```
initexmf --edit-config-file=pdflatex
```

which can be typed either on a command prompt in Windows or using Start ≫ Execute. As a result, an editor will be opened with the correct config file. A sample config file could be

```
main_memory=90000000
save_size=80000
```

or any of the config file entries which are listed below can be entered. Thanks to "LeSpocky" for his documentation in

http://blog.antiblau.de/2009/04/21/speicherlimits-von-miktex-erhoehen.

6.2.3 TEXLive or similar installations

In addition to the option to switch to `lualatex`, you can proceed as follows to keep existing `dvips` or `pdflatex` workflows.

For Unix installations, one needs to adjust config files. This can be done as follows:

1. Locate `texmf.cnf` on your system. On my Ubuntu installation, it is in

   `/usr/share/texmf/web2c/texmf.cnf`.

2. Either change `texmf.cnf` directly, or copy it to some convenient place. If you copy it, here is how to proceed:

   - keep only the changed entries in your local copy to reduce conflicts. TEX will always read *all* config files found in its search path.
   - Adjust the search path to find your local copy. This can be done using the environment variable `TEXMFCNF`. Assuming your local copy is in `~/texmf/mytexcnf/texmf.cnf`, you can write

     ```
     export TEXMFCNF=~/texmf/mytexcnf:
     ```

     to search first in your directory, then in all other system directories.

3. You should change the entries

   ```
   main_memory = n
   extra_mem_top = n
   extra_mem_bot = n
   max_strings = n
   param_size = n
   save_size = n
   stack_size = n
   ```

   The log–file usually contains information about the parameter which needs to be enlarged.

An example of this config file thing is shown below. It changes memory limits.

1. Create the file `~/texmf/mytexcnf/texmf.cnf` (and possibly the paths as well).

   ```
   % newly created file ~/texmf/mytexcnf/texmf.cnf:
   % If you want to change some of these sizes only for a certain TeX
   % variant, the usual dot notation works, e.g.,
   % main_memory.hugetex = 20000000
   main_memory = 230000000 % words of inimemory available; also applies to inimf&mp
   extra_mem_top = 10000000     % extra high memory for chars, tokens, etc.
   extra_mem_bot = 10000000     % extra low memory for boxes, glue, breakpoints, etc.
   save_size = 150000    % for saving values outside current group
   stack_size = 150000    % simultaneous input sources

   % Max number of characters in all strings, including all error messages,
   % help texts, font names, control sequences.  These values apply to TeX and MP.
   %pool_size = 1250000
   % Minimum pool space after TeX/MP's own strings; must be at least
   % 25000 less than pool_size, but doesn't need to be nearly that large.
   %string_vacancies = 90000
   % Maximum number of strings.
   %max_strings = 100000
   % min pool space left after loading .fmt
   %pool_free = 47500
   ```

2. Run `texhash` such that TEX updates its `~/texmf/ls-R` database.

3. Create the environment variable `TEXMFCNF` and assign the value '`~/texmf/mytexcnf:`' (including the trailing ':'!). For my linux system, this can be done using by adding

   ```
   export TEXMFCNF=~/texmf/mytexcnf:
   ```

   to `~/.bashrc`.

Unfortunately, TEX does not allow arbitrary memory limits, there is an upper bound hard coded in the executables.

6.3   Reducing Typesetting Time

PGFPLOTS does a lot of computations ranging from abstract coordinate computations to low level `.pdf` drawing commands (implemented by PGF). For complex plots, this may take a considerable time – especially for 3D plots.

6.3.1   LUA

If you use `compat=1.12` (or newer) and compile your documents by means of `lualatex`, PGFPLOTS activates its `lua backend`. This switch reduces the time to generate output files, especially for 3D plots.

/pgfplots/lua backend=true|false   (initially `true`)

> If `lua backend` is active and the document is processed by means of `lualatex`, PGFPLOTS activates scalability and performance improvements which result in the same output as without it, but with less time and with a smarter memory management.
>
> The feature relies on a partial reimplementation of PGFPLOTS in the fast scripting language LUA. In order to benefit from it, you need to
>
> 1. write `compat=1.12` (or newer) into your preamble and
>
> 2. use `lualatex` to translate your `.tex` files (or at least those which contain PGFPLOTS figures).
>
> The time to generate surface plots with this feature can be reduced to 25%–50% of the time required by the pure TeX implementation (i.e. `pdflatex`). Other plot types will also benefit from the feature.
>
> The `lua backend` works in two ways: first, it substitutes isolated routines by faster LUA pendants. This is relatively generic. Second, it replaces entire processing steps by an equivalent LUA implementation.[2] PGFPLOTS 1.12 comes with LUA implementations for important and long–running operations. This implementation will be used whenever possible. However, it only covers parts of the feature set: some features of PGFPLOTS are unsupported by the LUA backend. In this case, it will be switched off automatically and the TeX implementation will be used as fallback.
>
> The `lua backend` will be extended in order to gain more performance improvements and in order to cover more features. Please take a look at `lua debug` if you want to see if `lua backend` has been (de)activated for your figure.
>
> Note that the `lua backend` uses a different math engine with a higher accuracy. As a consequence, the appearance of a plot might have insignificant pixel differences compared to the output generated by `pdflatex`. It is generally recommended to stick with one way to generate a document, i.e. to use either `lualatex` *or* `pdflatex`. Migrating from one to another might change the appearance of your document due to `lua backend`.
>
> Eventually, PGFPLOTS might add computationally expensive features which can be implemented as part of `lua backend` and which will be unavailable without it.
>
> Note that `lua backend` requires a TeX distribution which supports at least LUA 5.2 (like TeX Live 2014). It will be deactivated automatically if your version of `lualatex` is shipped with an older LUA interpreter.
>
> Here are some guidelines how to benefit from `lua backend`:
>
> - Math expressions which involve macro definitions are unavailable in `lua backend`. Best-practise: prefer `declare function` over macro constants:

---

[2] An example for the first way is: every time PGFPLOTS makes a lookup in its `colormap` it transfers control over to the `luabackend` and the result is immediately communicated back to TeX. The main control flow resides in the slow TeX implementation. An example for the second way is `\addplot expression`: PGFPLOTS will copy the math expression and any related input arguments (including `samples` and `domain`) over to the `lua backend`. Then, the `lua backend` will apply all loops and collect coordinates which are finally handed over to the (TeX) implementation of PGF. Thus, the control flow resides in the fast LUA interpreter.
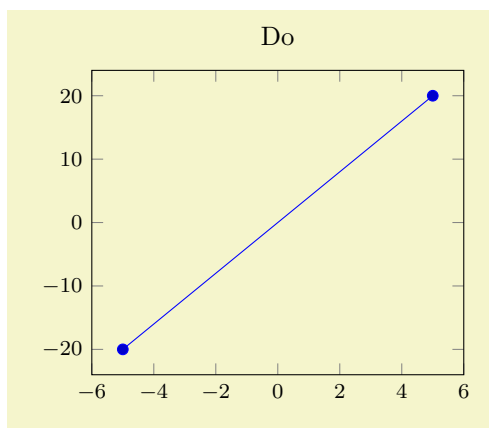
```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
    \begin{axis}[small,title=Do,samples=2]
    \addplot+[declare function={C=4;}] {C*x};
    \end{axis}
\end{tikzpicture}
```
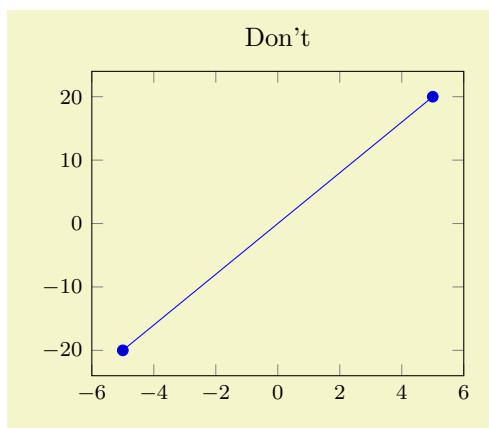


```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
    \begin{axis}[small,title=Don't,samples=2]
    \def\constantC{4}
    \addplot {\constantC*x};
    \end{axis}
\end{tikzpicture}
```

Both are semantically equivalent, but since LUA cannot interprete TEX macros, it refuses to process the "Don't" case. The "Don't" case results in a log message

```
Package pgfplots info on input line 16: Deactivating LUA version of
plot expression for plot 0 (type 'pgfplothandlerlineto'):
y expression '\constantC *x' contains a TeX macro.
```

- Any operation which requires "native" TEX code is unavailable in lua backend. This includes x filter/.code={...} since /.code cannot be mapped to LUA. Best-practise: prefer x filter/.expression over x filter/.code:
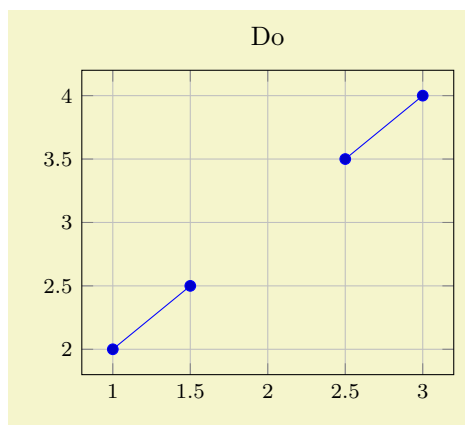

```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
    \begin{axis}[small,grid=major,title=Do]
    \addplot+[
        unbounded coords=jump,
        y filter/.expression={y==3 ? nan : y},
    ]
    table {
    x    y
    1    2
    1.5  2.5
    2    3
    2.5  3.5
    3    4
    };
    \end{axis}
\end{tikzpicture}
```

- Plot expression can be processed entirely in LUA, all other input coordinate types use TEX to read the value and hand-over to LUA.
- There are a couple of operations for which the lua backend is planned for future releases.

/pgfplots/lua debug   (no value)

/pgfplots/lua debug=false|off|off and silent|verbose|compileerror

> Typically, the lua backend works silently: PGFPLOTS decides if it is active and if it supports the current operation and proceeds accordingly. If both conditions are satisfied, it will transfer control to the lua backend. If one of them is not met, it will automatically fall back to the old TEX implementation. As a consequence, it cannot be sensed right-away, only the time to compile pictures will vary.
>
> This key controls how PGFPLOTS handles the case where the lua backend is active, but cannot be used because some encountered feature is unsupported.
>
> The choices false and off deactivate LUA debugging. In this case, PGFPLOTS will *only* write log messages if it used the TEX implementation instead of the lua backend. In addition, it will only write the messages into the .log file (but not into the console output).
>
> The choice off and silent writes neither information messages nor debug messages: it is the same as off but without the log message if the TEX implementation has been used. It is the least verbose choice.
>
> The choice verbose will also write success messages into the .log file (not into the console).
>
> The choice compileerror will abort compilation if the lua backend is active but does not support the current figure or plot.
>
> Note that PGFPLOTS might come with limited expensive operations which are only available in the lua backend. These items will result in compile errors if the lua backend cannot be used for some reason.

6.3.2 Compiling Images Just Once

One possibility to reduce typesetting time is to tell PGF to generate single, temporary .pdf (or .eps) documents for a subset (or all) graphics in one run and re-use these temporary images in successive runs. For PGFPLOTS, this is the most effective way to reduce typesetting time for larger documents. It can be accomplished using the external library described in Section 7.1.

Chapter 7

Import/Export From Other Formats

This section contains information of how to single pictures into separate PDF graphics files (or EPS graphics files). Furthermore, it explains a matlab (®) script which allows to convert from matlab to PGFPLOTS.

7.1 Export to PDF/EPS

It is possible to export images to single PDF-documents using routines of PGF and/or TikZ.

7.1.1 Using the Automatic Externalization Framework of TikZ

```
\usepgfplotslibrary{external} % LaTeX and plain TeX
\usepgfplotslibrary[external] % ConTeXt
\usetikzlibrary{pgfplots.external} % LaTeX and plain TeX
\usetikzlibrary[pgfplots.external] % ConTeXt
```

The external library offers a convenient method to export every single tikzpicture into a separate .pdf (or .eps). Later runs of LaTeX will simply include these graphics, thereby reducing typesetting time considerably.

The library can also be used to submit documents to authors who do not even have PGFPLOTS or TikZ installed.

Technical foreword: The external library has been written by Christian Feuersänger (author of PGFPLOTS). It has been contributed to TikZ as general purpose library, so the reference documentation along with all tweaks can be found in [7, Section "Externalization Library"]. The command `\usepgfplotslibrary{external}` is actually just a wrapper which loads `\usetikzlibrary{external}` or, if this library does not yet exist because the installed PGF has at most version 2.00, it will load a copy which is shipped with PGFPLOTS.

The external library has been designed such that *no changes* to the document as such are necessary. The idea is as follows:

1. Every `\begin{tikzpicture}` ... `\end{tikzpicture}` gets a file name. The file name can be assigned manually with `\tikzsetnextfilename{`⟨*output file name*⟩`}` or automatically, in which case ⟨*tex file name*⟩`-figure`⟨*number*⟩ is used with an increasing ⟨*number*⟩.

2. The library writes the resulting images using system calls of the form `pdflatex --jobname` ⟨*output file name*⟩ automatically, using the write18 system call of TeX. It is the same framework which can be used to call gnuplot.

The only steps which are necessary is to use

`\usepgfplotslibrary{external}`

`\tikzexternalize`

somewhere in your document's preamble (see below for system-dependent configuration options). No further modification to the document is necessary. Suppose we have a file called `test.tex`:

```
\documentclass{article}

\usepackage{pgfplots}

\usepgfplotslibrary{external}
\tikzexternalize% activate externalization!

\begin{document}
    \begin{figure}
        \begin{tikzpicture}
        \begin{axis}
            \addplot {x^2};
        \end{axis}
        \end{tikzpicture}
    \caption{Our first external graphics example}
    \end{figure}

    \begin{figure}
        \begin{tikzpicture}
        \begin{axis}
            \addplot {x^3};
        \end{axis}
        \end{tikzpicture}
    \caption{A second graphics}
    \end{figure}
\end{document}
```

To enable the system calls, we type

```
pdflatex -shell-escape test
```

and LATEX will now generate the required graphics files `test-figure0.pdf` and `test-figure1.pdf` automatically. Any further call to `pdflatex` will simply use `\includegraphics` and the `tikzpicture`s as such are no longer considered (you need a different command line switch for MikTEX, see the shell escape option).

If a figure shall be remade, one can simply delete all or selected graphics files and regenerate them. Alternatively, one can use the command `\tikzset{external/force remake}` somewhere in the document to remake every following picture automatically.

There are three ways to modify the file names of externalized figures:

- Changing the overall file name using a prefix,
- Changing the file name for a single figure using `\tikzsetnextfilename`,
- Changing the file name for a restricted set of figures using figure name.

/tikz/external/prefix=`{⟨file name prefix⟩}`   (initially empty)

  A shortcut for `\tikzsetexternalprefix{⟨file name prefix⟩}`, see below.

`\tikzsetexternalprefix{⟨file name prefix⟩}`

  Assigns a common prefix used by all file names. For example,

```
\tikzsetexternalprefix{figures/}
```

  will prepend `figures/` to every external graphics file name.

`\tikzsetnextfilename{⟨file name⟩}`

  Sets the file name for the *next* TikZ picture or `\tikz` short command. It will *only* be used for the next picture.

  Pictures for which no explicit file name has been set will get automatically generated file names.

  Please note that prefix will still be prepended to ⟨file name⟩.

```
\documentclass{article}
% main document, called main.tex
\usepackage{tikz}

\usepgfplotslibrary{external}
\tikzexternalize[prefix=figures/]% activate with a name prefix

\begin{document}

\tikzsetnextfilename{firstplot}
\begin{tikzpicture} % will be written to 'figures/firstplot.pdf'
\begin{axis}
    \addplot {x};
\end{axis}
\end{tikzpicture}

\begin{tikzpicture} % will be written to 'figures/main-figure0.pdf'
   \draw[help lines] (0,0) grid (5,5);
\end{tikzpicture}
\end{document}
```

```
pdflatex -shell-escape main
```

/tikz/external/figure name={⟨*name*⟩}

Same as \tikzsetfigurename{⟨*name*⟩}.

\tikzsetfigurename{⟨*name*⟩}

Changes the names of *all* following figures. It is possible to change figure name during the document using \tikzset{external/figure name={⟨*name*⟩}}. A unique counter[1] will be used for each different ⟨*name*⟩, and each counter will start at 0.

The value of prefix will be applied after figure name has been evaluated.

```
\documentclass{article}
% main document, called main.tex
\usepackage{tikz}

\usepgfplotslibrary{external}
\tikzexternalize% activate externalization!

\begin{document}

% will be written to 'main-figure0.pdf'
\begin{tikzpicture}
\begin{semilogyaxis}
    \addplot {exp(x)};
\end{semilogyaxis}
\end{tikzpicture}

{
  \tikzset{external/figure name={subset_}}
  A simple image is \tikz \fill (0,0) circle(5pt);. % will be written to 'subset_0.pdf'

  \begin{tikzpicture} % will be written to 'subset_1.pdf'
     \begin{axis}
         \addplot {x^2};
     \end{axis}
  \end{tikzpicture}
}% here, the old file name will be restored:

\begin{tikzpicture} % will be written to 'main-figure1.pdf'
   \begin{axis}
           \addplot[domain=1e-3:100] {1/x};
   \end{axis}
\end{tikzpicture}
\end{document}
```

The scope of figure name ends with the next closing brace (as all values set by \tikzset do).

---

[1]These counters are stored into different *macros*. In other words: no TEX register will be needed.

Remark: Use `\tikzset{external/figure name/.add={⟨prefix⟩}{⟨suffix⟩}}` to prepend a ⟨prefix⟩ and append a ⟨suffix⟩ to the actual value of `figure name`. Might be useful for something like

```
\tikzset{external/figure name=main}

% uses main_0.pdf, main_1.pdf, ...

\chapter{The first section}
{\tikzset{external/figure name/.add={}{_firstsection}}
    ...
    % uses main_firstsection_0.pdf, main_firstsection_1.pdf, ...
}

\chapter{The second section}
{\tikzset{external/figure name/.add={}{secondsection_}}
    ...
    % uses main_secondsection_0.pdf, main_secondsection_1.pdf, ...
    \section{Second subsection}
    {\tikzset{external/figure name/.add={}{sub_}}
        ...
        % uses main_secondsection_sub_0.pdf, main_secondsection_sub_1.pdf, ...
    }
    % uses main_secondsection_2.pdf, main_secondsection_3.pdf, ...
}
```

`\tikzappendtofigurename{⟨suffix⟩}`

Appends ⟨suffix⟩ to the actual value of `figure name`.

It is a shortcut for `\tikzset{external/figure name/.add={}{⟨suffix⟩}}` (a shortcut which is also supported if TikZ is not installed, see below).

Configuration option for eps output or MikTEX: Since the `external` lib works by means of system calls, it has to be modified to fit the local system. This is necessary for MikTEX since it uses a different option to enable these system calls. It is also necessary for EPS output since this involves a different set of utilities.

Note that the *most important part* is to enable system calls. This is typically done by typesetting your document with `pdflatex -shell-escape` or `pdflatex -enable-write18` (MikTEX). These options *need to be configured in your TEX editor*. Besides this step, one may want to configure the system call:

`/tikz/external/system call={⟨template⟩}`

A template string used to generate system calls. Inside of ⟨template⟩, the macro `\image` can be used as placeholder for the image which is about to be generated while `\texsource` contains the main file name (in truth, it contains `\input{⟨main file name⟩}`, but that doesn't matter).

The default is

```
\tikzset{external/system call={pdflatex \tikzexternalcheckshellescape -halt-on-error
    -interaction=batchmode -jobname "\image" "\texsource"}
```

where `\tikzexternalcheckshellescape` inserts the value of the configuration key `shell escape` if and only if the current document has been typeset with `-shell-escape`[2].

For `eps` output, you can (and need to) use

```
\tikzset{external/system call={latex \tikzexternalcheckshellescape -halt-on-error
    -interaction=batchmode -jobname "\image" "\texsource" &&
    dvips -o "\image".ps "\image".dvi}}
```

The argument ⟨template⟩ will be expanded using `\edef`, so any control sequences will be expanded. During this evaluation, '\\' will result in a normal backslash, '\'. Furthermore, double quotes '"', single quotes ''', semicolons and dashes '-' will be made to normal characters if any package uses them as macros. This ensures compatibility with the `german` package, for example.

---

[2]Note that this is always true for the default configuration. This security consideration applies mainly for `mode=list and make` which will also work *without* shell escapes.

/tikz/**external/shell escape**={⟨*command-line arg*⟩}   (initially -shell-escape)

> Contains the command line option for latex which enables the \write18 feature.
>
> For TEX-Live, this is -shell-escape. For MikTEX, you should use \tikzexternalize[shell escape=-enable-write18].

Support for Labels and References In External Files   The external library comes with extra support for \label and \ref (and other commands which usually store information in the .aux file) inside of external files.

There are, however, some points which need your attention when you try to use

a) \ref to something in the main document inside of an externalized graphics or

b) \label in the externalized graphics which is referenced in the main document.

For point a), a \ref inside of an externalized graphics works *only* if you issue the required system call *manually* or by make. The initial configuration **mode**=convert with system call does *not* support \ref. But you can copy–paste the system call generated by **mode**=convert with system call and issue it manually. The reason is that \ref information is stored in the main .aux file – but this auxiliary file is not completely written when **mode**=convert with system call is invoked (there is a race condition). Note that \pageref is not supported (sorry). Thus: if you have \ref inside of external graphics, consider using **mode**=list and make or copy–paste the system call for the image(s) and issue it manually.

Point b) is realized automatically by the external library. In detail, a \label inside of an externalized graphics causes the external library to generate separate auxiliary files for every external image. These files are called ⟨*imagename*⟩.dpth. The extension .dpth indicates that the file also contains the image's depth (the baseline key of TikZ). Furthermore, anything which would have been written to an .aux file will be redirected to the .dpth file – but only things which occur inside of the externalized tikzpicture environment. When the main document loads the image, it will copy the .dpth file into the main .aux file. Then, successive compilations of the main document contain the external \label information. In other words, a \label in an external graphics needs the following work flow:

1. The external graphics needs to be generated together with its .dpth (usually automatically by TikZ).

2. The main document includes the external graphics and copies the .dpth content into its main .aux file.

3. The main document needs to be translated once again to re-read its .aux file[3].

There is just a special case if a \label/\ref drawn as a tikzpicture. This is, for example, the case for the legend \ref images or for the \pgfplotslegendfromname feature. In such cases, you need to proceed as for case a) since **mode**=convert with system call can't handle that stuff on its own.

In other words: a \label in an external document works automatically, just translate the main document often enough. A \ref might need manual adjustments as described for case a) above.

Operation Modes

/tikz/**external/mode**=convert with system call|list and make|...   (initially convert with system call)

> This allows to change the default operation mode. There are a handful of choices possible, all of them are described in detail in [7, section "Externalization Library"]. The most useful ones are probably the initial configuration convert with system call and the specialized choice list and make.
>
> The choice list and make configures the library to check if there are already external graphics and uses them. If there are no graphics, the library will *skip* the figure. However, it will also generate a makefile to generate the graphics, and a list of all required graphics files.
>
> It is not required to use make: the library expects you to generate the images somehow and it doesn't care about the "how". Using make -f ⟨*name-of-tex-file*⟩.makefile -j 2 allows parallel execution

---

[3]Note that it is not possible to activate the content of an auxiliary file after \begin{document} in LATEX.

which might, indeed, be an option. Furthermore, the makefile also supports file dependencies: if one of your data tables has been updated, the external graphics will be remade automatically. PGFPLOTS tells the external library about any file dependencies (input files and tables).

The two modes have the following characteristics:

1. `convert with system call` is automatic and does everything on–the–fly. However, it *can't* work with `\ref` and/or `\label` information in external pictures.

2. `list and make` requires either manual (by issuing the system calls manually) or semi–automatic conversion (using the generated ⟨*main*⟩.`makefile`), and multiple runs of `pdflatex`. The generated Makefile can be processed in parallel. Furthermore, `list and make` provides *full support* for `\ref` and `\label`: any `\label` defined inside of an externalized graphics is still available for the main document.

   If you have legends with `legend to name` or `\label`/`\ref`, you need to generate the graphics defining the `\label` (or `legend to name`), then run `pdflatex` twice on the main document. Afterwards, you can externalize the legend graphics.

The complete reference documentation and remaining options are documented in [7, "Externalization Library"]. This reference also contains information about

- how to use `\tikzset{external/force remake}` and `\tikzset{external/remake next}` to remake selected figures,

- how to disable the externalization partially with `\tikzset{external/export=false}` or completely with `\tikzexternaldisable`,

- how to optimize the speed of the conversion process using `\tikzset{external/optimize command away=\myExpensiveMacro}`,

- how to add further remake-dependencies with `\tikzpicturedependsonfile{`⟨*name*⟩`}` and/or `\tikzexternalfiledependsonfile{`⟨*external file*⟩`}{`⟨*name*⟩`}`,

- examples how to enable `png` export,

- how to typeset such a document without PGF installed or

- how to provide work-arounds with `.pdf` images and bounding box restrictions.

Using the Library Without PGF or PGFPLOTS Installed   There is a small replacement package `tikzexternal.sty` which can be used once every figure has been exported. The idea is to uncomment `\usepackage{tikz}` and `\usepackage{pgfplots}` and write `\usepackage{tikzexternal}` instead:

```
% \usepackage{tikz}
% \usepackage{pgfplots}
\usepackage{tikzexternal}
\tikzexternalize% activate externalization

\begin{document}
\begin{tikzpicture}
    ...
\end{tikzpicture}
...
\end{document}
```

You do not need PGF, TikZ or PGFPLOTS installed. What you need is `tikzexternal.sty` and all generated figures (consisting of the image files, '`.pdf`' and the '`.dpth`' files containing information of the `baseline` option). The file `tikzexternal.sty` is shipped with PGF in the directory

```
latex/pgf/utilities/tikzexternal.sty
```

and a copy is shipped with PGFPLOTS in

```
tex/generic/pgfplots/oldpgfcompatib/pgfplotsoldpgfsupp_tikzexternal.sty
```

Just copy the file into your directory and rename it to `tikzexternal.sty`.

Attention: The small replacement package doesn't support key–value interfaces. Thus, it is necessary to use `\tikzsetexternalprefix` instead of the `prefix` option and `\tikzsetfigurename` instead of the `figure name` option since `\tikzset` is not available in such a context. Also, you may want to define a dummy–macro `\pgfplotsset` if you have used `\pgfplotsset`.

7.1.2 Using the Externalization Framework of PGF "By Hand"

Another way to export TeX-pictures to single graphics files is to use the externalization framework of PGF, which requires more work but works more generally than the `external` library. The basic idea is to encapsulate the desired parts with

   `\beginpgfgraphicnamed{`⟨*output file name*⟩`}`
   ⟨*picture contents*⟩
   `\endpgfgraphicnamed`.

Furthermore, one needs to tell PGF the name of the main document using

   `\pgfrealjobname{`⟨*the real job's name*⟩`}`

in the preamble. This enables two different modes:

1. The first is the normal typesetting mode. LaTeX checks whether a file named ⟨*output file name*⟩ with one of the accepted file extensions exists – if that is the case, the graphics file is included with `\pgfimage` and the ⟨*picture contents*⟩ is skipped. If no such file exists, the ⟨*picture contents*⟩ is typeset normally. This mode is applied if `\jobname` equals ⟨*the real job's name*⟩.

2. The second mode applies if `\jobname` equals ⟨*output file name*⟩, it initiates the "conversion mode" which is used to write the graphics file ⟨*output file name*⟩. In this case, *only* ⟨*picture contents*⟩ is written to `\jobname`, the complete rest of the LaTeX is processed as normal, but it is silently discarded.

   This mode needs to be started manually with `pdflatex --jobname` ⟨*output file name*⟩ for every externalized graphics file.

A complete example may look as follows.

```
\documentclass{article}

\usepackage{pgfplots}

\pgfrealjobname{test}

\begin{document}
    \begin{figure}
        \beginpgfgraphicnamed{testfigure}
        \begin{tikzpicture}
        \begin{axis}
            \addplot {x^2};
        \end{axis}
        \end{tikzpicture}
        \endpgfgraphicnamed
    \caption{Our first external graphics example}
    \end{figure}

    \begin{figure}
        \beginpgfgraphicnamed{testfigure2}
        \begin{tikzpicture}
        \begin{axis}
            \addplot {x^3};
        \end{axis}
        \end{tikzpicture}
        \endpgfgraphicnamed
    \caption{A second graphics}
    \end{figure}
\end{document}
```

The file is named `test.tex`, and it is processed (for example) with

```
pdflatex test
```

Now, we type

```
pdflatex --jobname testfigure test
pdflatex --jobname testfigure2 test
```

to enter conversion mode. These last calls will *only* write the contents of our named graphics environments, one for ⟨*testfigure*⟩ and one for ⟨*testfigure2*⟩ into the respective output files testfigure.pdf and testfigure2.pdf.

In summary, one needs \pgfrealjobname and calls pdflatex --jobname ⟨*graphics file*⟩ for every externalized graphics environment. Please note that it is absolutely necessary to use the syntax above, *not* \begin{pgfgraphicnamed}.

These steps are explained in much more detail in Section"Externalizing Graphics" of [7].

Attention: Do not forget a correct \pgfrealjobname statement! If it is missing, externalization simply won't work. If it is wrong, any call to LATEX will produce empty output files.

It should be noted that this approach of image externalization is not limited to Ti*k*Z picture environments. In fact, it collects everything between the begin and end statements into the external file. It is implicitly assumed that the encapsulated stuff is one box, but you can also encapsulate complete paragraphs using something like the LATEX minipage (or a \vbox which is not as powerful but does not affect the remaining document that much).

/pgf/images/aux in dpth=true|false   (initially false)

> If this boolean is set to true, any \label information generated inside of the external image is stored into the already mentioned .dpth file. The main document can thus reference label information of externalized parts of the document (although you may need to run latex several times).
>
> Label support is provided for \ref, and probably \cite. The \pageref command is only partially supported.

Using the Library Without PGF **Installed**   Simply uncomment the packages \usepackage{tikz} and \usepackage{pgfplots} and use

```
\long\def\beginpgfgraphicnamed#1#2\endpgfgraphicnamed{%
    \begingroup
    \setbox1=\hbox{\includegraphics{#1}}%
    \openin1=#1.dpth
    \ifeof1 \box1
    \else
        \read1 to\pgfincludeexternalgraphicsdp \closein1
        \dimen0=\pgfincludeexternalgraphicsdp\relax
        \hbox{\lower\dimen0 \box1 }%
    \fi
    \endgroup
}
```

instead. This will include the generated graphics files (and it will respect the baseline information stored in .dpth files). Consequently, you won't need PGF or PGFPLOTS installed. See Section"Externalizing Graphics" of [7] for details.

7.2   Importing From Matlab

7.2.1   Importing Mesh Data From Matlab To PGFPlots

While it is easy to write Matlab vectors to files (using save P.dat data -ASCII), it is more involved to export mesh data.

The main problem is to communicate the mesh structure to PGFPLOTS.

Here is an example how to realize this task: in Matlab, we have mesh data X, Y and Z which are matrices of the same size. For example, suppose we have

```
[X,Y] = meshgrid( linspace(-1,1,5), linspace(4,5,10) );
Z = X + Y;
surf(X,Y,Z)
```

as data. Then, we can generate an $N \times 3$ table containing all single elements in column–wise ordering with

```
data = [ X(:) Y(:) Z(:) ]
% or -ascii
save P.dat data -ASCII
size(X)
ans =
   10.00    5.00
```

where the second command stores the $N \times 3$ table into `P.dat`. Finally, we can use

    \addplot3[surf,mesh/rows=10,mesh/ordering=colwise,shader=interp] file {P.dat};

in PGFPLOTS to read this data. We need to provide either the number of rows (10 here) or the number of columns – and the ordering (which is `colwise` for Matlab matrices).

An alternative which is faster in PGFPLOTS would be to transpose the matrices in Matlab and tell PGFPLOTS they are in `rowwise` ordering. So, the last step becomes

```
XX=X'; YY=Y'; ZZ=Z';
data = [ XX(:) YY(:) ZZ(:) ]
save P.dat data -ASCII
```

with PGFPLOTS command

    \addplot3[surf,mesh/cols=10,mesh/ordering=rowwise,shader=interp] file {P.dat};.

7.2.2 matlab2pgfplots.m

This is a Matlab (®) script which attempts to convert a Matlab figure to PGFPLOTS. It requires Matlab version 7.4 (or higher).

Attention: This script is largely outdated and supports only a very small subset of PGFPLOTS. You may want to look at `matlab2tikz`, a conversion script of Nico Schlömer available at

    http://www.mathworks.com/matlabcentral/fileexchange/22022-matlab2tikz

which also uses PGFPLOTS for the LaTeX conversion.

The idea of `matlab2pgfplots.m` is to

- use a complete matlab figure as input,

- acquire axis labels, axis scaling (log or normal) and legend entries,

- acquire all plot coordinates

and write an equivalent `.pgf` file which typesets the plot with PGFPLOTS.

The intention is *not* to simulate matlab. It is a first step for a conversion. Type

```
> help matlab2pgfplots
```

on your matlab prompt for more information about its features and its limitations.

This script is experimental.

7.2.3 matlab2pgfplots.sh

A `bash`-script which simply starts matlab and runs

```
f=hgload( 'somefigure.fig' );
matlab2pgfplots( 'outputfile.pgf', 'fig', f );
```

See matlab2pgfplots.m above.

7.2.4 Importing Colormaps From Matlab

Occasionally, you may want to reuse your matlab colormap in PGFPLOTS. Here is a small Matlab script which converts it to PGFPLOTS:

```
C = colormap;  % gets data of the current colormap.
% C = colormap(jet) % gets data of "jet"
eachnth = 1;
I = 1:eachnth:size(C,1); % this is nonsense for eachnth=1 -- but perhaps you don't want each color.
CC = C(I,:);
TeXstring = [ ...
 sprintf('\\pgfplotsset{\n\tcolormap={matlab}{\n') ...
 sprintf('\t\trgb=(%f,%f,%f)\n',CC') ...
 sprintf('\t}\n}\n') ]
```

7.3 SVG Output

It is possible to write every single TikZ picture into a scalable vector graphics (`.svg`) file. This has nothing to do with PGFPLOTS, it is a separate driver of PGF. Please refer to [7, Section "Producing HTML / SVG Output"].

7.4 Generate pgfplots Graphics Within Python

Mario Orne DÍAZ ANADÓN contributed a small python script `pgfplots.py` which provides a simple interface to generate PGFPLOTS figures from within python. It can be found in the PGFPLOTS installation directory, in `pgfplots/scripts/pgfplots/pgfplots.py`; documentation can be found in the file.

Chapter 8

Utilities and Basic Level Commands

This section documents commands which provide access to more basic elements of PGFPLOTS. Most of them are closely related to the basic level of PGF, especially various point commands which are specific to an axis. Some of them are general purpose utilities like loops.

However, most elements in this section are only interesting for advanced users – and perhaps only for special cases.

8.1 Utility Commands

`\foreach`⟨*variables*⟩ in ⟨*list*⟩ {⟨*commands*⟩}

A powerful loop command provided by TikZ, see [7, Section Utilities].

> Iterating 1. Iterating 2. Iterating 3. Iterating 4.

```
\foreach \x in {1,2,...,4} {Iterating \x. }%
```

A PGFPLOTS related example could be

```
\foreach \i in {1,2,...,10} {\addplot table {datafile\i}; }%
```

`\pgfplotsforeachungrouped`⟨*variable*⟩ in ⟨*list*⟩ {⟨*command*⟩}

A specialised variant of `\foreach` which can do two things: it does not introduce extra groups while executing ⟨*command*⟩ and it allows to invoke the math parser for (simple!) ⟨x_0⟩,⟨x_1⟩,...,⟨x_n⟩ expressions.

> Iterating 1. Iterating 2. Iterating 3. Iterating 4. All collected = , 1, 2, 3, 4.

```
\def\allcollected{}
\pgfplotsforeachungrouped \x in {1,2,...,4} {Iterating \x. \edef\allcollected{\allcollected, \x}}%
All collected = \allcollected.
```

A more useful example might be to work with tables. The following example is taken from PGFPLOTSTABLE:

```
\pgfplotsforeachungrouped \i in {1,2,...,10} {%
    \pgfplotstablevertcat{\output}{datafile\i} % appends 'datafile\i' -> '\output'
}%
% since it was ungrouped, \output is still defined (would not work
% with \foreach)
```

Remark: The special syntax ⟨*list*⟩=⟨x_0⟩,⟨x_1⟩,...,⟨x_n⟩, i.e. with two leading elements, followed by dots and a final element, invokes the math parser for the loop. Thus, it allows larger number ranges than any other syntax if `/pgf/fpu` is active. In all other cases, `\pgfplotsforeachungrouped` invokes `\foreach` and provides the results without TeX groups.

Keep in mind that inside of an axis environment, all loop constructions (including custom loops, `\foreach` and `\pgfplotsforeachungrouped`) need to be handled with care: loop arguments can only be used in places where they are immediately evaluated; but PGFPLOTS postpones the evaluation of

many macros. For example, to loop over something and to generate axis descriptions of the form `\node at (axis cs:\i,0.5)....`, the loop macro `\i` will be evaluated in `\end{axis}` – but at that time, the loop is over and its value is lost. The correct way to handle such an application is to *expand* the loop variable *explicitly*. For example:

```
\pgfplotsforeachungrouped \i/\j in {
    1 / a,
    2 / b,
    3 / c
}{
    \edef\temp{\noexpand\node at (axis cs: \i,0.5) {\j};}
    % \show\temp % lets TeX show you what \temp contains
    \temp
}
```

The example generates three loop iterations: `\i=1`, `\j=a`; then `\i=2`, `j=b`; then `\i=3`, `\j=c`. Inside of the loop body, it expands them and assigns the result to a macro using an "expanded definition", `\edef`. The result no longer contains either `\i` or `\j` (since these have been expanded). Then, it invokes the resulting macro. Details about the TeX command `\edef` and expansion control can be found in the document [TeX-programming-notes.pdf](#) which comes with PGFPLOTS.

`\pgfplotsinvokeforeach{⟨list⟩} {⟨command⟩}`

A variant of `\pgfplotsforeachungrouped` (and such also of `\foreach`) which replaces any occurrence of `#1` inside of ⟨command⟩ once for every element in ⟨list⟩. Thus, it actually assumes that `{⟨command⟩}` is like a `\newcommand` body.

In other words, ⟨command⟩ is invoked for every element of ⟨list⟩. The actual element of ⟨list⟩ is available as `#1`.

As `\pgfplotsforeachungrouped`, this command does *not* introduce extra scopes (i.e. it is ungrouped as well).

The difference to `\foreach \x in ⟨list⟩{⟨command⟩}` is subtle: the `\x` would *not* be expanded whereas `#1` is.

```
Invoke them: [a] [b] [c] [d]        \pgfkeys{
                                       otherstyle a/.code={[a]},
                                       otherstyle b/.code={[b]},
                                       otherstyle c/.code={[c]},
                                       otherstyle d/.code={[d]}}
                                    \pgfplotsinvokeforeach{a,b,c,d}
                                        {\pgfkeys{key #1/.style={otherstyle #1}}}
                                    Invoke them:
                                    \pgfkeys{key a} \pgfkeys{key b}
                                    \pgfkeys{key c} \pgfkeys{key d}
```

The counter example would use a macro (here `\x`) as loop argument:

```
Invoke them: [d] [d] [d] [d]        \pgfkeys{
                                       otherstyle a/.code={[a]},
                                       otherstyle b/.code={[b]},
                                       otherstyle c/.code={[c]},
                                       otherstyle d/.code={[d]}}
                                    \pgfplotsforeachungrouped \x in {a,b,c,d}
                                        {\pgfkeys{key \x/.style={otherstyle \x}}}
                                    Invoke them:
                                    \pgfkeys{key a} \pgfkeys{key b}
                                    \pgfkeys{key c} \pgfkeys{key d}
```

Restrictions: you can't nest this command yet (since it does not introduce protection by scopes).

`\pgfmathparse{⟨expression⟩}`

Invokes the PGF math parser for ⟨expression⟩ and defines `\pgfmathresult` to be the result.

```
The result is '42.0'.               \pgfmathparse{1+41}

                                    The result is '\pgfmathresult'.
```

The math engine in PGF typically uses TEX's internal arithmetics. That means: it is well suited for numbers in the range $[-16384, 16384]$ and has a precision of 5 digits.

The number range is typically too small for plotting applications. PGFPLOTS improves the number range by means of `\pgfkeys{/pgf/fpu}\pgfmathparse{1+41}` to activate the "floating point unit" (fpu) and to apply all following operations in floating point.

In PGFPLOTS, the key `/pgfplots/use fpu` is typically on, which means that any coordinate arithmetics are carried out with the `fpu`. However, all PGF related drawing operations still use the standard math engine.

In case you ever need to process numbers of extended precision, you may want to use

The result is '$1 \cdot 10^6$'.

```
\pgfkeys{/pgf/fpu}%
\pgfmathparse{1000*1000}

The result is '\pgfmathprintnumber{\pgfmathresult}'.
```

Note that results of the `fpu` are typically not in human-readable format, so `\pgfmathprintnumber` is the preferred way to typeset such numbers.

Please refer to [7] for more details.

`/pgf/declare function`=⟨*function definitions*⟩

Allows to define one or more functions.

The argument ⟨*function definitions*⟩ can cantain one or more definitions, and each *must* be terminated by a semicolon:
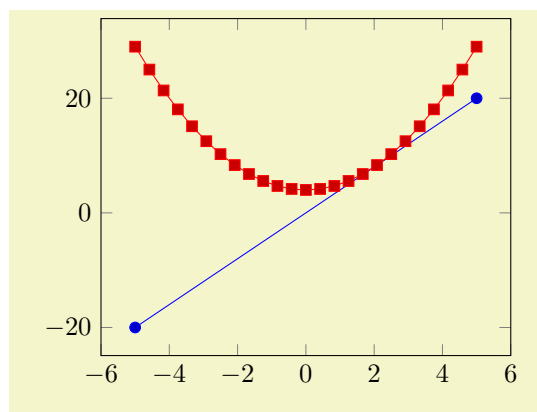

```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
    \begin{axis}[
        declare function={
            C=4;
            square(\t)=(\t)^2 + C;
        },
    ]
    \addplot+[samples=2] {C*x};

    \addplot {square(x)};
    \end{axis}
\end{tikzpicture}
```

The definitions as such have the form ⟨*function*⟩⟨*argument list*⟩ = ⟨*definition*⟩ where the ⟨*argument list*⟩ contains a comma-separated-list of arguments like `\t` or `\t,\a,\b`. The ⟨*definition*⟩ is a math expression which makes use of these arguments.

Please refer to [7] for more details.

`\pgfplotstableread`{⟨*file*⟩}

Please refer to the manual of PGFPLOTSTABLE, `pgfplotstable.pdf`, which is part of the PGF-PLOTS-bundle.

`\pgfplotstabletypeset`{⟨`\`*macro*⟩}

Please refer to the manual of PGFPLOTSTABLE, `pgfplotstable.pdf`, which is part of the PGF-PLOTS-bundle.

`\pgfplotsiffileexists`{⟨*filename*⟩}{⟨*true code*⟩}{⟨*false code*⟩}

Invokes ⟨*true code*⟩ if ⟨*filename*⟩ exists and ⟨*false code*⟩ if not. Can be used in looping macros, for example to plot every data file until there are no more of them.

`\pgfplotsutilifstringequal`{⟨*first*⟩}{⟨*second*⟩}{⟨*true code*⟩}{⟨*false code*⟩}

A simple "strcmp" tool which invokes ⟨*true code*⟩ if ⟨*first*⟩ =⟨*second*⟩ and ⟨*false code*⟩ otherwise. This does not expand macros.

\pgfkeys
\pgfeov
\pgfkeysvalueof
\pgfkeysgetvalue

These commands are part of the TikZ way of specifying options, its sub-package `pgfkeys`. The \pgfplotsset command is actually nothing but a wrapper around \pgfkeys.

A short introduction into \pgfkeys can be found in [9] whereas the complete reference is, of course, the TikZ manual [7].

The key \pgfkeysvalueof{⟨*key name*⟩} expands to the value of a key; \pgfkeysgetvalue{⟨*key name*⟩}{⟨\macro⟩} stores the value of ⟨*key name*⟩ into ⟨\macro⟩. The \pgfeov macro is used to delimit arguments for code keys in \pgfkeys, please refer to the references mentioned above.

8.2 Commands Inside Of PGFPLOTS Axes

\autoplotspeclist

This command should no longer be used, although it will be kept as technical implementation detail. Please use the 'cycle list' option, Section 4.7.7.

\logten

Expands to the constant $\log(10)$. Useful for logplots because $\log(10^i) = i\log(10)$. This command is only available inside of a TikZ-picture.

\pgfmathprintnumber{⟨*number*⟩}

Generates pretty–printed output[1] for ⟨*number*⟩. This method is used for every tick label.

The number is printed using the current number printing options, see the manual of PGFPLOTSTABLE which comes with this package for the different number styles, rounding precision and rounding methods.

\numplots

Inside of any of the axis environments, associated style, option or command, \numplots expands to the total number of plots.

\numplotsofactualtype

Like \numplots, this macro returns the total number of plots which have the same plot handler. Thus, if you have sharp plot active, it returns the number of all sharp plots. If you have ybar active, it returns the number of ybar plots and so on.

\plotnum

Inside of \addplot or any associated style, option or command, \plotnum expands to the current plot's number, starting with 0.

\plotnumofactualtype

Like \plotnum, but it returns the number among all plots of the same type. The number of all such plots is available using \numplotsofactualtype.

\coordindex

Inside of an \addplot command, this macro expands to the number of the actual coordinate (starting with 0).

It is useful together with x filter or y filter to (de)select coordinates.

8.3 Path Operations

\path
\draw

---

[1]This method was previously \prettyprintnumber. Its functionality has been included into PGF and the old command is now deprecated.

`\fill`
`\node`
`\matrix`

These commands are TikZ drawing commands all of which are documented in [7]. They are used to draw or fill paths, generate text nodes or aligned text matrices. They are equivalent to `\path[draw]`, `\path[fill]`, `\path[node]`, `\path[matrix]`, respectively.

`\path ... --⟨`*coordinate*`⟩ ... ;`

A TikZ path operation which connects the current point (the last one before `--`) and ⟨*coordinate*⟩ with a straight line.

`\path ... |-⟨`*coordinate*`⟩ ... ;`

A TikZ path operation which connects the current point and ⟨*coordinate*⟩ with *two* straight lines: first vertical, then horizontal.

`\path ... -|⟨`*coordinate*`⟩ ... ;`

A TikZ path operation which connects the current point and ⟨*coordinate*⟩ with *two* straight lines: first horizontal, then vertical.

`/tikz/xshift={⟨`*dimension*`⟩}`
`/tikz/yshift={⟨`*dimension*`⟩}`

These TikZ keys allow to shift something by ⟨*dimension*⟩ which is any TeX size (or expression).

`\pgfplotsextra{⟨`*low-level path commands*`⟩}`

A command to execute ⟨*low-level path commands*⟩ in a PGFPLOTS axis. Since any drawing commands inside of an axis need to be postponed until the axis is complete and the scaling has been initialised, it is not possible to simply draw any paths. Instead, it is necessary to draw them as soon as the axis is finished. This is done automatically for every TikZ path – and it is also done manually if you write `\pgfplotsextra{⟨`*commands*`⟩}`.
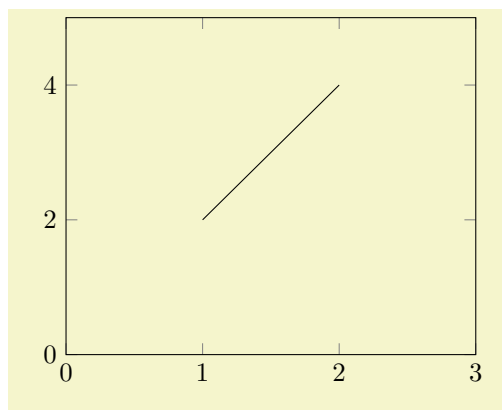

```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
    \begin{axis}[xmin=0,xmax=3,ymin=0,ymax=5]
    \pgfplotsextra{%
        \pgfpathmoveto{\pgfplotspointaxisxy{1}{2}}%
        \pgfpathlineto{\pgfplotspointaxisxy{2}{4}}%
        \pgfusepath{stroke}%
    }
    \end{axis}
\end{tikzpicture}
```

The example above initializes an axis and executes the basic level path commands as soon as the axis is ready. The execution of multiple `\path`, `\addplot` and `\pgfplotsextra` commands is in the same sequence as they occur in the environment[2].

`\pgfplotspathaxisoutline`

Generates a path which resembles the outline of the current axis. This path is used for clip paths and the background paths (if any).

8.4 Specifying Basic Coordinates

`\pgfplotspointaxisxy{⟨`*x coordinate*`⟩}{⟨`*y coordinate*`⟩}`

---

[2]Except for stacked plots where the sequence may be reverse, see the key `reverse stack plots`.

\pgfplotspointaxisxyz{⟨x coordinate⟩}{⟨y coordinate⟩}{⟨z coordinate⟩}

Point commands like \pgfpointxy which take logical, absolute coordinates and return a low–level point. Every transformation from user transformations to logarithms is applied.

Since the transformations are initialized after the axis is complete, this command needs to be postponed (see \pgfplotsextra).

This command is the basic–level variant of axis cs:⟨x coordinate⟩,⟨y coordinate⟩,⟨z coordinate⟩.

Note that this is also the default coordinate system during the visualization phase; in other words: if you write \draw (1,2) -- (1,4), PGFPLOTS will automatically use (axis cs:1,2) -- (axis cs:1,4).

\pgfplotspointaxisdirectionxy{⟨x coordinate⟩}{⟨y coordinate⟩}
\pgfplotspointaxisdirectionxyz{⟨x coordinate⟩}{⟨y coordinate⟩}{⟨z coordinate⟩}

Point commands like \pgfpointxy which take logical, *relative* coordinates and return a low–level point. Every transformation from user transformations to logarithms is applied. The difference to \pgfplotspointaxisxy is that the shift of the linear transformation is skipped here (compare disabledatascaling).

This command is the basic–level variant of axis direction cs:⟨x coordinate⟩,⟨y coordinate⟩,⟨z coordinate⟩. Please refer to the documentation of axis direction cs for more details.

Use this command whenever something of *relative* character like directions or lengths need to be supplied. One use-case is to draw ellipses:
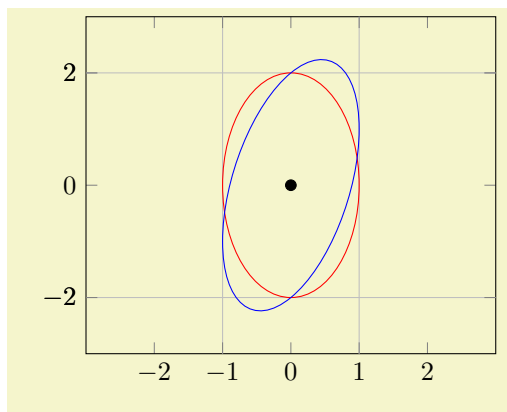
```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
\begin{axis}[
    xmin=-3,    xmax=3,
    ymin=-3,    ymax=3,
    extra x ticks={-1,1},
    extra y ticks={-2,2},
    extra tick style={grid=major},
]
    \draw[red] \pgfextra{
      \pgfpathellipse{\pgfplotspointaxisxy{0}{0}}
        {\pgfplotspointaxisdirectionxy{1}{0}}
        {\pgfplotspointaxisdirectionxy{0}{2}}
      % see also the documentation of
      % 'axis direction cs' which
      % allows a simpler way to draw this ellipse
    };
    \draw[blue] \pgfextra{
      \pgfpathellipse{\pgfplotspointaxisxy{0}{0}}
        {\pgfplotspointaxisdirectionxy{1}{1}}
        {\pgfplotspointaxisdirectionxy{0}{2}}
    };
    \addplot [only marks,mark=*] coordinates
        { (0,0) };
\end{axis}
\end{tikzpicture}
```

Since the transformations are initialized after the axis is complete, this command needs to be provided either inside of a TikZ \path command (like \draw in the example above) or inside of \pgfplotsextra.

\pgfplotspointrelaxisxy{⟨rel x coordinate⟩}{⟨rel y coordinate⟩}
\pgfplotspointrelaxisxyz{⟨rel x coordinate⟩}{⟨rel y coordinate⟩}{⟨rel z coordinate⟩}

Point commands which take *relative* coordinates such that $x = 0$ is the *lower* x axis limit and $x = 1$ the *upper* x axis limit.

These commands are used for rel axis cs.

Please note that the transformations are only initialised if the axis is complete! This means you need to provide \pgfplotsextra.

\pgfplotspointdescriptionxy{⟨x fraction⟩}{⟨y fraction⟩}
\pgfplotsqpointdescriptionxy{⟨x fraction⟩}{⟨y fraction⟩}

Point commands such that {0}{0} is the lower left corner of the axis' bounding box and {1}{1} the upper right one; everything else is in between. The 'q' variant is quicker as it doesn't invoke the math parser on its arguments.

They are used for `axis description cs`, see Section 4.9.1.

\pgfplotspointaxisorigin

A point coordinate at the origin, $(0, 0, 0)$. If the origin is not part of the axis limits, the nearest point on the boundary is returned instead.

This is the same coordinate as returned by the `origin` anchor.

\pgfplotstransformcoordinatex{⟨*x coordinate of an axis*⟩}
\pgfplotstransformcoordinatey{⟨*y coordinate of an axis*⟩}
\pgfplotstransformcoordinatez{⟨*z coordinate of an axis*⟩}

Defines \pgfmathresult to be the low-level PGF coordinate corresponding to the input argument.

The command applies any `[xyz] coord trafo` keys, data scalings and/or logarithms or whatever PGF-PLOTS does to map input coordinates to internal coordinates.

The result can be used inside of a \pgfpointxy statement (i.e. it still needs to be scaled with the respective PGF unit vector).
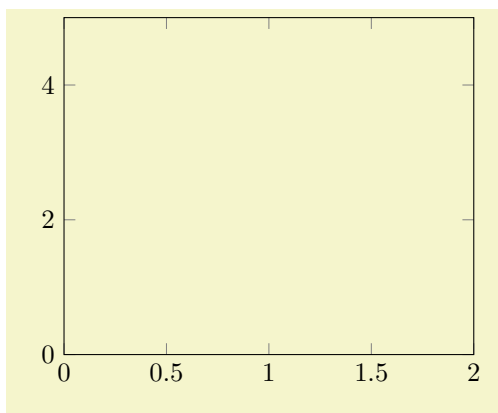
```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
    \begin{axis}[xmin=0,xmax=2,ymin=0,ymax=5]
    \pgfplotsextra{%
        \pgfplotstransformcoordinatex{1}%
        \let\xcoord=\pgfmathresult
        \pgfplotstransformcoordinatey{1}%
        \let\ycoord=\pgfmathresult
        \pgfpathcircle
            {\pgfqpointxy{\xcoord}{\ycoord}}
            {5pt}%
        \pgfusepath{fill}%
    }%
    \end{axis}
\end{tikzpicture}
```

The result of this command is also available as math method `transformcoordinatex` (see the documentation for `axis cs`).

Please note that the transformations are only initialised if the axis is complete. This means you need to provide \pgfplotsextra as is shown in the example above.

\pgfplotstransformdirectionx{⟨*x direction of an axis*⟩}
\pgfplotstransformdirectiony{⟨*y direction of an axis*⟩}
\pgfplotstransformdirectionz{⟨*z direction of an axis*⟩}

Defines \pgfmathresult to be a low-level PGF *direction vector component*.

A direction vector needs to be *added* to some coordinate in order to get a coordinate, compare the documentation for \pgfplotspointaxisdirectionxy and `axis direction cs`.

The argument ⟨*x direction of an axis*⟩ is processed in (almost) the same way as for the macro which operates on absolute positions, \pgfplotstransformcoordinatex. The only difference is that *directions* need no shifting transformation.

The result of this command is also available as math method `transformdirectionx` (see the documentation for `axis direction cs`).

See `axis direction cs` for details and examples about this command.

\pgfplotspointunitx
\pgfplotspointunity
\pgfplotspointunitz

Low–level point commands which return the canvas x, y or z unit vectors.

The \pgfplotspointunitx is the PGF unit vector in x direction.

These vectors are essentially the same as \pgfqpointxyz{1}{0}{0}, \pgfqpointxyz{0}{1}{0}, and \pgfqpointxyz{0}{0}{1}, respectively.

The unit z vector is only defined for three dimensional axes.

`\pgfplotsunitxlength`
`\pgfplotsunitylength`
`\pgfplotsunitzlength`
`\pgfplotsunitxinvlength`
`\pgfplotsunityinvlength`
`\pgfplotsunitzinvlength`

Macros which expand to the vector length $\|x_i\|$ of the respective unit vector x_i or the inverse vector length, $1/\|x_i\|$. These macros can be used inside of `\pgfmathparse`, for example.

The x_i are the `\pgfplotspointunitx` variants.

`\pgfplotsqpointoutsideofaxis`{⟨*three-char-string*⟩}{⟨*coordinate*⟩}{⟨*normal distance*⟩}

Provides a point coordinate on one of the available four axes in case of a two dimensional figure or on one of the available twelve axes in case of a three dimensional figure.

The desired axis is uniquely identified by a three character string, provided as first argument to the command. The first of the three characters is '`0`' if the x coordinate of the specified axis passes through the lower axis limit. It is '`1`', if the x coordinate of the specified axis passes through the upper axis limit. Furthermore, it is '`2`' if it passes through the origin. The second character is also either 0, 1 or 2 and it characterizes the position on the y axis. The third character is for the third dimension, the z axis. It should be left at '`0`' for two dimensional plots. However, *one* of the three characters should be '`v`', meaning the axis <u>v</u>aries. For example, `v01` denotes $\{(x, y_{\min}, z_{\max})|x \in \mathbb{R}\}$.

The second argument, ⟨*coordinate*⟩ is the logical coordinate on that axis. Since two coordinates of the axis are fixed, ⟨*coordinate*⟩ refers to the <u>v</u>arying component of the axis. It must be a number without unit; no math expressions are supported here.

The third argument ⟨*normal distance*⟩ is a dimension like `10pt`. It shifts the coordinate away from the designated axis in direction of the outer normal vector. The outer normal vector always points away from the axis. It is computed using `\pgfplotspointouternormalvectorofaxis`.

There are several variants of this command which are documented in the source code. One of them is particularly useful:

`\pgfplotsqpointoutsideofaxisrel`{⟨*three-char-string*⟩}{⟨*axis fraction*⟩}{⟨*normal distance*⟩}

This point coordinate is a variant of `\pgfplotsqpointoutsideofaxis` which allows to provide an ⟨*axis fraction*⟩ instead of an absolute coordinate. The fraction is a number between 0 (lower axis limit) and 1 (upper axis limit), i.e. it is given in percent of the total axis. It is possible to provide negative values or values larger than one.

The `\pgfplotsqpointoutsideofaxisrel` command is similar in spirit to `rel axis cs`.

There is one speciality in conjunction with reversed axes: if the axis has been reversed by `x dir`=`reverse` and, in addition, `allow reversal of rel axis cs` is true, the value 0 denotes the *upper* limit while 1 denotes the *lower* limit. The effect is that coordinates won't change just because of axis reversal.

`\pgfplotspointouternormalvectorofaxis`{⟨*three-char-string*⟩}

A point command which yields the outer normal vector of the respective axis. The normal vector has length 1 (computed with `\pgfpointnormalised`). It is the same normal vector used inside of `\pgfplotsqpointoutsideofaxis` and its variants.

The output of this command will be cached and re-used during the lifetime of an axis.

`\pgfplotsticklabelaxisspec`{⟨*x, y or z*⟩}

Expands to the three-character-identification for the axis containing tick labels for the chosen axis, either ⟨*x*⟩, ⟨*y*⟩ or ⟨*z*⟩.

`\pgfplotsvalueoflargesttickdimen`{⟨*x, y or z*⟩}

Expands to the largest distance of a tick position to its tick label bounding box in direction of the outer unit normal vector. It does also include the value of the `ticklabel shift` key.

This value is used for `ticklabel cs`.

`\pgfplotsmathfloatviewdepthxyz`{⟨*x*⟩}{⟨*y*⟩}{⟨*z*⟩}

`\pgfplotsmathviewdepthxyz{⟨x⟩}{⟨y⟩}{⟨z⟩}`

> Both macros define `\pgfmathresult` to be the "depth" of a three dimensional point $\bar{x} = (x, y, z)$. The depth is defined to be the scalar product of $\bar{x}$ with $\vec{d}$, the view direction of the current axis.
>
> For `\pgfplotsmathfloatviewdepthxyz`, the arguments are parsed as floating point numbers and the result is encoded in floating point. A fixed point representation can be generated with `\pgfmathfloattofixed{\pgfmathresult}`.
>
> For `\pgfplotsmathviewdepthxyz`, TeX arithmetics is employed for the inner product and the result is assigned in fixed point. This is slightly faster, but has considerably smaller data range.
>
> Both commands can only be used *inside* of a three dimensional PGFPLOTS axis (as soon as the axis is initialised, see `\pgfplotsextra`).

`\ifpgfplotsthreedim⟨true code⟩\else⟨else code⟩\fi`

> A TeX `\if` which evaluates the ⟨*true code*⟩ if the axis is three dimensional and the ⟨*else code*⟩ if not.

8.5 Accessing Axis Limits

It is also possible to access axis limits during the visualization phase, i.e. during `\end{axis}`. Please refer to the reference documentation for `xmin` on page 323.

8.6 Accessing Point Coordinate Values

During the visualization phase, PGFPLOTS provides access to the currently processed coordinate and its values.

This access requires a call to specific macros. These macros write the coordinate values to some publicy available key–value pairs. Then, the current point's x, y, z, and color data can be accessed.

`\pgfplotspointgetcoordinates`

> A macro which is supposed to be called during the visualization phase. Afterwards, the followings keys will be set:
>
> `/data point/x` will contain the current point's x coordinate.
>
> `/data point/y` will contain the current point's y coordinate.
>
> `/data point/z` will contain the current point's z coordinate (if applicable).
>
> `/data point/meta` will contain the current point's `point meta` value (if applicable).
>
> `/data point/index` will contain the current point's index in the coordinate stream. This is actually the same as `\coordindex`.
>
> The returned value are the same as they can be read on the axes, they are also the same as you would write them into `axis cs`.
>
> This means that any `x coord inv trafo` has been applied on the value. It also means that the exponential function has been called even though the internal coordinate was present in log format.
>
> This function is implicitly called for any `scatter` plot (including `nodes near coords`).
>
> This allows to access *all* coordinate values at once:
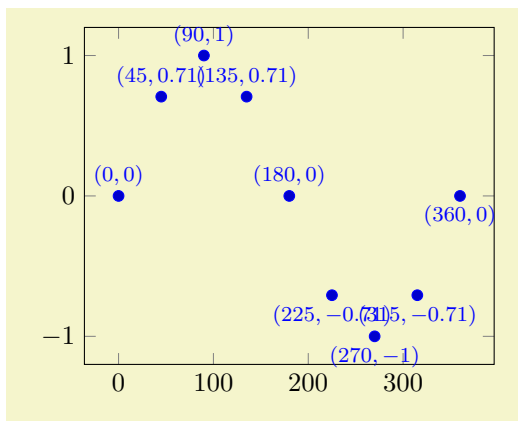
```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
\begin{axis}
    \addplot+[
        domain=0:360,
        samples=9,
        only marks,
        nodes near coords={%
            \footnotesize
            $(\pgfmathprintnumber
                {\pgfkeysvalueof{/data point/x}},
             \pgfmathprintnumber
                {\pgfkeysvalueof{/data point/y}})$%
        },
    ]
    {sin(x)};
\end{axis}
\end{tikzpicture}
```

Note that the preceding example would have been simpler if we would have printed just one value: `nodes near coords` resorts to the `point meta`. And that, in turn, contains the y coordinate anyway by default.

A more advanced example would be a `ybar` plot in which nodes shall be placed at the lower end of the axis, together with some dotted lines to the respective bars:
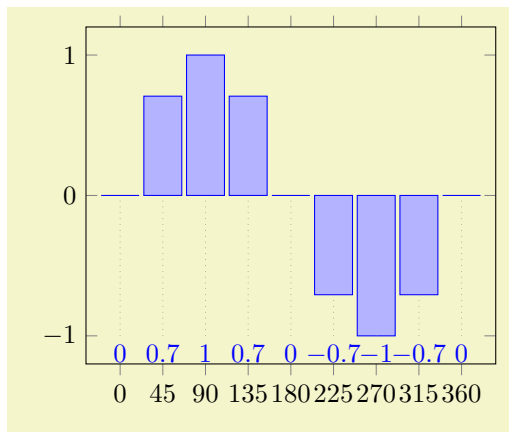

```
% Preamble: \pgfplotsset{width=7cm,compat=1.14}
\begin{tikzpicture}
\begin{axis}[
  ybar,
  nodes near coords,
  %
  % we want to provide absolute 'at' values
  % for the nodes:
  scatter/position=absolute,
  every node near coord/.style={
    at={(\pgfkeysvalueof{/data point/x},-1)},
    % pretty printing:
    anchor=north,
    /pgf/number format/fixed,
    /pgf/number format/precision=1,
    % assign a name which can be referenced below:
    name=NNC\pgfkeysvalueof{/data point/index},
  },
  % ... draw a dotted line between
  % the marker and the bar:
  /pgfplots/scatter/@post marker code/.add code={}{
    \draw[dotted,help lines]
    (NNC\pgfkeysvalueof{/data point/index})
    --
    (\pgfkeysvalueof{/data point/x},
      {min(0,\pgfkeysvalueof{/data point/y})});
  },
  % assign suitable tick labels:
  xtick=data,
]
% some dummy data:
\addplot+[
    domain=0:360,
    bar width=360/9,
    samples=9]
    {sin(x)};
\end{axis}
\end{tikzpicture}
```

\pgfplotspointgetnormalizedcoordinates

A macro which is very similar to \pgfplotspointgetcoordinates. Consequently, it is supposed to be called during the visualization phase.

It assigns the very same output macros, but the values are different. More precisely, it defines the macros

`/data point/x` will contain the current point's *normalized x* coordinate.

`/data point/y` will contain the current point's *normalized y* coordinate.

`/data point/z` will contain the current point's *normalized z* coordinate (if applicable).

`/data point/meta` will contain the current point's `point meta` value (if applicable).

`/data point/index` will contain the current point's index in the coordinate stream. This is actually the same as `\coordindex`.

The keyword `normalized` means that the values are in a suitable numerical form which can be consumed by the axis. To be more specific: any user `x coord inv trafo` is *ignored*. An important example would be `symbolic x coords`: the normalized coordinates would be some associated numbers, not the symbols. The results returned by `\pgfplotspointgetcoordinates` would be the symbols. For logarithm axes, the normalized values are the logs.

Typically, normalized values are much more useful when you want to apply some math operation like averaging or subtraction.

This function needs to be called explicitly. It is currently used by `ybar stacked` to align `nodes near coords`.

8.7 Layer Access

`\pgfplotsonlayer{`⟨*layer name*⟩`}`

A low-level command which will check if the current axis has layer support activated and, if so, calls `\pgfonlayer{`⟨*layer name*⟩`}`.

There must be a `\endpgfplotsonlayer` to delimit the environment.

`\endpgfplotsonlayer`

The end of `\pgfplotsonlayer`.

`\pgfonlayer{`⟨*layer name*⟩`}`

A low-level command of PGF which will collect everything until the matching `\endpgfonlayer` into layer ⟨*layer name*⟩.

The ⟨*layer name*⟩ must be active, i.e. it must be part of the layer names of `set layers`.

The only special case is if you call `\pgfdeclarelayer{discard}` somewhere: this special layer has a "magical name" which serves as `/dev/null` if it is enabled using `\pgfonlayer{discard}`: it does not need to be active and everything assigned to this layer will be thrown away if it is not part of the layer name configuration.

There must be a `\endpgfonlayer` to delimit the environment.

`\endpgfonlayer`

The end of `\pgfonlayer`.

`\pgfsetlayers{`⟨*layer list*⟩`}`

This is a low-level command of PGF. At the time of this writing, it is the only way to tell PGF which layers it shall use for the current / next picture. It is used implicitly by `set layers`.

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