



Figures in LaTeX

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1 Introduction

This guide describes how to use external graphics in your LaTeX document. Section 2 covers the macros that you need. The remainder of the guide is about the graphics themselves, and how to get them into LaTeX: section 3 discusses types of graphics, with examples; section 4 lists some programs and methods for creating and editing graphics, and section 5 explains how to convert them into formats that LaTeX can handle.

This guide does not go into creating graphics with LaTeX macros. You can read about it in *The Not So Short Introduction*, chapter 5 and the documentation of the respective packages.

2 The macros

Graphics inclusion is not built into the LaTeX core. You need to load a package which provides this facility¹:

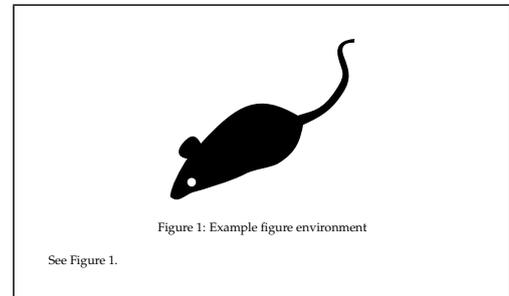
1. The examples here use the `graphicx` package. For very old documents which use `epsf` or `psfig` you can load the `epsfig` package instead. It supports the same syntax but makes use of the modern implementation of graphics inclusion. There should be no reason to keep using the old `epsf` or `psfig` packages.

```
\usepackage{graphicx}
...
\includegraphics{mouse}
```



or, if you want to put the graphic inside a figure environment:

```
\usepackage{graphicx}
...
\begin{figure}[h]
\centering
\includegraphics[blocks]
\caption{Example figure environment}%
\label{figenv}
\end{figure}
See Figure-\ref{figenv}.
```



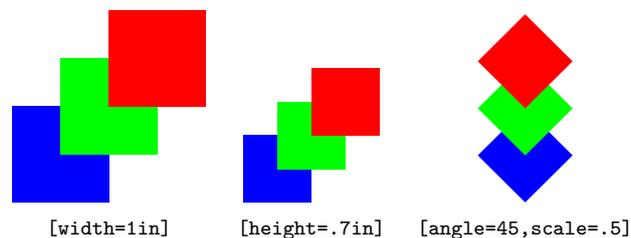
You can read more about the figure- and other floating environments in Oetiker et al., 2011 Section 2.12.

2.1 Optional parameters

You can scale and rotate your graphics with optional parameters:

```
\includegraphics[height=...,angle=...,...]{figure file}
```

The examples below illustrate scaling to a specified height or width, scaling by a factor and rotating:



2.2 Tips

- » If you want to resize your graphic to text width, use `[width=\linewidth]`. `\linewidth` is the current text width. It takes e.g. column typesetting and indenting within lists into account.
- » Most of the time, you can omit the extension, e.g. `.eps` or `.pdf`: L^AT_EX and pdflatex automatically pick file types they can handle; more about this in section 5 about file formats for L^AT_EX and pdflatex.
- » Don't use an absolute path such as `c:/course/graphics/figure`. Absolute paths make it hard to move your documents to another location or another system. You can put your graphics in the same directory as your L^AT_EX source and then just use the filename, or you can put them in a subdirectory and use a relative path such as `graphics/figure`.
- » Don't use the TeXnicCenter Insert Picture... menu item. This generates absolute paths and explicit extensions. In contrast, TeXstudio handles this in a sane way.

3 Types of graphics

Graphics can be defined in different ways, depending on the type of information they contain and on the software with which they have been created. Figures 1–3 contain some examples, each together with an enlarged details.

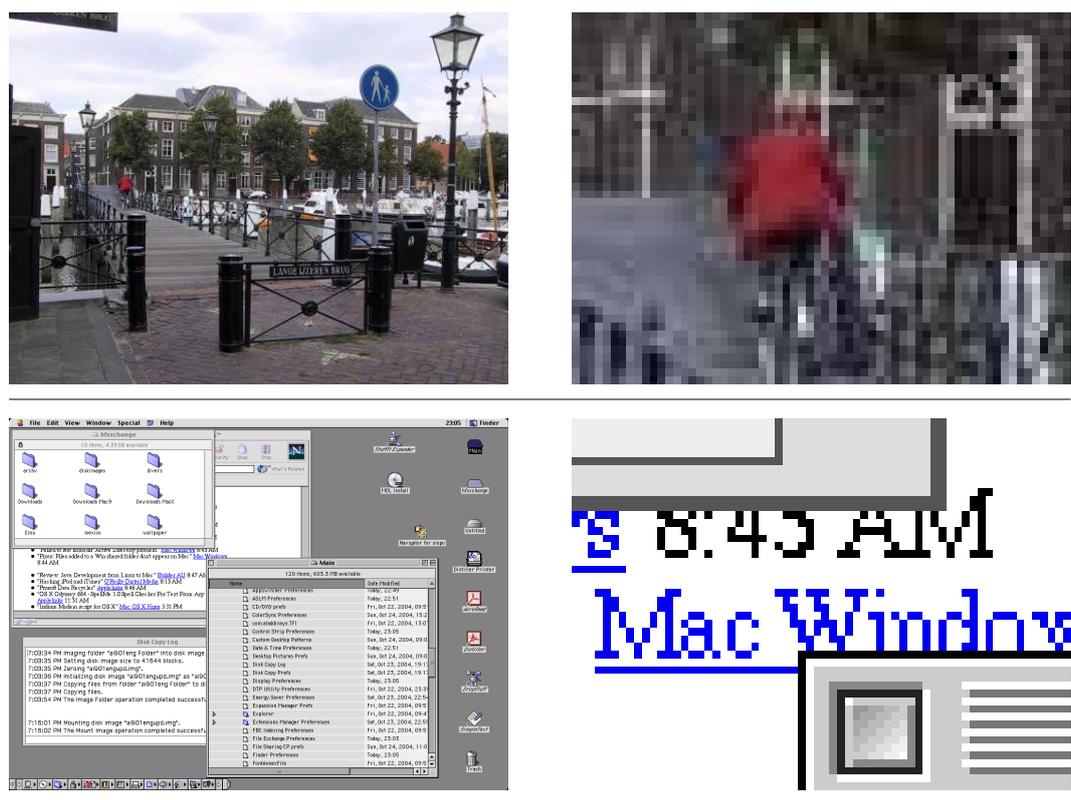


Figure 1. Bitmapped- or raster graphics: above a photograph, below a screenshot, both with an enlarged detail at the right

A *bitmap* or *raster graphic* is built up as a grid of pixels. Figure 1 shows a photograph and a screenshot. The pixels are obvious in the enlarged detail.

Vector graphics are defined in terms of lines, circles, curves and other geometric shapes. They do not pixelate at any scale; see figure 2.

Some file formats can contain both raster and vector data. In figure 3, the raster background becomes blocky when enlarged, but the text on top remains sharp.

3.1 More about bitmaps

Bitmapped file types. Common file extensions for bitmaps or raster images include .bmp, .gif, .jpg, .pbm, .png, .tif and .xpm. These file types are intended for exchange, *i.e.* they are not tied to any particular program.

Compression types. High-resolution bitmapped files can get very large. There are various ways to reduce those file sizes.

Lossless compression works by storing information in a more compact way. A very simplified example: instead of enumerating a thousand identical white pixels one by one, you can say at once that the next one thousand pixels are white. Lossless compression can be quite effective when there are large areas of solid colors or regular patterns. Png is a lossless bitmapped format that can be processed directly by pdflatex.

Lossless compression doesn't work so well with photographic images. When we no longer insist on exactly preserving every bit of information and accept *lossy* compression, then very good results can be reached with jpeg. At medium to high quality settings, the loss of information is essentially invisible, but the compression rate is easily 10:1. When you save in jpeg format you can usually make your own tradeoff between file size and image quality.

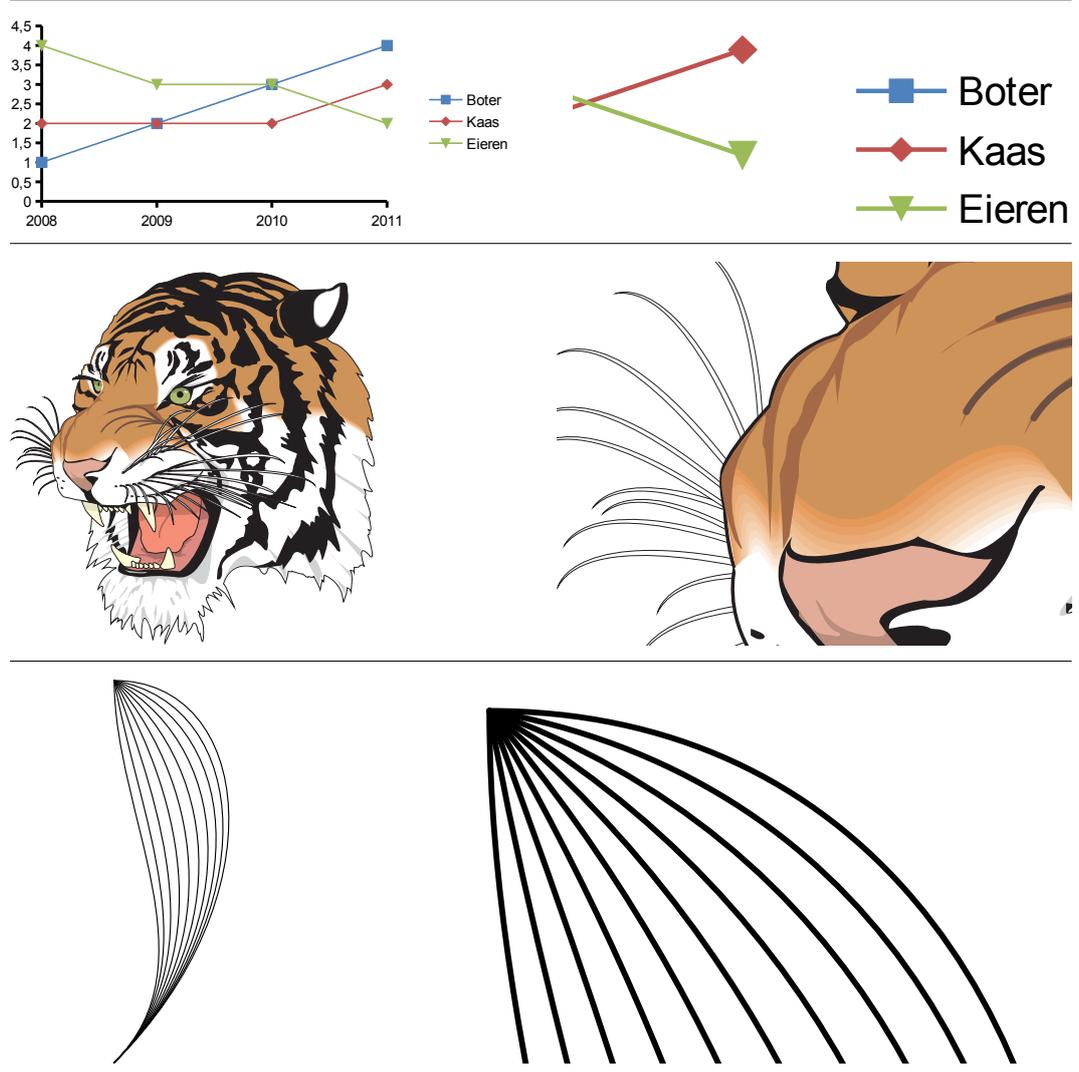


Figure 2. Vector art: a LibreOffice data plot, a drawing adapted from a Ghostscript example file and a graphic generated with MetaPost

For non-photographic bitmapped images such as screenshots or logos, jpeg compression produces visible artifacts; see figure 4. To be fair, for the right image quality was set very low in order to make the artifacts more obvious. Here, compression isn't all that good either compared to png. Nevertheless, many people use jpeg compression indiscriminately, even when png would have been much better.

For the record: of the above-mentioned raster image formats, .bmp, .pbm and .xpm are uncompressed, .gif and .png have lossless compression, .jpg lossy compression, and .tif may have any type of compression, or none at all.

Although .gif is compressed in a lossless way, it cannot contain full-color images, only images with a palette of up to 256 colors. For photographic images, this color reduction can do much more damage to the end result than lossy compression.

3.2 Bitmap resolutions

The resolution of a bitmap should be high enough to look sharp, but, in order to keep file size and loading times within bounds, the resolution should not be higher than necessary.

For screen viewing, the ideal resolution would be exactly one bitmap pixel per screen pixel, but



Figure 3. Raster and vector combined



Figure 4. Don't use jpeg compression for screenshots.

of course you may not know at what screen resolution and zoom level your document will be viewed.

For printing, good resolutions are:

Photographs. 150–300 DPI (dots per inch) depending on the output device. Most printers and imagesetters simulate grays and other tints with dot patterns or halftone screens. As a consequence, the effective printed resolution of a photograph is much lower than the resolution of the output device, no matter how high the resolution of the original photograph.

Charts and diagrams. 600–1200 DPI. 600 is enough to avoid visible blockiness. Higher resolutions can mean finer detail, if the printer resolution is also high. But vector formats are better for such graphics.

Screenshots. Keep the original resolution.

Of course I am talking about resolution after scaling; if you print a 5 cm wide, 300 DPI image at a width of 10 cm then the effective resolution is 150 DPI.

It will do no good to increase the resolution of an existing low-resolution image; it might even make the output fuzzier. So either try to get a better original, or use your bad picture as-is.

3.3 More about vector graphics

Eps and pdf. The two vector formats that matter here are eps (Encapsulated PostScript) and pdf. Pdf is an offshoot of PostScript. There are many similarities between the two formats,

and it is often possible to convert a file from one format to the other and back again without real loss of information; see section 5.2. Svg is another related format, but is currently not well-supported by T_EX.

These formats can contain vector objects, text and also bitmaps, all in the same file; see *e.g.* figure 3.

Problems with vector graphics.

Missing fonts. If some standard fonts (Times, Helvetica, Courier, Symbol, Zapf Dingbat) are not embedded then `epspdfk` (see section 5.2) can help. If the pdf output target is set to prepress then fonts will be embedded during conversion to pdf. `Epspdfk` can convert back and forth between eps and PostScript on the one hand and pdf on the other. You can either apply a pdf-to-eps-to-pdf conversion to individual graphics or a pdf-to-ps-to-pdf conversion to the document as a whole. With the upcoming version 0.6, direct conversion from pdf to pdf might also work.

If other fonts are missing then you have a real problem.

Zero-width lines. If your graphic has some very thin lines, then check by zooming in whether the lines have some positive width. A line width of zero will be interpreted by the output device as a width of one pixel, which is fine for the screen or for an old 300 DPI laserprinter, but not for a 2400 DPI imagesetter. A line width of *e.g.* 0.3pt should be safe. You may be able to fix this from within the program with which the graphic was created.

Transparency and fill patterns. Many programs and graphic formats do not support transparency or fill patterns; upon conversion these features might either get lost altogether or simulated with *e.g.* bitmaps, which might make the file much larger and virtually uneditable. Hang on to the original – which you should do in any case.

General fixes. You may be able to import the file in a draw program and fix problems there: substituting fonts, changing line widths, replacing pattern fills with something else; see section 4 on draw programs.

If the amount of text is small, *e.g.* just a logo, consider converting the text to curves, *i.e.* characters are replaced by their shapes, losing the reference to the font.

As a last resort, you can convert your graphic to a bitmapped png file of sufficiently high resolution.

3.4 Proprietary formats

Graphics editors can also have their own native format, *e.g.* `.psd` for PhotoShop, `.cdr` for Corel-Draw or `.xcf` for the Gimp. These formats support additional structure, which makes them better for editing, at least with the original graphics editor. Even if you save in a L^AT_EX-compatible format, you may want to preserve the native version as well for future editing. This is especially true for vector graphics.

Another trend is to store private information for future editing in a hidden stream in the exported file. The `svg`, `eps` and `pdf` formats can contain such hidden streams, and various programs use that fact. This private information may not be readable by another graphics editor, but a program such as L^AT_EX that only needs to render the file can simply ignore it.

4 Creating graphics

In computer graphics, the term drawing means making vector pictures and painting means making bitmapped pictures.

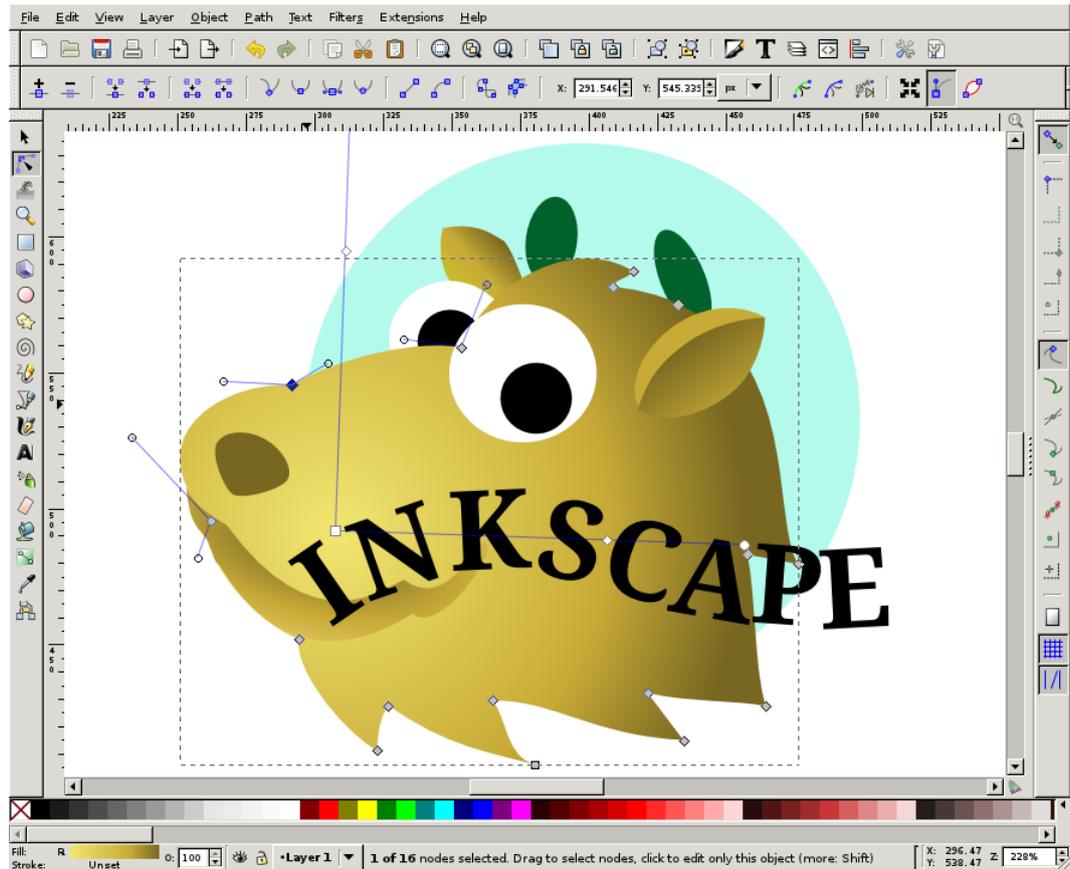


Figure 5. Inkscape, a free vector draw program for Linux, Windows and Mac OS X

You should be able to use any eps, pdf or bitmapped graphic with LaTeX and derivatives², although sometimes conversion may be needed. See section 5 for details. The only real concern is getting vector graphics intact into eps- or pdf format.

4.1 Drawings and diagrams

You can create drawings and diagrams in Word or PowerPoint. MS Office version 2010 has a nice pdf export option (Save as pdf; click on Options to specify what you actually want to export, e.g. the current selection). But do not forget to check out some free alternatives. *Inkscape* is a specialized draw program resembling CorelDRAW and Illustrator. It uses svg as its native format and can export to pdf. Or try the Draw module of *LibreOffice/OpenOffice.org*. This MS Office alternative is fairly good at reading and writing MS Office files, and also has a pdf export option.

If you spend a lot of time creating and editing vector graphics, and especially if you also need to ready your documents for professional printing, consider buying a professional draw program such as CorelDRAW or Illustrator, part of Adobe's Creative Suite.

Under Mac OS X there are several inexpensive commercial programs worth checking out. Since OS X supports pdf natively, getting a good pdf from your graphic is rarely a problem, even from cheap or office-centric graphics programs.

In any case, investigate at an early stage how to get your drawings into LaTeX, see section 5.

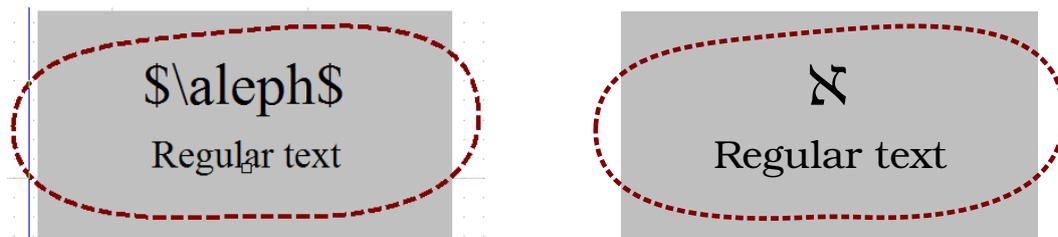


Figure 6. Text and math as shown by TpX and as rendered by the parent document

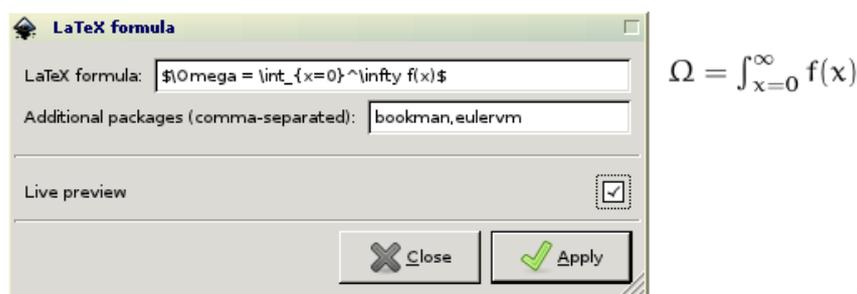


Figure 7. Entering a L^AT_EX equation in Inkscape

4.2 Draw programs with L^AT_EX support

L^AT_EX-oriented draw programs include *Ipe* (cross-platform) and *TpX* (Windows-only). *TpX* is also available from CTAN. Both are free.

Ipe renders text and formulas itself, using L^AT_EX. You can tune the output via preamble commands (Edit > Document properties).

TpX normally leaves the rendering of text and math to the parent document: when saving, it creates three files: an eps- and a pdf file with everything which is not text or math, and a L^AT_EX file with extension `.tpx` which typesets text and math and loads either the eps or the pdf. This *TpX* file has to be `\input-ed` into the parent document.

This way, text and math in the drawing are automatically in step with the document; see figure 6.

TpX has additional export options; see its documentation.

CTAN and Sourceforge (<http://sourceforge.net/directory/development/data-formats/tex-latex/>) contain several other such programs.

L^AT_EX support in Inkscape. Inkscape, already mentioned in section 4.1, also offers some forms of L^AT_EX support:

- » If Inkscape finds L^AT_EX and some auxiliary programs (Ghostscript, pstoeedit), it may offer support for L^AT_EX objects: Extensions > Render > L^AT_EX formula; see figure 7.
- » If you want editable L^AT_EX objects, you can try whether the `texttext` extension (url <http://pav.iki.fi/software/texttext/>, menu item Extensions > Tex Text) works for you.
- » If you save an Inkscape drawing to pdf, one of the export options is '*PDF+LaTeX: Omit text in PDF, and create LaTeX file*'. This appears to apply only to regular text.

4.3 Charts

Charts are normally generated as a byproduct of spreadsheets or mathematical software. Mathematical and statistical programs often have eps- or pdf export options, and sometimes also have

2. To be precise, the term 'derivative' applies to the underlying T_EX engine (pdf_{te}x, xet_{ex}, luat_{ex}), not to the L^AT_EX macro package on top of it.

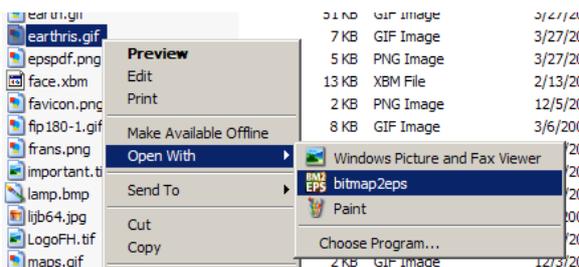


Figure 8. *Bitmap2eps*, a right-click item to convert a bitmap to eps format

support for LaTeX text labels. As to spreadsheets, see section 4.1.

4.4 Bitmaps: paint programs and image editors

There exists a large selection of free and inexpensive paint programs and image editors. As to pre-installed programs: Windows already includes Paint, a very basic bitmap editor, which, however, can read and write a variety of formats, and can also crop images. Mac OS X includes Preview. Besides reading pdf documents, this program can also read, convert and crop³ images.

4.5 Screenshots

You can take screenshots without specialized software:

Windows. The PrtScrn key will copy the entire screen to the clipboard, and Alt-PrtScrn the active window. Most paint- and image-editing programs can retrieve the screenshot from the clipboard, usually with Edit / Paste. They also have tools to crop images.

Mac OS X. Cmd-Shift-3 copies the entire screen to a file on your desktop, and Cmd-Shift-4 lets you make a selection.

Linux. Here, depending on your chosen desktop and configuration, PrtScrn will probably take a screenshot as well, either to the clipboard or to a file. I usually take screenshots with the Gimp (File > Acquire > Screenshot).

5 Converting to compatible formats

The LaTeX derivatives pdflatex, xelatex and lualatex all can use the bitmapped formats png and jpeg directly as graphics formats.

For vector graphics, you can use either pdf or eps, although eps requires a conversion⁴, and this may have been disabled for security reasons. If on-the-fly conversion is not available, you can still convert in a separate step; see section 5.2.

For the LaTeX plus dvips route, you are restricted to eps format. If at all possible, use one of the LaTeX alternatives.

5.1 Converting bitmaps to png, jpg and eps

Almost any image editor and paint program can convert to png and jpg. This is all you need unless you have to use LaTeX itself and need eps format. More advanced programs can export to eps (and to pdf).

For Windows Explorer, TeX Live 2011 and later add a right-click menu item *bitmap2eps* to

3. Indirectly, via 'New from clipboard'

4. In the case of pdflatex and lualatex, the eps is converted to a file *filename-eps-converted-to.pdf*, in the case of xelatex the converted code is written directly to the pdf output of the document without creation of an intermediate file.

bitmapped formats for conversion to eps; see figure 8. It makes use of the command-line converter `sam2p`, with `bmeps` as a fallback. MikTeX users can run `bmeps` from the command-line.

On Unix-based systems the obvious choice for a command-line converter is `convert`:

```
convert filename.png filename.eps
```

`Convert` is packaged for most Linux distributions as part of *ImageMagick*. `Convert` itself is included in *MacTeX*.

5.2 Converting between PostScript, eps and pdf

epstopdf. `Epstopdf` is the program used for on-the-fly conversion from eps to pdf. It is part of most T_EX distributions and is probably already on your system. `Epstopdf` uses `Ghostscript`, either a standalone version or the version built into the T_EX distribution.

Epspdf and epspdftk. `Epspdf` can convert back and forth between PostScript, eps and pdf, in many cases with no loss of information. It can also remove unwanted borders (compute tight boundingbox option) and convert some color graphics to grayscale. It uses `Ghostscript` and optionally `pdftops` from the `xpdf` suite.

`Epspdftk` is a GUI program, using `epspdf` in the background.

A L^AT_EX package `epspdfconversion` substitutes `epspdf` for `epstopdf` for on-the-fly conversion to pdf. Note that it needs shell-escape to be fully enabled; see the package documentation.

Convert. On many systems, `convert` from the *ImageMagick* suite will use `Ghostscript` when converting between eps and pdf, and will in that case convert vector graphics to vector graphics. Prefix the target pdf filename with `EPDF:` if you want to preserve the eps boundingbox. View the result at a high zoom level to make sure that it is indeed still a vector graphic.

Ghostscript and pdftops. You can also use *Ghostscript* directly for converting eps and PostScript to pdf, and either `Ghostscript` or `pdftops` from the *Xpdf* suite for converting in the other direction. `Ghostscript` includes various scripts/batchfiles to facilitate these conversions. But this is not the place for explaining the use of these programs.

Pdftcrop. This command-line utility is not exactly a converter, but it removes empty margins from each page in a pdf file, using `pdftex` and `Ghostscript`-generated boundingboxes. Included in both MikTeX and T_EX Live.

5.3 Exporting eps and PostScript from Windows programs

If a Windows program does not have a usable export option, then you can try to ‘print’ to a PostScript file.

For this, you need to have a PostScript printer driver. If you don’t have one installed, go to ‘Printers’ and start up the Add Printer wizard. Choose Local Printer and uncheck automatic detection. As printer port, you can pick `FILE`, otherwise you would have to manually check ‘Print to File’ anytime you print. A good choice for manufacturer and model would be ‘Generic’ and ‘MS Publisher Imagesetter’ respectively.

Pay attention to printer settings: in the Print dialog, click ‘Properties’, then ‘Advanced’ (on either tab). In the ‘Advanced Document Settings’ tree, under ‘Graphic’, ‘TrueType Font’ should be set to ‘Download as Softfont’⁵

Now navigate to first ‘Document Options’, then ‘PostScript Options’. For ‘PostScript Output Option’ the default setting is ‘Optimize for speed’. Change that to ‘Optimize for Portability’ or

5. The alternative setting is ‘Substitute with Device Font’. For prepress use, you should always include all fonts. It is possible to include fonts after the fact, when converting to pdf, but then you run the risk of noticeable discrepancies between the original font and the actually included font.

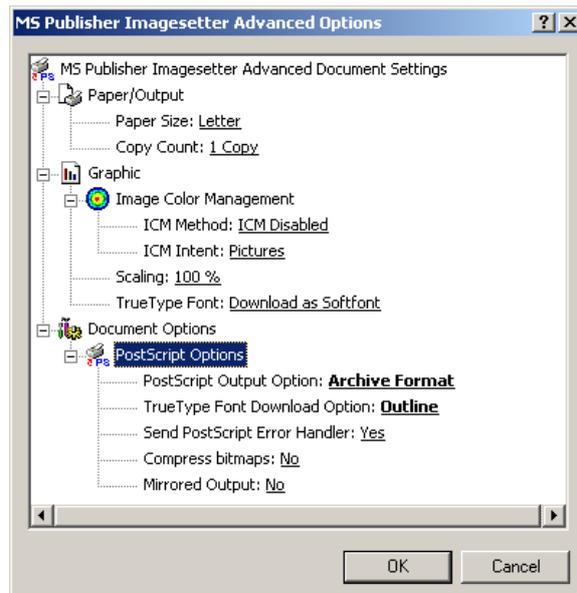


Figure 9. configuring a PostScript printer driver

‘Archive Format’, or, for single pages only, ‘Encapsulated PostScript’. These non-default options presumably produce cleaner PostScript code, without printer-specific hacks. Experiment with this and other options if you run into problems (e.g. bad-looking screen output, or part of a graphic getting cut off, or conversion to bitmap).

Next, the setting ‘TrueType Font Downloading Option’ should be set to ‘Outline’, not ‘Automatic’ or ‘Bitmap’.

URLs

CTAN. The Comprehensive T_EX Archive Network. URL: <http://mirror.ctan.org/>.

Epspdf and *epspdftk*. Available from CTAN. URL: <http://tex.aanhet.net/epspdftk/>.

Ghostscript. Free PostScript interpreter. URL: <http://ghostscript.com/>.

ImageMagick. For converting and manipulating images. URL: <http://imagemagick.org/>.

Inkscape. Draw program. URL: <http://inkscape.org/>.

Ipe. Draw program with L^AT_EX support. URL: <http://sourceforge.net/projects/ipe7/>.

LibreOffice. Office suite. URL: <http://www.libreoffice.org/>.

MacT_EX. T_EX Live for Mac OS. URL: <http://www.tug.org/mactex/>.

Oetiker, Tobias et al. (2011). *The Not So Short Introduction to L^AT_EX2_ε*. Included in most free T_EX distributions. URL: <http://mirror.ctan.org/info/lshort/>.

TpX. Draw program with L^AT_EX support; available from CTAN. URL: <http://sourceforge.net/projects/tpx/>.

Xpdf. Pdf viewer and utilities. URL: <http://www.foolabs.com/xpdf/>.