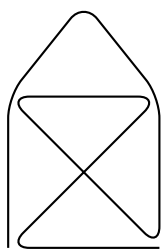# Part I
教程和指导

by Till Tantau

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 TikZ 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 规划绘图用时

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　关联图文内容

图形可以置于文本中的不同位置。既可以插在行内，也就是"文字中间"，也可以放在单独的"图片"中。由于印刷者（也就是人们）喜欢将页面"填满"（同时出于美学和经济的考虑），因此独立的图片通常会放到离相关文字很远的地方。基于技术原因，LaTeX 和 TeX 倾向于鼓励图形的这种"游离"形式。

插在行内的图形，或多或少和正文有些关联，因为周围的文字间接地解释了图形的标签，并且通常正文也会阐明这个图形和什么相关，展示了什么。

独立的图片则大不相同，读者在看到它们的时候，也许还没读到与之相关的文字，或者已经读过很久了。因此，如果你要绘制独立的图片，应该遵循如下指导原则：

- 独立的图片应当有一个标题，并且"顾名即可思义"。

  比方说，假设一张图展示了快排算法的不同阶段，那么图片的标题至少应当告诉读者，"该图展示了快排算法的不同阶段，如 xyz 页所述"，而不仅仅是"快排算法"。

- 好的标题会加上尽可能多的上下文信息。比如你会写："该图展示了快排算法的不同阶段，如 xyz 页所述。在第一行中，选择基准元素 5，这会造成 ..."这些信息当然也可以在正文中写出，但是放在标题里保证了上下文。不要害怕写一个长达五行的标题。（你的编辑可能会因此讨厌你，你可以把讨厌反弹回去。）

- 在正文中，你可以这样引用图片："有一个快排的'实际'例子，见第 xyz 页的图 2.1。"

- 很多讲样式和排版的书，会建议你不要缩写成 "Fig. 2.1"，而是应该写 "Figure 2.1"。

  反对缩写的主要论据是，"不应在缩写这种地方浪费句点的价值"。意思是，句点会让读者以为句子结束于 "Fig"，并且需要"有意识的回溯"，才能发现句子根本没有结束。

  支持缩写的论据是，节省空间。

  我个人并不信服任何一种论据。一方面，我还没见过有力的证据，表明缩写会降低阅读速度；另一方面，在大多数文章中，如果将所有 "Figure" 缩写成 "Fig."，省下的空间几乎连一行都不到。我会避免使用缩写。

1.4　统一图文风格

人们在绘图时犯得最多的一个"错误"（记住，设计中的"错误"通常只是"无知"），也许就是图形和文字的式样不搭。

一个很常见的情况是，文章的配图来自几个不同的程序。作者可能用 GNUPLOT 作图，XFIG 画图表，以及插入一张 .eps 格式的图片（它是合作者画的，不知道用的什么程序）。这些图很可能用了不同的线宽和字体，尺寸也不同。此外，作者在插入图片的时候，还经常用 `[height=5cm]` 这样的选项将图片缩放到"漂亮的尺寸"。

如果写文字也用这种方法的话，那么就相当于：不同的章节用不同的字体和字号。书写定理时，在某些章节中都加了下划线，在另一个章节则全用大写字母，再在另外一个章节用红色字体。此外，不同页面的边距还不一样。读者和编辑一定不能忍受这样的文字，但是对于图形他们常常不得不忍受。

为了保持图文风格一致，请忠于如下指导原则：

- 不要缩放图形。

  意思是说，如果用别的程序画图，那么要输出"正确的尺寸"。

- 在图文中使用相同的字体。

- 在图文中使用相同的线宽。

  普通文本的"线宽"是指，T 这样的字母中竖直笔画的宽度。在 TeX 中，这个值通常是 $0.4\,\mathrm{pt}$。不过有些期刊不接受线宽低于 $0.5\,\mathrm{pt}$ 的图形。

- 图文中使用统一的颜色。比方说，如果正文用红色表示警告，那么在图形中的重要部分也应该用红色；如果正文用蓝色表示结构元素，比如大标题和章节标题，那么在图形中也应该用蓝色表示结构元素。

  不过，图形也可以用符合内在逻辑的（logical intrinsic）颜色。比如无论你正常用什么颜色，读者一般总是会认为，绿色表示"正面的、前进、好"（positive, go, ok），而红色表示"警醒、警告、行动"（alert, warning, action）。

用不同的图形程序绘图，几乎不可能保持风格一致。因此，你应该考虑忠于一种图形程序。

1.5 图的标签

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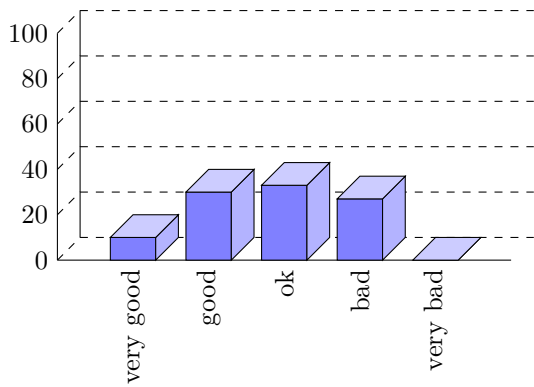
Both the table and the "plot" have about the same size. If your first thought is "the graphic looks nicer than the table," try to answer the following questions based on the information in the table or in the graphic:

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:
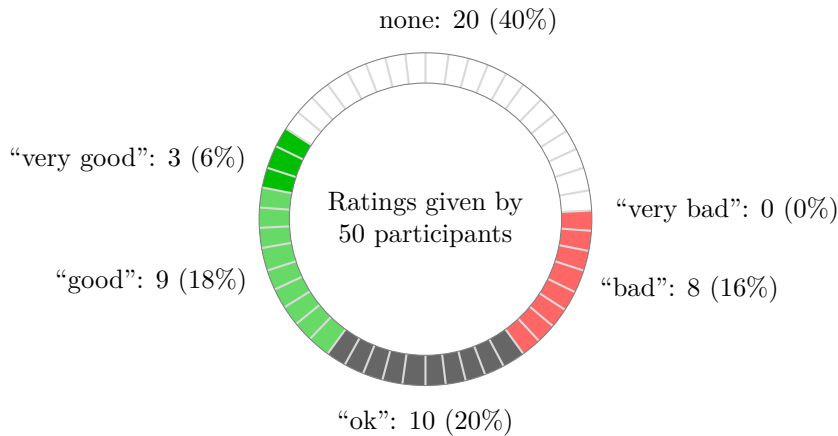
The above graphic has about the same information density as the table (about the same size and the same numbers are shown). In addition, one can directly "see" that there are more good or very good ratings than bad ones. One can also "see" that the number of people who gave no rating at all is not negligible, 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:
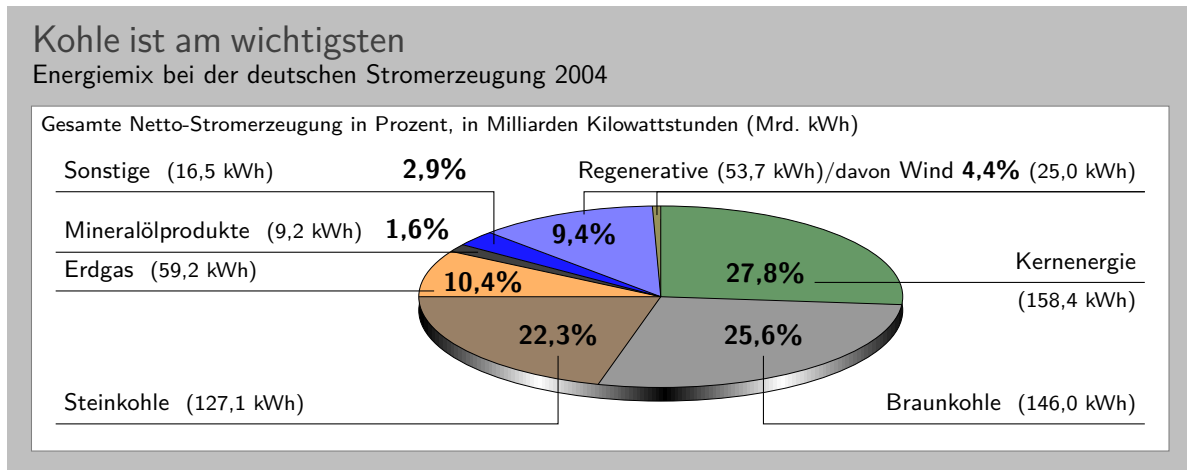
This graphic has been redrawn in Ti*k*Z, but the original looks almost exactly the same.

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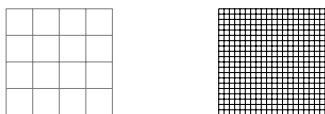
  Even though the left grid comes first in English reading order, the right one is much more likely to be seen first: The white-to-black contrast is higher than the gray-to-white contrast. In addition, there are more "places" adding to the overall contrast in the right grid.

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.