Part I
教程和指导

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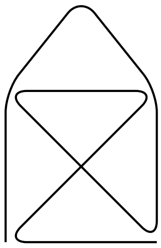
为了帮你入门 Ti*k*Z，本手册没有立刻给出长长的安装和配置过程，而是直接从教程开始。这些教程解释了该系统所有基本特性和部分高级特性，并不深入所有细节。这部分还指导你在用 Ti*k*Z 绘图时，如何继续前进。



```
\tikz \draw[thick,rounded corners=8pt]
  (0,0) -- (0,2) -- (1,3.25) -- (2,2) -- (2,0) -- (0,2) -- (2,2) -- (0,0) -- (2,0);
```

1 绘图指导

这一节不是讲 PGF 和 Ti*k*Z 的，而是讲在科学报告、论文和书籍中绘制图形时，通用的指导和原则。

本节的指导原则源自不同的地方，我想声明的内容，大多都只是“常识”，一些基于我的个人经历（当然，我希望并不只是我个人的偏好），一些来自图形设计和排版的书籍（还没写参考文献，见谅）。

当有人给你列出一堆指导原则时，你首先得问自己：我真的应该遵循这些指导原则吗？这是个重要的问题，因为有很多好理由不去遵循这些通用的指导原则。给出这些指导原则的人，目标可能和你的并不一致。比如说，某条指导可能写“用红色来强调”，这可能非常适合用投影仪做的报告，但是对于黑白打印的内容来说，红色可能就起了*相反的*效果。指导原则几乎总是用于处理特定的情况，在错误的情况下遵守它只会弊大于利。

关于排版的基本规则，你要知道的第二件事是：“每一条规则都可以打破，只要你确实“意识到”你在打破某条规则。”这条规则也适用于绘图。上面那句话换个说法，就是：“排版时唯一的错误，就是对发生的事一无所知。”如果你想打破一条规则并且清楚后果，那么打破它。

1.1 规划绘图需要的时间

如果你要写一篇图很多的文章，那么一个重要的因素是，画这些图要花多久。你怎样计算绘图所需的时间呢？

我们假设，画一张图花费的时间，等于写同样篇幅的文字。比如我写文章，初稿可能一页一小时，到后面修改时，每页可能需要两到四小时。那么，要画半页左右的图，*初稿*我预计需要半个小时，后面还需要一到两小时，完成最终的图。

在许多出版物甚至是优秀的期刊中，作者和编辑明显在文字上花了很多工夫，但是似乎只花了五分钟就画好了所有图。通常这些图好像就是“后加上的”，或者只是统计软件的截图。正如后面会讨论的，像 GNUPLOT 这种软件默认画出来的图，质量并不高。

结合文字绘制信息图，从而帮助读者理解，是一个困难而漫长的过程。

- 把图形作为你文章的一等公民。图形值得花费同文字相等的时间和精力。事实上，相比文字，绘图可能值得投入*更多*的时间，因为人们第一眼看到的就是图形，也更关注图形。
- 给图形的绘制和修改规划尽可能多的时间，就像对待同等篇幅的文字一样。
- 信息量大的困难的图形，可能需要更多的时间。
- 简单的图形需要更少的时间，但是无论如何，很可能你并不想在文章里放“非常简单的图”，就像你不想在文章中写同等篇幅“非常简单的文字”一样。

1.2 绘图的工作流程

你写一篇（科学）文章，通常会遵循下面的模式：你有一些结果或者想法要阐述。写文章时一般会先列一个粗糙的大纲，然后分别写各个章节，得到初稿。在成稿写好前，一般要不停地大量地修改。一篇好的期刊文章，初稿里几乎没有一句到最后还没改过的。

绘图也遵循相同的模式：

- 决定图形想要表达什么。一定要有意识地思考，“图形应该告诉读者什么？”
- 列一个“大纲”，也就是图形整体的大致“轮廓”，包含最重要的元素。在这一步，笔纸一般很有帮助。
- 补充和完善图形的细节，得到初稿。
- 根据文章内容，不断修改图形。

1.3 Linking Graphics With the Main Text

Graphics can be placed at different places in a text. Either, they can be inlined, meaning they are somewhere "in the middle of the text" or they can be placed in stand-alone "figures." Since printers (the people) like to have their pages "filled," (both for aesthetic and economic reasons) stand-alone figures may traditionally be placed on pages in the document far away from the main text that refers to them. LaTeX and TeX tend to encourage this "drifting away" of graphics for technical reasons.

When a graphic is inlined, it will more or less automatically be linked with the main text in the sense that the labels of the graphic will be implicitly explained by the surrounding text. Also, the main text will typically make it clear what the graphic is about and what is shown.

Quite differently, a stand-alone figure will often be viewed at a time when the main text that this graphic belongs to either has not yet been read or has been read some time ago. For this reason, you should follow the following guidelines when creating stand-alone figures:

- Stand-alone figures should have a caption than should make them "understandable by themselves."

  For example, suppose a graphic shows an example of the different stages of a quicksort algorithm. Then the figure's caption should, at the very least, inform the reader that "The figure shows the different stages of the quicksort algorithm introduced on page xyz." and not just "Quicksort algorithm."

- A good caption adds as much context information as possible. For example, you could say: "The figure shows the different stages of the quicksort algorithm introduced on page xyz. In the first line, the pivot element 5 is chosen. This causes. . . " While this information can also be given in the main text, putting it in the caption will ensure that the context is kept. Do not feel afraid of a 5-line caption. (Your editor may hate you for this. Consider hating them back.)

- Reference the graphic in your main text as in "For an example of quicksort 'in action,' see Figure 2.1 on page xyz."

- Most books on style and typography recommend that you do not use abbreviations as in "Fig. 2.1" but write "Figure 2.1."

  The main argument against abbreviations is that "a period is too valuable to waste it on an abbreviation." The idea is that a period will make the reader assume that the sentence ends after "Fig" and it takes a "conscious backtracking" to realize that the sentence did not end after all.

  The argument in favor of abbreviations is that they save space.

  Personally, I am not really convinced by either argument. On the one hand, I have not yet seen any hard evidence that abbreviations slow readers down. On the other hand, abbreviating all "Figure" by "Fig." is most unlikely to save even a single line in most documents. I avoid abbreviations.

1.4 Consistency Between Graphics and Text

Perhaps the most common "mistake" people do when creating graphics (remember that a "mistake" in design is always just "ignorance") is to have a mismatch between the way their graphics look and the way their text looks.

It is quite common that authors use several different programs for creating the graphics of a paper. An author might produce some plots using GNUPLOT, a diagram using XFIG, and include an `.eps` graphic a coauthor contributed using some unknown program. All these graphics will, most likely, use different line widths, different fonts, and have different sizes. In addition, authors often use options like `[height=5cm]` when including graphics to scale them to some "nice size."

If the same approach were taken to writing the main text, every section would be written in a different font at a different size. In some sections all theorems would be underlined, in another they would be printed all in uppercase letters, and in another in red. In addition, the margins would be different on each page. Readers and editors would not tolerate a text if it were written in this fashion, but with graphics they often have to.

To create consistency between graphics and text, stick to the following guidelines:

- Do not scale graphics.

  This means that when generating graphics using an external program, create them "at the right size."

- Use the same font(s) both in graphics and the body text.
- Use the same line width in text and graphics.

  The "line width" for normal text is the width of the stem of letters like T. For TEX, this is usually 0.4 pt. However, some journals will not accept graphics with a normal line width below 0.5 pt.
- When using colors, use a consistent color coding in the text and in graphics. For example, if red is supposed to alert the reader to something in the main text, use red also in graphics for important parts of the graphic. If blue is used for structural elements like headlines and section titles, use blue also for structural elements of your graphic.

  However, graphics may also use a logical intrinsic color coding. For example, no matter what colors you normally use, readers will generally assume, say, that the color green as "positive, go, ok" and red as "alert, warning, action."

Creating consistency when using different graphic programs is almost impossible. For this reason, you should consider sticking to a single graphics program.

1.5 Labels in Graphics

Almost all graphics will contain labels, that is, pieces of text that explain parts of the graphics. When placing labels, stick to the following guidelines:

- Follow the rule of consistency when placing labels. You should do so in two ways: First, be consistent with the main text, that is, use the same font as the main text also for labels. Second, be consistent between labels, that is, if you format some labels in some particular way, format all labels in this way.
- In addition to using the same fonts in text and graphics, you should also use the same notation. For example, if you write 1/2 in your main text, also use "1/2" as labels in graphics, not "0.5". A π is a "π" and not "3.141". Finally, $e^{-i\pi}$ is "$e^{-i\pi}$", not "-1", let alone "-1".
- Labels should be legible. They should not only have a reasonably large size, they also should not be obscured by lines or other text. This also applies to labels of lines and text *behind* the labels.
- Labels should be "in place." Whenever there is enough space, labels should be placed next to the thing they label. Only if necessary, add a (subdued) line from the label to the labeled object. Try to avoid labels that only reference explanations in external legends. Reader have to jump back and forth between the explanation and the object that is described.
- Consider subduing "unimportant" labels using, for example, a gray color. This will keep the focus on the actual graphic.

1.6 Plots and Charts

One of the most frequent kind of graphics, especially in scientific papers, are *plots.* They come in a large variety, including simple line plots, parametric plots, three dimensional plots, pie charts, and many more.

Unfortunately, plots are notoriously hard to get right. Partly, the default settings of programs like GNUPLOT or Excel are to blame for this since these programs make it very convenient to create bad plots.

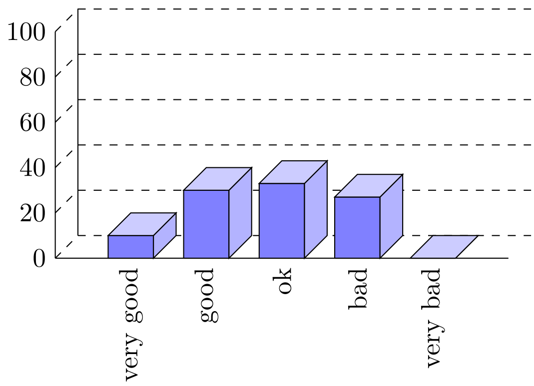
The first question you should ask yourself when creating a plot is: Are there enough data points to merit a plot? If the answer is "not really," use a table.

A typical situation where a plot is unnecessary is when people present a few numbers in a bar diagram. Here is a real-life example: At the end of a seminar a lecturer asked the participants for feedback. Of the 50 participants, 30 returned the feedback form. According to the feedback, three participants considered the seminar "very good," nine considered it "good," ten "ok," eight "bad," and no one thought that the seminar was "very bad."

A simple way of summing up this information is the following table:

Rating given	*Participants (out of 50) who gave this rating*	*Percentage*
"very good"	3	6%
"good"	9	18%
"ok"	10	20%
"bad"	8	16%
"very bad"	0	0%
none	20	40%

What the lecturer did was to visualize the data using a 3D bar diagram. It looked like this (except that in reality the numbers where typeset using some extremely low-resolution bitmap font and were near-unreadable):



Both the table and the "plot" have about the same size. If your first thought is "the graphic looks nicer than the table," try to answer the following questions based on the information in the table or in the graphic:

1. How many participants where there?
2. How many participants returned the feedback form?
3. What percentage of the participants returned the feedback form?
4. How many participants checked "very good"?
5. What percentage out of all participants checked "very good"?
6. Did more than a quarter of the participants check "bad" or "very bad"?
7. What percentage of the participants that returned the form checked "very good"?

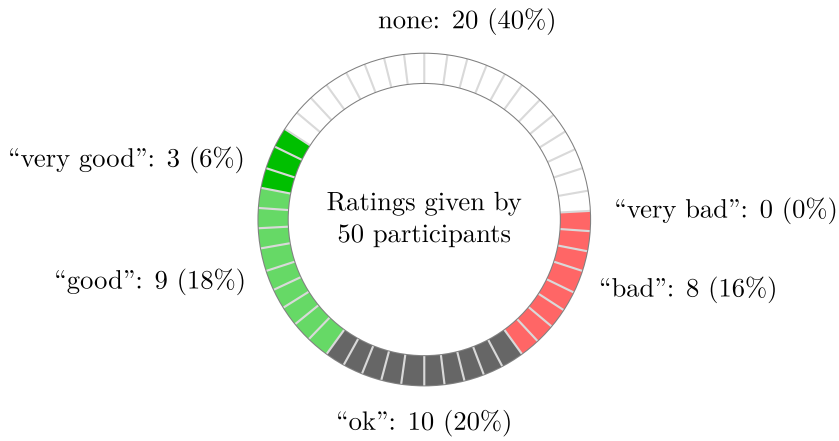
Sadly, the graphic does not allow us to answer *a single one of these questions*. The table answers all of them directly, except for the last one. In essence, the information density of the graphic is very close to zero. The table has a much higher information density; despite the fact that it uses quite a lot of white space to present a few numbers. Here is the list of things that went wrong with the 3D-bar diagram:

- The whole graphic is dominated by irritating background lines.
- It is not clear what the numbers at the left mean; presumably percentages, but it might also be the absolute number of participants.
- The labels at the bottom are rotated, making them hard to read.

  (In the real presentation that I saw, the text was rendered at a very low resolution with about 10 by 6 pixels per letter with wrong kerning, making the rotated text almost impossible to read.)
- The third dimension adds complexity to the graphic without adding information.
- The three dimensional setup makes it much harder to gauge the height of the bars correctly. Consider the "bad" bar. It the number this bar stands for more than 20 or less? While the front of the bar is below the 20 line, the back of the bar (which counts) is above.

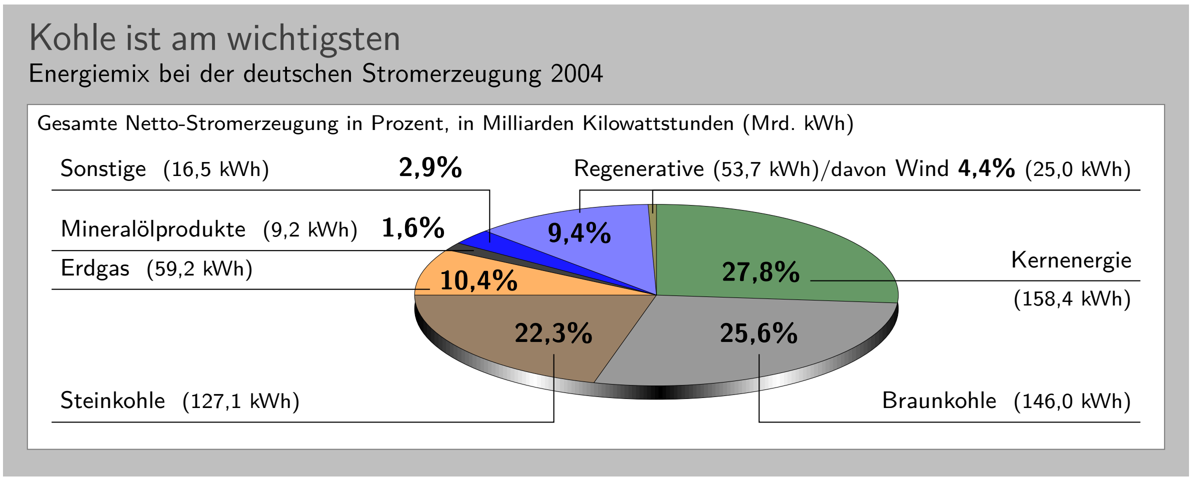
- It is impossible to tell which numbers are represented by the bars. Thus, the bars needlessly hide the information these bars are all about.
- What do the bar heights add up to? Is it 100% or 60%?
- Does the bar for "very bad" represent 0 or 1?
- Why are the bars blue?

You might argue that in the example the exact numbers are not important for the graphic. The important things is the "message," which is that there are more "very good" and "good" ratings than "bad" and "very bad." However, to convey this message either use a sentence that says so or use a graphic that conveys this message more clearly:



The above graphic has about the same information density as the table (about the same size and the same numbers are shown). In addition, one can directly "see" that there are more good or very good ratings than bad ones. One can also "see" that the number of people who gave no rating at all is not negligible, which is quite common for feedback forms.

Charts are not always a good idea. Let us look at an example that I redrew from a pie chart in *Die Zeit*, June 4th, 2005:



This graphic has been redrawn in Ti*k*Z, but the original looks almost exactly the same.

At first sight, the graphic looks "nice and informative," but there are a lot of things that went wrong:

- The chart is three dimensional. However, the shadings add nothing "information-wise," at best, they distract.
- In a 3D-pie-chart the relative sizes are very strongly distorted. For example, the area taken up by the gray color of "Braunkohle" is larger than the area taken up by the green color of "Kernenergie" *despite the fact that the percentage of Braunkohle is less than the percentage of Kernenergie.*

- The 3D-distortion gets worse for small areas. The area of "Regenerative" somewhat larger than the area of "Erdgas." The area of "Wind" is slightly smaller than the area of "Mineralölprodukte" *although the percentage of Wind is nearly three times larger than the percentage of Mineralölprodukte.*

  In the last case, the different sizes are only partly due to distortion. The designer(s) of the original graphic have also made the "Wind" slice too small, even taking distortion into account. (Just compare the size of "Wind" to "Regenerative" in general.)

- According to its caption, this chart is supposed to inform us that coal was the most important energy source in Germany in 2004. Ignoring the strong distortions caused by the superfluous and misleading 3D-setup, it takes quite a while for this message to get across.

  Coal as an energy source is split up into two slices: one for "Steinkohle" and one for "Braunkohle" (two different kinds of coal). When you add them up, you see that the whole lower half of the pie chart is taken up by coal.

  The two areas for the different kinds of coal are not visually linked at all. Rather, two different colors are used, the labels are on different sides of the graphic. By comparison, "Regenerative" and "Wind" are very closely linked.

- The color coding of the graphic follows no logical pattern at all. Why is nuclear energy green? Regenerative energy is light blue, "other sources" are blue. It seems more like a joke that the area for "Braunkohle" (which literally translates to "brown coal") is stone gray, while the area for "Steinkohle" (which literally translates to "stone coal") is brown.

- The area with the lightest color is used for "Erdgas." This area stands out most because of the brighter color. However, for this chart "Erdgas" is not really important at all.

Edward Tufte calls graphics like the above "chart junk." (I am happy to announce, however, that *Die Zeit* has stopped using 3D pie charts and their information graphics have got somewhat better.)

Here are a few recommendations that may help you avoid producing chart junk:

- Do not use 3D pie charts. They are *evil.*
- Consider using a table instead of a pie chart.
- Do not apply colors randomly; use them to direct the readers's focus and to group things.
- Do not use background patterns, like a crosshatch or diagonal lines, instead of colors. They distract. Background patterns in information graphics are *evil.*

1.7 Attention and Distraction

Pick up your favorite fiction novel and have a look at a typical page. You will notice that the page is very uniform. Nothing is there to distract the reader while reading; no large headlines, no bold text, no large white areas. Indeed, even when the author does wish to emphasize something, this is done using italic letters. Such letters blend nicely with the main text—at a distance you will not be able to tell whether a page contains italic letters, but you would notice a single bold word immediately. The reason novels are typeset this way is the following paradigm: Avoid distractions.

Good typography (like good organization) is something you do *not* notice. The job of typography is to make reading the text, that is, "absorbing" its information content, as effortless as possible. For a novel, readers absorb the content by reading the text line-by-line, as if they were listening to someone telling the story. In this situation anything on the page that distracts the eye from going quickly and evenly from line to line will make the text harder to read.

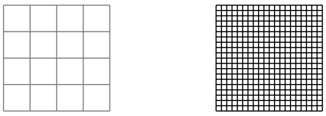
Now, pick up your favorite weekly magazine or newspaper and have a look at a typical page. You will notice that there is quite a lot "going on" on the page. Fonts are used at different sizes and in different arrangements, the text is organized in narrow columns, typically interleaved with pictures. The reason magazines are typeset in this way is another paradigm: Steer attention.

Readers will not read a magazine like a novel. Instead of reading a magazine line-by-line, we use headlines and short abstracts to check whether we want to read a certain article or not. The job of typography is to steer our attention to these abstracts and headlines, first. Once we have decided that we want to read an article, however, we no longer tolerate distractions, which is why the main text of articles is typeset exactly the same way as a novel.

The two principles “avoid distractions” and “steer attention” also apply to graphics. When you design a graphic, you should eliminate everything that will “distract the eye.” At the same time, you should try to actively help the reader “through the graphic” by using fonts/colors/line widths to highlight different parts.

Here is a non-exhaustive list of things that can distract readers:

- Strong contrasts will always be registered first by the eye. For example, consider the following two grids:

  Even though the left grid comes first in English reading order, the right one is much more likely to be seen first: The white-to-black contrast is higher than the gray-to-white contrast. In addition, there are more “places” adding to the overall contrast in the right grid.

  Things like grids and, more generally, help lines usually should not grab the attention of the readers and, hence, should be typeset with a low contrast to the background. Also, a loosely-spaced grid is less distracting than a very closely-spaced grid.

- Dashed lines create many points at which there is black-to-white contrast. Dashed or dotted lines can be very distracting and, hence, should be avoided in general.

  Do not use different dashing patterns to differentiate curves in plots. You lose data points this way and the eye is not particularly good at “grouping things according to a dashing pattern.” The eye is *much* better at grouping things according to colors.

- Background patterns filling an area using diagonal lines or horizontal and vertical lines or just dots are almost always distracting and, usually, serve no real purpose.

- Background images and shadings distract and only seldomly add anything of importance to a graphic.

- Cute little clip arts can easily draw attention away from the data.