Introduction to LaTeX

Lecture IV: Graphs, Tables and Code

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Include Graphs

Before all, you need the `graphics` or `graphicx` package, where `graphicx` is an extended and enhanced one. So you are recommended to insert the command in the preamble of your document.

Command

```
\usepackage{graphicx}
```

Then you can use the command `\includegraphics` to insert images of many formats, including `jpg`, `png` images and even other `pdf` files. `eps` images should be supported by most modern LaTeX distributions as well.

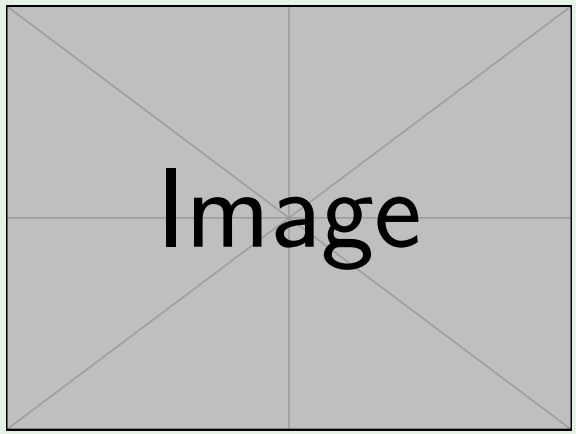
Command

```
\includegraphics[options]{filename}
```

There are some example images defined, you can insert them if the figure is not yet ready when writing LaTeX code. They are `example-image`, `example-image-golden`, `example-image-a`, `example-image-b` and etc.

Example

```
1  \includegraphics[width=0.4\textwidth]{example-image}
```



We usually use the `width` option to adjust the size of the image, according to a ratio of `\textwidth`, which means the maximum width of text here.

Options of Include Graphs

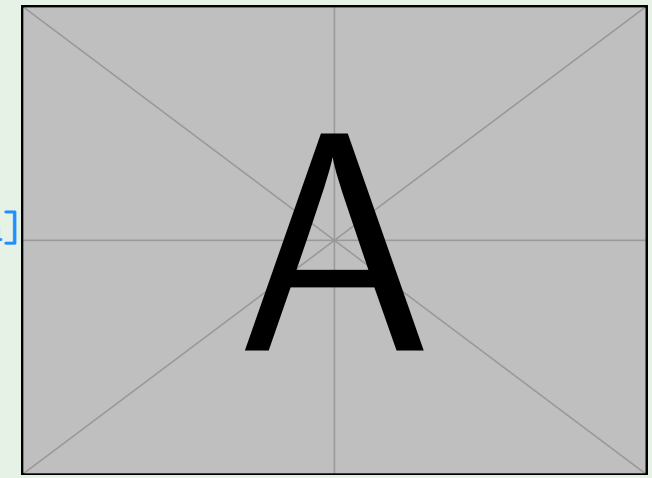
Here some useful `options` are listed:

- `height` - use any LaTeX measuring unit.
- `width` - use any LaTeX measuring unit.
- `scale` - scale the graph to this proportion
- `angle` - rotate the graph in anti-clockwise by this angle

LaTeX measuring unit can be `\textwidth`, `\linewidth`, `\textheight`, `\lineheight`, cm, pt, em, and etc..

Example

```
1  \includegraphics[width=4cm]
2  {example-image-a}
```



The figure Environment

The figure environment provides a wrapper of image inserted by \includegraphics, which add caption and label (reference) to an image. They are especially useful in report and paper writing, here is a template of how to use the environment.

Command

```
\begin{figure}[position]
  \centering
  \includegraphics[options]{filename}
  \caption{caption}
  \label{fig:label}
\end{figure}
```

- filename - the filename or relative path of the graph you want to insert, usually placed in the same or child directory as the tex file
- position - we usually use !htbp or !H here, which will be introduced later in this chapter
- caption - the caption displayed above/under the graph
- label - used for references in a document (will be

Labels and References

You can use `\ref` to have a reference of a figure by its label. The figures will be automatically numbered (like equations), and the reference is also a hyperlink.

Example

```
\begin{figure}[!htbp]
  \centering
  \includegraphics[
    width=0.8\textwidth,
    angle=90
  ]{example-image-b}
  \caption{Example Image B
  ↪  rotated by 90 degree.}
  \label{fig:img-b}
\end{figure}
B was shown in Figure
\ref{fig:img-b}.
```

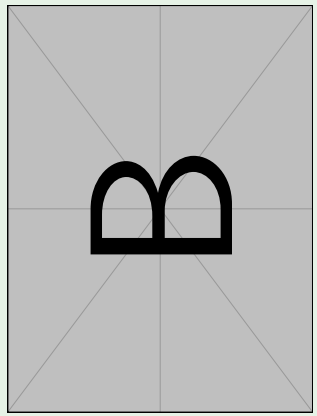


Figure 1: Example Image B rotated by 90 degree.

B was shown in Figure 1.

Floats and Positions

Floats are containers for things in a document that cannot be broken over a page. LaTeX by default recognizes `figure` and `table` (will be introduced later) floats.

If you don't provide the `position` option, LaTeX will try to help you find a place to set the figure. However, the position is often not ideal, so you need to add some specifiers yourselves.

- `h` - Place the float here, i.e., approximately at the same point it occurs in the source text (however, not exactly at the spot)
- `t` - Position at the top of the page.
- `b` - Position at the bottom of the page.
- `p` - Put on a special page for floats only.
- `!` - Override internal parameters LaTeX uses for determining "good" float positions.
- `H` - Places the float at precisely the location in the LaTeX code. Requires the float package, i.e., `\usepackage{float}`.

Include Multiple Graphs

A useful extension is the `subcaption` package, which provides a `subfigure` environment to add multiple subfigures in a figure.

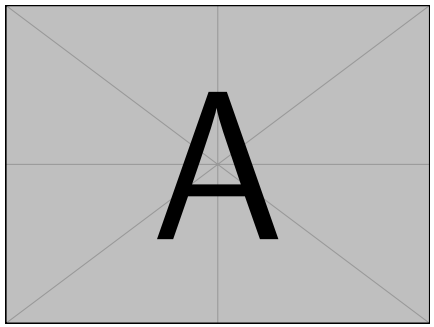
Note that there is also a package called `subfigure`, but is has been deprecated (not maintained), please do not use it. Another package called `subfig` provides the same commands as that of `subfigure` package. However, they can't be used together.

In simplicity, if there is some compatibility problem with your template after you tried the `subcaption` package, choose the `subfig` package.

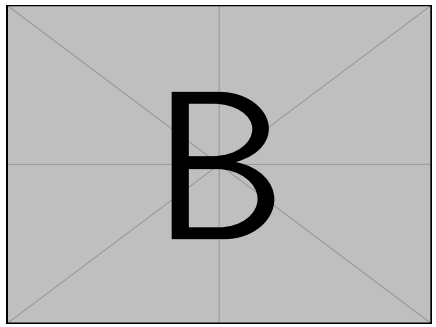
Here is an example with the `subcaption` package.

Example

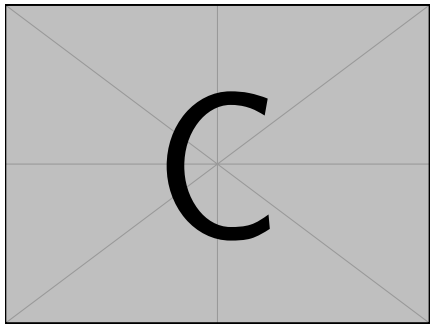
```
\begin{figure}
    \centering
    \begin{subfigure}{0.3\textwidth}
        ↪ \includegraphics[width=\textwidth]{example-image
        \caption{Example Image A.}
        \label{fig:subcaption-a}
    \end{subfigure}
    ~
    \begin{subfigure}{0.3\textwidth}
        ↪ \includegraphics[width=\textwidth]{example-image
        \caption{Example Image B.}
        \label{fig:subcaption-b}
    \end{subfigure}

    \begin{subfigure}{0.3\textwidth}
        ↪ \includegraphics[width=\textwidth]{example-image
        \caption{Example Image C.}
        \label{fig:subcaption-c}
    \end{subfigure}
    \caption{Example Images}\label{fig:subcaption}
\end{figure}
```



(a) Example Image A.



(b) Example Image B.



(c) Example Image C.

Figure 2: Example Images

As shown in Figure 2, the figures can be arranged in columns and rows.

Between Figure 2a and Figure 2b, a ~ was added. You can add desired spacing between images, e. g. ~, `\quad`, `\qquad`, `\hfill` (fill all rest horizontal spaces) and etc..

Between Figure 2b and Figure 2c, a newline was added. It will force the subfigure onto a new line.

The references of subfigures can be used by their `\label` as well. For example, above references are generated by these commands:

Example

```
\ref{fig:subcaption}
\ref{fig:subcaption-a}
\ref{fig:subcaption-b}
\ref{fig:subcaption-c}
```

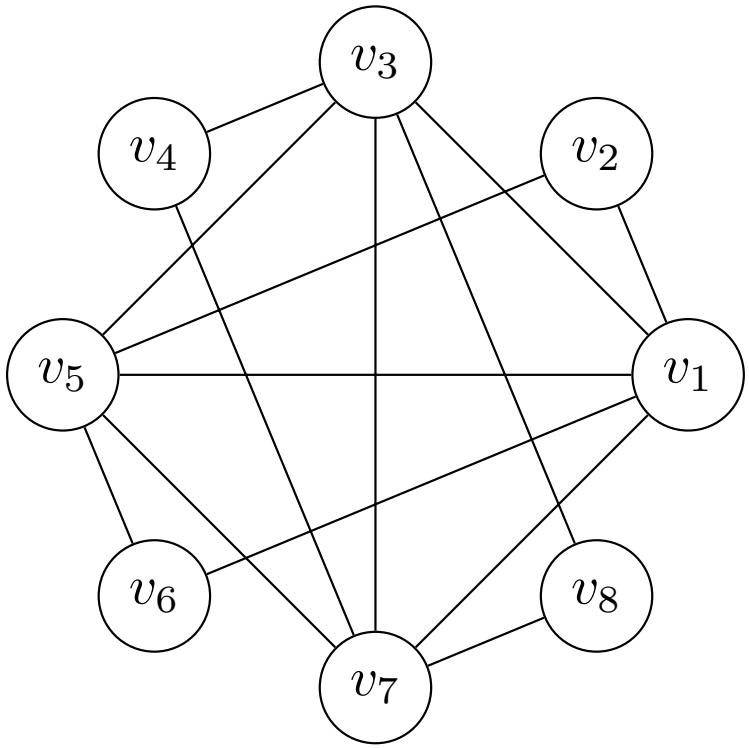
The tikz and pgf packages

The tikz and pgf packages can help you draw graphs in LaTeX for example:

Example

```
\begin{tikzpicture}[scale=2, bend angle=22.5]
\tikzstyle{every node}=[draw,shape=circle];
\foreach \i in {1,...,8}
{
\path (45*\i-45:1cm) node (v\i) {$v_\i$};
}
\draw
(v1) -- (v2) (v3) -- (v4) (v5) -- (v6) (v7) -- (v8)
(v1) -- (v3) (v3) -- (v5) (v5) -- (v7) (v7) -- (v1)
(v2) -- (v5) (v4) -- (v7) (v6) -- (v1) (v8) -- (v3)
(v1) -- (v5) (v3) -- (v7);
\end{tikzpicture}
```

This will generate a simple graph which consists of eight nodes:



There may be a lecture about `tikz` and `pgf` in the future. If you are now interested in it, please refer to the pgf manuel by `texdoc tikz` or `texdoc pgf`.

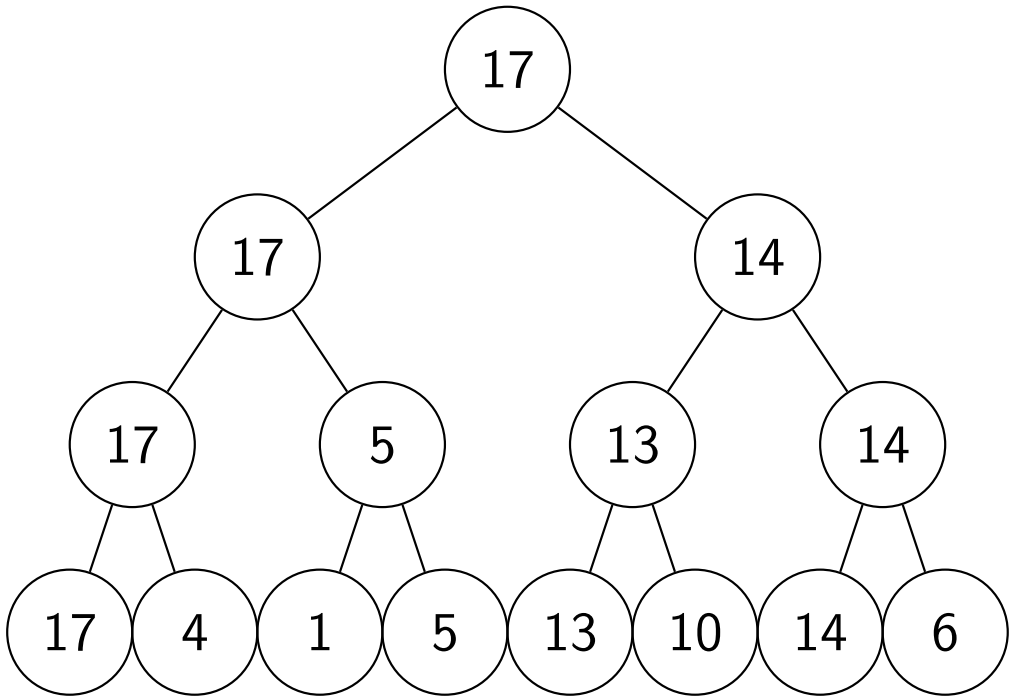
Another example:

Example

```
\begin{tikzpicture}[scale=0.8]
\tikzstyle{every node}=[draw,shape=circle,minimum
↪  size=0.8cm];
\node {17}[sibling distance=4cm]
child { node {17}[sibling distance=2cm]
    child {
        node {17}[sibling distance=1cm]
        child { node {17} }
        child { node {4} }
    }
    child {
        node {5}[sibling distance=1cm]
        child { node {1} }
        child { node {5} }
    }
}
child { node {14}[sibling distance=2cm]
    child {
        node {13}[sibling distance=1cm]
        child { node {13} }
        child { node {10} }
```

```
21          }
22          child {
23              node {14}[sibling distance=1cm]
24              child { node {14} }
25              child { node {6} }
26          }
27      };
28      \end{tikzpicture}
```

This will generate a binary tree:



The tabular Environment

Table is another common element in LaTeX, usually you will need the array package for enhanced functions of tables. You can insert the command in the preamble of your document.

Command

```
\usepackage{array}
```

Example

```
\begin{tabular}{|l|c|r|}
  \hline
  Title 1 & Title 2 &
  ↪  Title 3 \\
  \hline
  1 & 2 & 3 \\
  \hline
\end{tabular}
```

Title 1	Title 2	Title 3
1	2	3

The syntax is similar to the align environment in maths. & is used to split the columns are \\ is used to split the rows.

Column Format

Command

```
\begin{tabular}{format}
...
\end{tabular}
```

`format` can be set as follow:

- `|` - represents a vertical separate line between two columns
- `l` - align left in this column
- `c` - align center in this column
- `r` - align right in this column

Example

`|l|l|l|`

Title 1	Title 2	Title 3
1	2	3

`||c|cc||`

Title 1	Title 2	Title 3
1	2	3

With the help of the `array` package, more formats are available:

- `p{width}` - Equivalent to `\parbox[t]{width}`, vertically aligned bottom
- `b{width}` - Equivalent to `\parbox[b]{width}`, vertically aligned top
- `m{width}` - Equivalent to `\parbox{width}`, vertically aligned middle
- `>{decl.}` - Can be used after a letter option, inserts `decl` before the entry.
- `<{decl.}` - Can be used before a letter option, inserts `decl` after the entry.

`t` and `b` may be very confusing, but that's how they work in `\parbox`. With these new formats, the columns can be defined more flexibly.

Example

```
1  \begin{tabular}
2  {|p{1.2cm}|b{1.2cm}|m{1.2cm}|}
3    \hline
4    Aligned Bottom &
     ↪  Aligned Top &
```

Aligned Bottom	Aligned Top	Aligned Middle

`t`, `b` and `m` only affect the vertical alignment. If you want to control the width and make the text horizontally centered as well, you can use `>{\centering}` to insert a `\centering` before the text in that column. You can also insert `>{$}` and `<{$}` to generate a column in math mode.

Example

```
\begin{tabular}{|>{\centering}m{2cm}|>{$}b{2cm}<{$}|}
  \hline
  Row of Text &
  \text{Row of Maths} \\
  \hline
  First & x \\
  Second & x^2 \\
  \hline
\end{tabular}
```

Row of Text	Row of Maths
First	x
Second	x^2

If a column type will be used many times, and also very long, you can define a new column type by yourselves. You can use

Command

```
\newcolumntype{new type}{>{some declarations}{old type}<{some more declarations}}
```

If you want to repeat a format for multiple times, you can use `*{num}{format}`. Here's an example of the usage of `\newcolumntype` with multiple columns form.

Example

```
1  \newcolumntype{C}{>{$}c<{$}}
2  \newcolumntype{L}{>{$}l<{$}}
3  \newcolumntype{R}{>{$}r<{$}}
4
5  \begin{tabular}{|L|
   ↪  *{2}{C|} R|}
6    \hline
7    \text{First} &
     ↪  \text{Second} &
8    \text{Second} &
     ↪  \text{Third} \\
9    \hline
10   x & x^2 & x^2 & x^3 \\
11   \hline
12   y & y^2 & y^2 & y^3 \\
13   \hline
14 \end{tabular}
```

First	Second	Second	Thi
x	x^2	x^2	x
y	y^2	y^2	y

Horizontal Lines

We usually need horizontal lines in tables. As shown in the examples above, you can add a `\hline` at the beginning of a row.

If you only want to draw a partial line, use `\cline[start-end]`.

Example

```
\begin{tabular}{c|l|c|r}
  \hline\hline
  & Title 1 & Title 2 &
  ↪  Title 3 \\
  \cline{2-4}
  Table & 1 & 2 & 3 \\
  \cline{2-4}
  & 4 & 5 & 6 \\
  \hline\hline
\end{tabular}
```

	Title 1	Title 2	Titl
Table	1	2	
	4	5	

Here we draw a table with a multirow, but it only works with multirows of odd row number. A more convenient method of drawing multirows will be introduced.

Combine Rows and Columns

There are two commands being used to combine rows and columns

Command

`\multicolumn{ncols}{format}{text}`

- `ncols` - the number of columns to be merged
- `format` - the format of the merged column, excluding the left `|` (eg. `c|`)
- `text` - the text in the merged column

`\multirow{nrows}{width}[fixup]{text}`

- `nrows` - the number of rows to be merged
- `width` - the width of the merged rows (use `*` for auto)
- `fixup` - the vertical position of the text (optional, default in the center)
- `text` - the text in the merged row

To use the `\multirow` command, you need to insert the package `multirow` in the preamble of your document.

Example

```
\centering
\begin{tabular}{|c|c|c|c|c|}
  \hline
  \multirow{4}{*}{Table} & Title 1 & Title 2 & Title 3
  ↪  & Title 4 \\
  \cline{2-5}
  & \multicolumn{2}{c|}{Text 1} &
  \multicolumn{2}{c|}{\multirow{3}{*}{Text 3}} \\
  \cline{2-3}
  & \multicolumn{2}{c|}{Text 2} & \multicolumn{2}{c|}{}
  ↪  \\
  \cline{2-3}
  & Text 4 & Text 5 & \multicolumn{2}{c|}{} \\
  \hline
\end{tabular}
```

Table	Title 1	Title 2	Title 3	Title 4
	Text 1		Text 3	
	Text 2			
	Text 4	Text 5		

Just leave blank in the rest rows of `\multirow`.

Table Generators

With `\multirow` and `\multicolumn`, we can almost draw tables of any style, but this coding process can never be as easy as the graphic one, like making tables in Word or Excel. Is there any ways to convert graphic tables into LaTeX codes directly?

- Use LaTeX Table Generator: http://www.tablesgenerator.com/
- LaTeX Complex Table Editor: https://www.latex-tables.com/
- Excel2latex: https://ctan.org/tex-archive/support/excel2latex/

The `table` Environment

The `table` environment is used to arrange the place of a tabular, similar to the `figure` environment. Here is a template of how to use the environment.

Command

```
\begin{table}[position]
  \centering
  \begin{tabular}{format}
    ...
  \end{tabular}
  \caption{caption}
  \label{table:label}
\end{table}
```

The `position`, `caption`, `label` are same as those in the `figure` environment.

Recall the Positions

We usually want to place the graphs or tables just below or above the content where we mention them, but even when we type `[h]` in position, you can not ensure that it will appear at the ideal position, and there are several methods to make up for this. You can try them one by one:

1. Change `[h]` to `[!h]`
2. Change `[!h]` to `[!H]`
3. Use `\newpage` to move the following content to the next page

Usually you don't need to pay too much attention about where the figures and tables are exactly are because you can use `\ref` to reference them. And the numbering of figures and tables will strictly follow the order of their code.

`figure` and `table` in Two-column Documents

If you are writing a document using two columns (i.e. you started your document with something like `\documentclass[twocolumn]{article}`), you might have noticed that you can't use floating elements that are wider than the width of a column (using a LaTeX notation, wider than `0.5\textwidth`), otherwise you will see the figure or table overlapping with text.

If you really have to use such wide elements, the only solution is to use the "starred" variants of the floating environments:

Command

```
\begin{figure*}[position]
  ...
\end{figure*}
```

```
\begin{table*}[position]
  ...
\end{table*}
```

Those "starred" versions work like the standard ones, but

The array Environment

When you use tabular in maths environment, the text format in the tabular won't be italic. However, there is a replacement of tabular, which is the array environment.

Command

```
\begin{array}{format}
  ...
\end{array}
```

The options and usages of these two environment are exactly the same.

Though the environment is not provided by the array package (it's built-in one), you are also recommended to use this package for enhancements.

The minted Package

All of the code in this lecture are highlighted by the minted package. To use it, simply insert the command in the preamble of your document.

Command

```
\usepackage{minted}
```

This is a very special package, it depends a program out of LaTeX called pygmentize, which is a code highlighting package written in Python.

You can install the package through pip (assuming you have Python 2 or 3 and pip installed) in your terminal:

Command

```
pip install Pygments
```

And then you can examine in your terminal whether pygmentize is your PATH by directly running it. You also need to add an option -shell-escape to your LaTeX compiler because LaTeX need this permission to run other