The Ipe manual

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1 Welcome to the Wonderful World of Ipe!

... where making pictures is as easy as `$\pi$` ...

Preparing figures for a scientific article is a time-consuming process. If you are using the LaTeX document preparation system in an environment where you can include (encapsulated) Postscript figures or PDF figures, then the extensible drawing editor Ipe may be able to help you in the task. Ipe allows you to prepare and edit drawings containing a variety of basic geometry primitives like lines, splines, polygons, circles etc.

Ipe also allows you to add text to your drawings, and unlike most other drawing programs, Ipe treats these text object as LaTeX text. This has the advantage that all usual LaTeX commands can be used within the drawing, which makes the inclusion of mathematical formulae (or even simple labels like "q_i") much simpler. Ipe processes your LaTeX source and includes its Postscript or PDF rendering in the figure.

In addition, Ipe offers you some editing functions that can usually only be found in professional drawing programs or CAD systems. For instance, it incorporates a context sensitive snapping mechanism, which allows you to draw objects meeting in a point, having parallel edges, objects aligned on intersection points of other objects, rectilinear and c-oriented objects and the like. Whenever one of the snapping modes is enabled, Ipe shows you *Fifi*, a secondary cursor, which keeps track of the current aligning.

One of the nicest features of Ipe is the fact that it is *extensible*. You can write your own functions, so-called *ipelets*. Once registered with Ipe by adding them to your ipelet path, you can use those functions like Ipe's own editing functions. (In fact, some of the functions in the standard Ipe distribution are actually implemented as ipelets.) Ipelets can be written in Lua, an easy-to-learn interpreted language that is embedded into Ipe, or also in C++. Among others, there is an ipelet to compute Voronoi diagrams.

Making a presentation is another task that requires drawing figures. You can use Ipe to prepare presentations in PDF format. Ipe offers many features to make attractive presentations.

Ipe tries to be self-explanatory. There is online help available, and most commands tell you about options, shortcuts, or errors. Nevertheless, it would probably be wise to read at least a few sections of this manual. The chapter on general concepts and the chapter explaining the snapping functions would be a useful read. If you want to use Ipe to prepare presentations, you should also read the chapter on presentations.

2 About Ipe files

Ipe 7 creates (Encapsulated) Postscript or PDF files. These files can be used in any way that PDF or Postscript files are used, such as viewed with Ghostview, with Acrobat Reader or Xpdf, edited with Acrobat, or included in Latex/Pdflatex documents. However, Ipe cannot read arbitrary

Postscript or PDF files, only files it has created itself. This is because files created by Ipe contain a special hidden stream that describes the Ipe objects. (So if you edit your Ipe-generated PDF file in a different program such as Adobe Acrobat, Ipe will not be able to read the file again afterwards.)

You decide in what format to store a figure when saving it for the first time. Ipe gives you the option of saving with extensions "pdf" (PDF), and "ipe" (XML). Files saved with extension "ipe" are XML files and contain no PDF information. The precise XML format used by Ipe is documented later in this manual. XML files can be read by any XML-aware parser, and it is easy for other programs to generate XML output to be read by Ipe. You probably don't want to keep your figures in XML format, but it is excellent for communicating with other programs, and for converting figures between programs.

There are a few interesting uses for Ipe documents:

Figures for Latex documents. Ipe was originally written to make it easy to make figures for Latex documents. If you are not familiar with including figures in Latex, you can find details here.

Presentations. Ipe is not a presentation tool like Powerpoint or Keynote. An Ipe presentation is simply a PDF file that has been created by Ipe, and which you present during your talk using, say, Acrobat Reader on an LCD projector. Alternatively, you may want to try IpePresenter by Dmitriy Morozov. The chapter on presentations explains Ipe features meant for making presentations.

SVG files. Figures in SVG format can be used to include scalable figures in web pages. Ipe does not save in SVG format directly, but the tool "iperender" allows you to convert an Ipe document to SVG format. This conversion is one-way, although the auxiliary tool *svgtoipe* also allows you to convert SVG figures to Ipe format.

Bitmaps. Sometimes Ipe can be useful for creating bitmap images. Again, the "iperender" tool can render an Ipe document as a bitmap in PNG format.

3 General Concepts

After you start up Ipe, you will see a window with a large gray area containing a white rectangle. This area, the *canvas*, is the drawing area where you will create your figures. The white rectangle is your "sheet of paper", the first page of your document. (While Ipe doesn't stop you from drawing outside the paper, such documents generally do not print very well.)

At the top of the window, above the canvas, you find two toolbars: one for snapping modes, grid size and angular resolution; and another one to select the current mode.

On the left hand side of the canvas you find an area where you can select object properties such as stroke and fill color, pen width, path properties, text size, and mark size. Below it is a list of the *layers* of the current page.

All user interface elements have tool tips—if you move the mouse over them and wait a few seconds, a short explanation will appear.

The mode toolbar allows you to set the current *Ipe mode*. Roughly speaking, the mode determines what the left mouse button will do when you click it in the figure. The leftmost five buttons select modes for selecting and transforming objects, the remaining buttons select modes for creating new objects.

Pressing the right mouse button pops up the object context menu in any mode.

In this chapter we will discuss the general concepts of Ipe. Understanding these properly will be essential if you want to get the most out of Ipe.

3.1 Order of objects

An Ipe drawing is a sequence of geometric objects. The order of the objects is important—wherever two objects overlap, the object which comes first in Ipe's sequence will hide the other ones. When new objects are created, they are added in *front* of all other objects. However, you can change the position of an object by putting it in front or in the back, using the "Front" and "Back" functions in the *Edit* menu.

3.2 The current selection

Whenever you call an Ipe function, you have to specify which objects the function should operate on. This is done by *selecting* objects. The selected objects (the *selection*) consists of two parts: the *primary* selection consists of exactly one object (of course, this object could be a group). All additional selected objects form the *secondary* selection. Some functions (like the context menu) operate only on the primary selection, while others treat primary and secondary selections differently (the align functions, for instance, align the secondary selections with respect to the primary selection.)

The selection is shown by outlining the selected object in color. Note that the primary selection is shown with a slightly different look.

The primary and secondary selections can be set in selection mode. Clicking the left mouse button close to an object makes that object the primary selection and deselects all other objects. If you keep the Shift key pressed while clicking with the left mouse key, the object closest to the mouse will be added to or deleted from the current selection. You can also drag a rectangle with the mouse—when you release the mouse button, all objects inside the rectangle will be selected. With the Shift key, the selection status of all objects inside the rectangle will be switched.

To make it easier to select objects that are below or close to other objects, it is convenient to understand exactly how selecting objects works. In fact, when you press the mouse button, a list of all objects is computed that are sufficiently close to the mouse position (the exact distance is set as the `select_distance` in *prefs.lua*). This list is then sorted by increasing distance from the mouse and by increasing depth in the drawing. If Shift was not pressed, the current selection is now cleared. Then the first object in the list is presented. Now, while still keeping the mouse button pressed, you can use the Space key to step through the list of objects near the mouse in order of increasing depth and distance. When you release the right mouse button, the object is selected (or deselected).

When measuring the distance from the mouse position to objects, Ipe considers the boundary of objects only. So to select a filled object, don't just click somewhere in its interior, but close to its boundary.

Another way to select objects is using the *Select all* function from the *Edit* menu. It selects all objects on the page. Similarly, the *Select all in layer* function in the *Layer* menu selects all objects in the active layer.

3.3 Moving and scaling objects

There are three modes for transforming objects: *translate*, *stretch*, and *rotate*. If you hold the shift key while pressing the left mouse button, the stretch function keeps the aspect ratio of the objects (an operation we call *scaling*), and the translate function is restricted to horizontal and vertical translations.

Normally, the transformation functions work on the current selection. However, to make it more convenient to move around many different objects, there is an exception: When the mouse button is pressed while the cursor is not near the current selection, but there *is* some other object close to the cursor, *that* object is moved, rotated, or scaled instead.

By default, the *rotate* function rotates around the center of the bounding box for the selected objects. This behavior can be overridden by specifying an axis system (Section 5.3). If an axis system is set, then the origin is used as the center.

The *scale* and *stretch* functions use a corner of the bounding box for the selected objects as the fix-point of the transformation. Again, if an axis system is set, the origin of the system is used instead.

It is often convenient to rotate or scale around a vertex of an object. This is easy to achieve by setting the origin of the axis system to that vertex, using the *Snap to vertex* function for setting the axis system.

3.4 Stroke and fill colors

Path objects can have two different colors, one for the boundary and one for the interior of the object. The Postscript terms *stroke* and *fill* are used to denote these two colors. Stroke and fill color can be selected independently in the *Properties* window. Imagine preparing a drawing by hand, using a pen and black ink. What Ipe draws in its *stroke* color is what you would stroke in black ink with your pen. Probably you would not use your pen to fill objects, but you would use a brush, and maybe even a different kind of paint like water color. Well, the *fill* color is Ipe's "brush".

When you create a path object, you'll have to tell Ipe whether you want it stroked, filled, or both. This is set in the *Path properties* field. Clicking near the right end of the field will cycle through the three modes "stroked", "stroked & filled", and "filled." You can also use the context menu of the path properties field.

Text objects and arrows only use the stroke color, even for the filled arrows. You would also use a pen for these details, not the brush.

The mark shapes "disk" and "square" also use only the stroke color. You can make bicolored marks using the mark shapes "fdisk" and "fsquare".

3.5 Pen, dash style, arrows, and tiling patterns

The *path properties* field is used to set all properties of path objects except for the pen width, which is set using the selector just above the path properties field. The dash-dot pattern (solid line, dashed, dotted etc.) effect for the boundaries of *path objects*, such as polygons and polygonal lines, splines, circles and ellipses, rectangles and circular arcs. It does not effect text or marks.

Line width is given in Postscript points (1/72 inch). A good value is something around 0.4 or 0.6.[1]

By clicking near the ends of the segment shown in the path properties field, you can toggle the front and rear arrows. Only polygonal lines, splines, and circular arcs can have arrows.

If you draw a single line segment with arrows and set it to "filled only", then the arrows will be drawn using the fill color (instead of the stroke color), and the segment is not drawn at all. This is sometimes useful to place arrows that do not appear at the end of a curve.

Various shapes and sizes of arrows are available through the context menu in the path properties field. You can add other shapes and sizes using a stylesheet.

The arrow shapes *arc* and *farc* are special. When the final segment of a path object is a circular arc, then these arcs take on a curved shape that depends on the radius of the arc. They are designed to look right even for arcs with rather small radius.

A tiling pattern allows you to hatch a path object instead of filling it with a solid color. Only path objects can be filled with a tiling pattern. The pattern defines the slope, thickness, and density of the hatching lines, their color is taken from the object's fill color. You can select a

[1] The line width can be set to zero to get the thinnest line the device can produce (i.e. approximately the same as 0.15 for a 600 dpi printer or 0.3 for a 300 dpi printer). The PDF and Postscript authorities discourage using this feature, since it makes your Postscript files device-dependent.

tiling pattern using the context menu in the path properties field. You can define your own tiling patterns in the documents stylesheet.

3.6 Transparency

Ipe supports a simple model of transparency. You can set the opacity of path objects and text objects: an opacity of 1.0 means a fully opaque object, while 0.5 would mean that the object is half-transparent. All opacity values you wish to use in a document must be defined in its stylesheet.

3.7 Symbolic and absolute attributes

Attributes such as color, line width, pen, mark size, or text size, can be either absolute (a number, or a set of numbers specifying a color) or symbolic (a name). Symbolic attributes must be translated to absolute values by a *stylesheet* for rendering.

One purpose of stylesheets is to be able to reuse figures from articles in presentations. Obviously, the figure has to use much larger fonts, markers, arrows, and fatter lines in the presentation. If the original figure used symbolic attributes, this can be achieved by simply swapping the stylesheet for another one.

The Ipe user interface is tuned for using symbolic attribute values. You can use absolute colors, pen width, text size, and mark size by clicking the button to the left of the selector for the symbolic names.

When creating an object, it takes its attributes from the current user interface settings, so if you have selected an absolute value, it will get an absolute attribute. Absolute attributes have the advantage that you are free to choose any value you wish, including picking arbitrary colors using a color chooser. In symbolic mode, you can only use the choices provided by the current *stylesheet*.

The choices for symbolic attributes provided in the Ipe user interface are taken from your stylesheet.

3.8 Zoom and pan

You can zoom in and out the current drawing using a mouse wheel or the zoom functions. The minimum and maximum resolution can be customized. Ipe displays the current resolution at the bottom right (behind the mouse coordinates).

Related are the functions *Normal size* (which sets the resolution to 72 pixels per inch), *Fit page* (which chooses the resolution so that the current page fills the canvas), *Fit objects* (which chooses the resolution such that the objects on the page fill the screen), and *Fit selection* (which does the same for the selected objects only). All of these are in the *Zoom* menu.

You can *pan* the drawing either with the mouse in *Pan* mode, or by pressing the "x" key ("here") with the mouse anywhere on the canvas. The drawing is then panned such that the cursor position is moved to the center of the canvas. This shortcut has the advantage that it also works while you are in the middle of any drawing operation. Since the same holds for the *zoom in* and *zoom out* buttons and keys, you can home in on any feature of your drawing *while* you are adding or editing another object.

3.9 Groups

It is often convenient to treat a collection of objects as a single object. This can be achieved by *grouping* objects. The result is a geometric object, which can be moved, scaled, rotated etc. as a whole. To edit its parts or to move parts of it with respect to others, however, you have to *un-group* the object, which decomposes it into its component objects. To un-group a group object, select it, bring up the object menu, and select the *Ungroup* function.

Group objects can be elements of other groups, so you can create a hierarchy of objects.

You can also add a clipping path to a group, which will restrict the drawing of the group to the area inside the clipping path.

3.10 Layers

A page of an Ipe document consists of one or more layers. Each object on the page belongs to a layer. There is no relationship between layers and the back-to-front ordering of objects, so the layer is really just an attribute of the object.

The layers of the current page are displayed in the layer list, at the bottom left of the Ipe window. The checkmark to the left of the layer name determines whether the layer is visible. The layer marked with a yellow background is the *active* layer. New objects are always created in the active layer. You can change the active layer by left-clicking on the layer name.

By right-clicking on a layer name, you open the layer context menu that allows you to change layer attributes, to rename layers, to delete empty layers, and to change the ordering of layers in the layer list (this ordering has no other significance).

A layer may be editable or locked. Objects can be selected and modified only if their layer is editable. Locked layer are displayed in the layer list with a pink background. You can lock and unlock layers from the layer context menu, but note that the active layer cannot be locked.

A layer may have snapping on or off—objects will behave magnetically only if their layer has snapping on. Layers without snapping are displayed dimmed in the layer list.

Layers are also used to create pages that are displayed incrementally in Acrobat Reader. Once you have distributed your objects over various layers, you can create *views*, which defines in what order which layers of the page are shown.

3.11 Mouse shortcuts

For the beginner, choosing a selection or transformation mode and working with the left mouse button is easiest. Frequent Ipe users don't mind to remember the following shortcuts, as they allow you to perform selections and transformations without leaving the current mode:

	Left Mouse	Right mouse
Plain	(*)	context menu
Shift	(*)	pan
Ctrl	select	stretch
Ctrl+Shift	select non-destructively	scale
Alt	translate	rotate
Alt+Shift	translate horizontal/vertical	rotate

The fields marked (*) depend on the current mode.

The middle mouse button always pans the canvas. The right mouse button brings up the object context menu.

If you have to use Ipe with a two-button mouse, where you would normally use the middle mouse button (for instance, to move a vertex when editing a path object), you can hold the Shift-key and use the right mouse button.

If you are not happy with these shortcuts, they can be changed easily.

4 Object types

Ipe supports five different types of objects that can be placed on a page, namely path objects (which includes all objects with a stroked contour and filled interior, such as (poly)lines, polygons, splines, splinegons, circles and ellipses, circular and elliptic arcs, and rectangles), text objects,

image objects, group objects, and reference objects (which means that a symbol is used at a certain spot on the page).

Path and text objects are created by clicking the left mouse button somewhere on the canvas using the correct Ipe mode. Group objects are created using the *Group* function in the *Edit* menu. Image objects are added to the document using the *Insert image* ipelet. Reference objects can be created either using mark mode, or using the *Symbols* ipelet.

4.1 Path objects

Path objects are defined by a set of *subpaths*, that is, curves in the plane. Each subpath is either open or closed, and consists of straight line segments, circular or elliptic arc segments, parabola segments (or, equivalently, quadratic Bézier splines), cubic Bézier splines, and cubic B-spline segments. The curves are drawn with the stroke color, dash style, and line width; the interior of the object specified is filled using the fill color.

The distinction between open and closed subpaths is meaningful for stroking only, for filling any open subpath is implicitely closed. Stroking a set of subpaths is identical to stroking them individually. This is not true for filling: using several subpaths, one can construct objects with holes, and more complicated pattern. The filling algorithm is normally the *even-odd rule* of Postscript/PDF: To determine whether a point lies inside the filled shape, draw a ray from that point in any direction, and count the number of path segments that cross the ray. If this number is odd, the point is inside; if even, the point is outside.

Ipe can draw arrows on the first and last segment of a path object, but only if that segment is part of an open subpath.

There are several Ipe modes that create path objects in different ways. All modes create an object consisting of a single subpath only. To make more complicated path objects, such as objects with holes, you create each boundary component separately, then select them all and use the *Compose paths* function in the *Edit* menu. The reverse operation is *Decompose path*, you find it in the context menu of a path object that has several subpaths.

You can also create complicated paths by joining curves sequentially. For this to work, the endpoint of one path must be (nearly) identical to the begin point of the next—easy to achieve using snapping. You select the path objects you wish to join, and call *Join paths* in the *Edit* menu. You can also join several open path objects into a single closed path this way.

Circles can be entered in three different ways. To create an ellipse, create a circle and stretch and rotate it. Circular arcs can be entered by clicking three points on the arc or by clicking the center of the supporting circle as well as the begin and end vertex of the arc. They can be filled in Postscript fashion, and can have arrows. You can stretch a circular arc to create an elliptic arc.

A common application for arcs is to mark angles in drawings. The snap keys are useful to create such arcs: set arc creation to *center & 2 pts*, select *snap to vertex* and *snap to boundary*, click first on the center point of the angle (which is magnetic) and click then on the two bounding lines.

There are two modes for creating more complex general path objects. The difference between *line* mode and *polygon* mode is that the first creates an open path, the latter generates a closed one. As a consequence, the *line* mode uses the current arrow settings, while the *polygon* mode doesn't.

The path object created using line or polygon mode consists of segments of various types. The initial setting is to create straight segments. By holding the shift-key when pressing the left mouse button one can switch to uniform B-splines. One can also add quadratic Bézier spline segments, cubic Bézier spline segments, and circular arc segments as follows:

To add a quadratic Bézier spline (that is, a parabola), click twice in polyline mode for the first two control points. Then press the q key and click on the third (last) control point.

Similarly, to add a cubic Bézier spline, click three times in polyline mode on the first three control points. Press the c key, and click on the last control point.

Circular arcs can be added as follows: Click twice in polyline mode, once on the starting point of the arc, then on a point in the correct tangent direction. Press the a key, and click on the endpoint of the arc.

To make curves where segments of different type are joined with identical tangents, you can press the y key whenever you are starting a new segment: this will set the coordinate system centered at the starting point of the segment, and aligned with the tangent to the previous segment.

For the mathematically inclined, a more precise description of the segments that can appear on a subpath follows. More details can be found in Foley et al.[2] and other text books on splines.

A subpath consists of a sequence of segments. Each segment is either a straight line segment, an elliptic arc, a quadratic Bézier spline, a cubic Bézier spline, or a uniform cubic B-spline.

The quadratic Bézier spline defined by control points p_0, p_1, and p_2, is the curve

$$P(t) = (1-t)^2 p_0 + 2t(1-t)p_1 + t^2 p_2,$$

where t ranges from 0 to 1. This implies that it starts in p_0 tangent to the line p_0p_1, ends in p_2 tangent to the line p_1p_2, and is contained in the convex hull of the three points. Any segment of any parabola can be expressed as a quadratic Bézier spline.

For instance, the piece of the unit parabola $y = x^2$ between $x = a$ and $x = b$ can be created with the control points

$$\begin{aligned} p_0 &= (a, a^2) \\ p_1 &= (\frac{a+b}{2}, ab) \\ p_2 &= (b, b^2) \end{aligned}$$

Any piece of any parabola can be created by applying some affine transformation to these points.

The cubic Bézier spline with control points p_0, p_1, p_2, and p_3 is the curve

$$R(t) = (1-t)^3 p_0 + 3t(1-t)^2 p_1 + 3t^2(1-t)p_2 + t^3 p_3.$$

It starts in p_0 being tangent to the line p_0p_1, ends in p_3 being tangent to the line p_2p_3, and lies in the convex hull of the four control points.

Uniform cubic B-splines approximate a series of $m+1$ control points p_0, p_1, ..., p_m, $m \geq 3$, with a curve consisting of $m-2$ cubic polynomial curve segments s_0, s_1, ..., s_{m-3}. Every such curve segment is defined by four of the control points. In fact, curve segment s_i is defined by the points p_i, p_{i+1}, p_{i+2}, and p_{i+3}. If the curve is closed (a *splinegon*), it contains three additional curve segments s_{m-2}, s_{m-1}, and s_m, defined by appending p_0, p_1, and p_2 to the end of the sequence. A uniform B-spline segment on an open subpath of an Ipe path object is defined by repeating both the first and last control point three times, so as to make the segment begin and end in these points.

The segment s_i is the cubic curve segment with the following parametrization.

$$Q(t) = \frac{(1-t)^3}{6} p_i + \frac{3t^3 - 6t^2 + 4}{6} p_{i+1} + \frac{-3t^3 + 3t^2 + 3t + 1}{6} p_{i+2} + \frac{t^3}{6} p_{i+3},$$

where t ranges from 0 to 1.

Since the point $Q(t)$ is a convex combination of the four control points, the curve segment s_i lies in the convex hull of p_i to p_{i+3}. Furthermore, it follows that any affine transformation can be applied to the curve by applying it to the control points. Note that a control point p_i has influence on only four curve segments, s_{i-3}, s_{i-2}, s_{i-1}, and s_i. Thus, when you edit a spline object and move a control point, only a short piece of the spline in the neighborhood of the control point will move.

[2] J. D. Foley, A. Van Dam, S. K. Feiner, and J. F. Hughes, *Computer Graphics: Principles and Practice*, Addison-Wesley, 1990.

4.2 Text objects

Text objects come in two flavors: simple *labels*, and *minipages*. There are two variants of these: *titles* (a label that serves as the title of the page), and *textbox* (a minipage that spans the entire width of the page).

The position you have to click to start creating a *label* object is normally the leftmost baseline point (but this can be changed by changing the object's horizontal and vertical alignment). A popup window appears where you can enter Latex source code.

A *minipage* object is different from a simple text object in that its width is part of its definition. When you create a minipage object, you first have to drag out a horizontal segment for the minipage. This is used as the top edge of the minipage—it will extend downwards as far as necessary to accomodate all the text. Minipages are formatted using, not surprisingly, Latex's `minipage` environment. Latex tries to fill the given bounding box as nicely as possible. It is possible to include center environments, lemmas, and much more in minipages.

To create a *textbox* object, simply press F10. Ipe automatically places the object so that it spans the entire width of the page (the *layout* settings in the stylesheet determine how much space is left on the sides), and places it vertically underneath the textboxes already on the page. This is particularly convenient for creating presentations with a lot of text, or with items that appear one by one.

Title objects are managed by Ipe automatically. They are special labels that are created using *Edit title & sections* in the *Page* menu. Their color, size, alignment, and position on the page is determined by the stylesheet.

You can use any LaTeX-command that is legal inside a `\makebox` (for labels) or inside a `minipage` (for minipages). You cannot use commands that involve a non-linear translation into PDF, such as commands to generate hyperlinks or to include external images.

You can use color in your text objects, using the `\textcolor` command, like this:

```
This is in black. \textcolor{red}{This is in red.} This is in black.
```

All the symbolic colors of your current stylesheet are also available as arguments to `\textcolor`. You can also use absolute colors, for instance:

```
This is in black. \textcolor[rgb]{1,1,0}{This is in yellow.} This is in black.
```

If you need LaTeX-commands that are defined in additional LaTeX packages, you can include (`\usepackage`) those in the LaTeX preamble, which can be set in *Document properties* in the *Edit* menu.

After you have created or edited a text object, the Ipe screen display will show the beginning of the Latex source. You can select *Run Latex* from the *File* menu to create the PDF/Postscript representation of the object. This converts all the text objects in your document at once, and Ipe will display a correct rendition of the text afterwards.

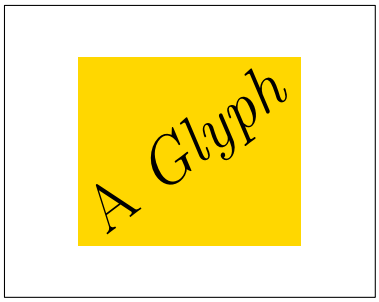
If the Latex conversion process results in errors, Ipe will automatically show you the log file created by the Latex run. If you cannot figure out the problem, look in the section on troubleshooting (Section 8.3).

You can use Unicode text, such as accented characters, Greek, Cyrillic, Chinese, Japanese, or Korean, in your text objects, once you have set up the necessary style files and fonts (Section 8.4).

When Ipe computes the bounding box for a piece of text, it relies entirely on the dimensions that Latex provides. Sometimes glyphs are larger than their "official" dimensions, and as a result this bounding box is too tight. In the following figure, "A" and "G" stick out of the golden rectangle (the bounding box computed by Ipe based on the Latex dimensions) at the top, "y" sticks out at the bottom:

When you experience that text in your figures is clipped, you may have to enlarge the figure's bounding box using a "BBOX" layer.

The opposite problem can occur when you use transformed text. Ipe computes the bounding box for the transformed text by transforming the bounding box for the original text, and the result can be too large:



If this is a problem, you can put the text object inside a group and set a clipping path for the group.

4.3 Image objects

Images are inserted using the *Insert image* ipelet (in the *Ipelets* menu). Once in a drawing, you can scale, stretch, and rotate an image. You can read in some scanned drawing and draw on top of it within Ipe. This is useful if you have a drawing on paper and want to make an Ipe version of it.

There are three functions for inserting images: one for images in general, one for JPEG images, and one for pasting from the clipboard.

If your image is in a lossless bitmap format such as PNG, GIF, or BMP, then the first function is appropriate. If your image is in JPEG (JPG) format, then the second function is the right one (it results in much smaller files, as the image is then stored internally in JPEG format, instead of a bitmap). You can also paste an image that is on the clipboard (this should not be used for JPEG images, as you would then store the bitmap). One has to be a bit careful with this, as *Insert bitmap* does accept JPG files.

Images are stored efficiently in PDF format. It is reasonable to create PDF presentations with lots of JPEG photographs in Ipe. Saving in Postscript is *not efficient*, as Ipe generates clean 7-bit Postscript files. Also, multiple copies of the same image are embedded only once in PDF documents, but are embedded once for each occurrence in Postscript output.

4.4 Group objects

Group objects are created by selecting any number of objects and using the *Group* function from the *Edit* menu. The grouped objects then behave like a single object. To modify a group object, it has to be decomposed into its parts using *Ungroup*.

A clipping path can be added to a group object. The group will then be clipped to this path—nothing will be drawn outside the clipping path. To add a clipping path, select a group as the

primary selection, and a path object as the secondary selection. Then select *Add clipping path* from the group's context menu.

4.5 Reference objects and symbols

A symbol is a single Ipe object (which can of course be a group) that is defined in a document's stylesheet. A reference object is a reference to a symbol, placed at a given position on the page.

Symbols can be parameterized with stroke and fill color, pen width, and symbol size. Whether or not a symbol accepts which parameter is visible from the symbol's name: if it takes any parameter, the name must end in a pair of parentheses containing some of the letters "s", "f", "p", "x" (in this order), for the parameters stroke, fill, pen, and size. References to parameterized symbols allow all the attributes that the symbol accepts.

All references can be translated around the page. Whether or not the symbol can be rotated or stretched depends on the definition of the symbol in the stylesheet.

If a symbol named "Background" exists in your stylesheet, it is automatically displayed on each page, at the very back. To suppress the automatic display, create a layer named "BACKGROUND" on the page, and set it to be invisible. Note that the background symbol is *not* shown in Postscript output!

Marks are symbols with special support from the Ipe user interface. They are used to mark points in the drawing, and come in several different looks (little circles, discs, squares, boxes, or crosses). You can define your own mark shapes by defining appropriate symbols in your stylesheet.

Note that marks behave quite different from path objects. In particular, you should not confuse a disc mark with a little disc created as a circle object:

- a solid mark (type *disk* and *square*) only obeys the stroke color (but *fdisk* and *fsquare* marks are filled with the fill color)
- when you scale a mark, it will not change its size (you can change the mark size from the properties panel, though)
- when you rotate a mark, it does not change its orientation

You can change a mark's shape and size later.

5 Snapping

One of the nice features of Ipe is the possibility of having the mouse *snap* to other objects during entry or moving. Certain features on the canvas become "magnetic", and it is very easy to align objects to each other, to place new objects properly with respect to the present objects and so on.

Snapping comes in three flavors: *grid snapping*, *context snapping*, and *angular snapping*.

In general, you turn a snapping mode on by pressing one of the buttons in the *Snap* toolbar, or selecting the equivalent functions in the Snap menu. The buttons are independent, you can turn them on and off independently. (The snapping modes, however, are not independent. See below for the precise interaction.) The keyboard shortcuts are rather convenient since you will want to toggle snapping modes on and off while in the middle of creating or editing some object.

Whenever one of the snapping modes is enabled, you will see a little cross near the cursor position. This is the secondary cursor *Fifi*.[3] Fifi marks the position the mouse is snapped to.

[3]Fifi is called after the dog in the `rogue` computer game installed on most Unix systems in the 1980's, because it also keeps running around your feet.

5.1 Grid snapping

Grid snapping is easy to explain. It simply means that the mouse position is rounded to the nearest grid point. Grid points are points whose coordinates are integer multiples of the *grid size*, which can be set in the box in the *Snap* field. You have a choice from a set of possible grid sizes. The units are Postscript points (in LaTeX called `bp`), which are equal to 1/72 of an inch.

You can ask Ipe to show the grid points by selecting the function *Grid visible* from the *View* menu. The same function turns it off again.

5.2 Context snapping

When *context snapping* is enabled, certain features of the objects of your current drawing become magnetic. There are three buttons to enable three different features of your objects: vertices, the boundary, and intersection points.

When the mouse is too far away from the nearest interesting feature, the mouse position will not be "snapped". The snapping distance can be changed by setting *Snapping distance* value in the preference dialog. If you use a high setting, you will need to toggle snapping on and off during drawing. Some people prefer to set snapping on once and for all, and to set the snap distance to a very small value like 3 or 4.

The features that you can make "magnetic" are the following:

vertices are vertices of polygonal objects, control points of multiplicity three of splines, centers of circles and ellipses, centers and end points of circular arcs, and mark positions.

boundaries are the object boundaries of polygonal objects, splines and splinegons, circles and ellipses, and circular arcs.

intersections are the intersection points between the boundaries of path objects.

5.3 Angular snapping

When *angular snapping* is enabled, the mouse position is restricted to lie on a set of lines through the *origin* of your current *axis system*. The lines are the lines whose angle with the *base direction* is an integer multiple of the snap angle. The snap angle can be set in the second box in the Snap toolbar. The values are indicated in degrees. So, for a snapping angle of 45°, we get the snap lines indicated in Figure 1. (In the figure the base direction—indicated with the arrow—is assumed horizontal.)

For a snap angle of 180 degrees, snapping is to a single line through the current origin.

In order to use angular snapping, it is important to set the axis system correctly. To set the origin, move the mouse to the correct position, and press the `F1`-key. Note that angular snapping is *disabled* while setting the origin. This way you can set a new origin for angular snapping without leaving the mode first. Once the origin has been set, the base direction is set by moving to a point on the desired base line, and pressing the `F2`-key. Again, angular snapping is disabled. Together, origin and base direction determine the current *axis system*. Remember that the origin is also used as the fix-point of scale, stretch, and rotate operations, if it is set.

You can un-set the current axis system by pressing `Shift-F2`. This also turns off angular snapping.

You can set origin and base direction at the same time by pressing `F3` when the mouse is very near (or snapped to) an edge of a polygonal object. The origin is set to an endpoint of the edge, and the base direction is aligned with it. This is useful to make objects parallel to a given edge.

For drawing rectilinear or c-oriented polygons, the origin should be set to the previous vertex at every step. This can be done by pressing `F1` every time you click the left mouse button, but that would not be very convenient. Therefore, Ipe offers a second angular snap mode, called *automatic*

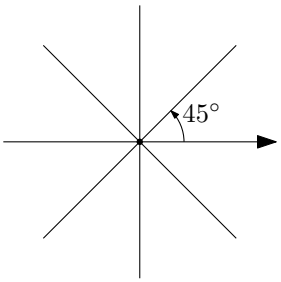


Figure 1: Snap lines

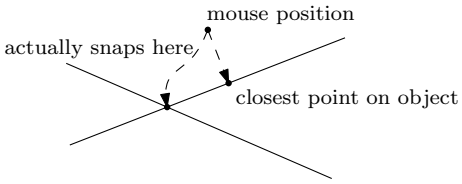


Figure 2: Snapping priorities

angular snapping. This mode uses an independent origin, which is automatically set every time you add a vertex when creating a polygonal object. Note that while the origin is independent of the origin set by `F1`, the base direction and the snap angle used by automatic angular snapping is the same as for angular snapping. Hence, you can align the axis system with some edge of your drawing using `F3`, and then use automatic angular snapping to draw a new object that is parallel or orthogonal to this edge.

This snapping mode has another advantage: It remains silent and ineffective until you start creating a polygonal object. So, even with automatic angular snapping already turned on, you can still freely place the first point of a polygon, and then the remaining vertices will be properly aligned to make a c-oriented polygon.

The automatic angular snapping mode is never active for any non-polygonal object. In particular, to *move* an object in a prescribed direction, you have to use normal angular snapping.

A final note: Many things that can be done with angular snapping can also be done by drawing auxiliary lines and using context snapping. It is mostly a matter of taste and exercise to figure out which mode suits you best.

5.4 Interaction of the snapping modes

Not all the snapping modes can be active at the same time, even if all buttons are pressed. Here we have a close look at the possible interactions, and the priorities of snapping.

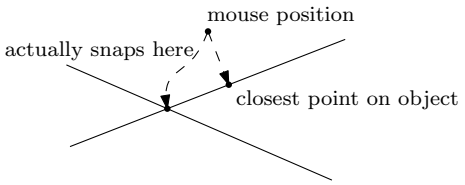
The two angular snapping modes restrict the possible mouse positions to a *one-dimensional* subspace of the canvas. Therefore, they are incompatible with the modes that try to snap to a zero-dimensional subspace, namely vertex snapping, intersection snapping, and grid snapping. Consequently, when one of the angular snapping modes is *on*, vertex snapping, intersection snapping, and grid snapping are ineffective.

On the other hand, it is reasonable to snap to boundaries while in an angular snapping mode, and this function is actually implemented correctly. When both angular and boundary snapping are *on*, Ipe will compute intersections between the snap lines with the boundaries of your objects, and whenever the mouse position *on* the snap line comes close enough to an intersection, the mouse is snapped to that intersection.

The two angular snapping modes themselves can also coexist in the same fashion. If both angular and automatic angular snapping are enabled, Ipe computes the intersection point between the snap lines defined by the two origins and snaps there. It the snap lines are parallel or coincide, automatic angular snapping is used.

When no angular snapping mode is active, Ipe has three priorities. First, Ipe checks whether the closest vertex or intersection point is close enough. If that is not the case, the closest boundary edge is determined. If even that is too far away, Ipe uses grid snapping (assuming all these modes are enabled).

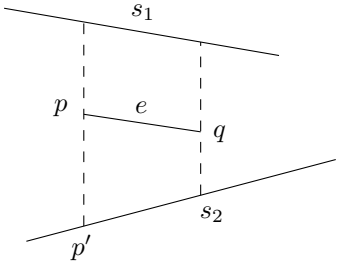
Note that this can actually mean that snapping is *not* to the *closest* point on an object. Especially for intersections of two straight edges, the closest point can never be the intersection point, as in the figure below!



5.5 Examples

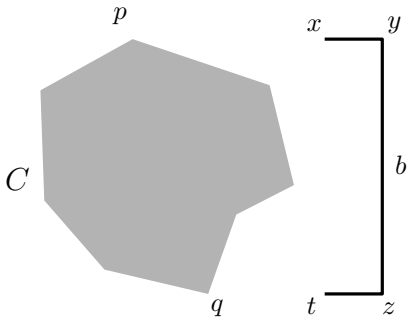
It takes some time and practice to feel fully at ease with the different snapping modes, especially angular snapping. Here are some examples showing what can be done with angular snapping.

Example 1: We are given segments s_1, s_2, and e, and we want to add the dashed vertical extensions through p and q.



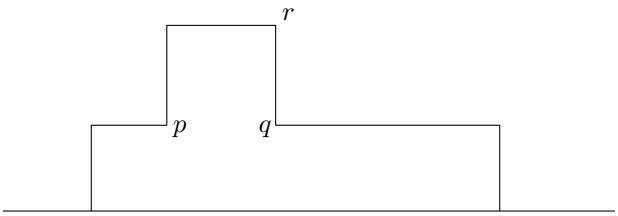
- set `F4` and `F5` snapping on, go into *line* mode, and reset axis system with `Shift-F2`,
- go near p, press `F1` and `F8` to set origin and to turn on angular snap.
- go near p', click left, and extend segment to s_2.
- go near q, press `F1` to reset origin, and draw second extension in the same way.

Example 2: We are given the polygon C, and we want to draw the bracket b, indicating its vertical extension.



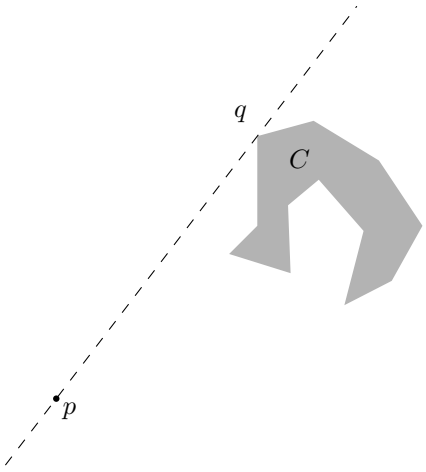
- set `F4` and `F9` snapping on, go into *line* mode, reset axis system, set snap angle to 90°.
- go near p, press `F1` and `F8` to set origin and angular snapping
- go to x, click left, extend segment to y, click left
- now we want to have z on a horizontal line through q: go near q, and press `F1` and `F8` to reset origin and to turn on angular snapping. Now both angular snapping modes are on, the snap lines intersect in z.
- click left at z, goto x and press `F1`, goto t and finish bracket.

Example 3: We want to draw the following "skyline". The only problem is to get q horizontally aligned with p.



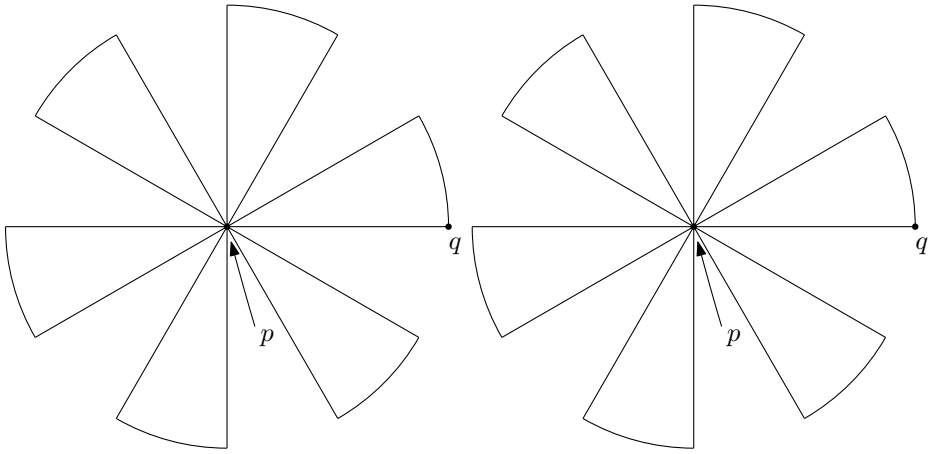
- draw the baseline using automatic angular snapping to get it horizontal.
- place p with boundary snapping, draw the rectilinear curve up to r with automatic angular snapping in 90° mode.
- now go to p and press `F1` and `F8`. The snap lines intersect in q. Click there, turn off angular snapping with `Shift-F2`, and finish curve. The last point is placed with boundary snapping.

Example 4: We want to draw a line through p, tangent to C in q.



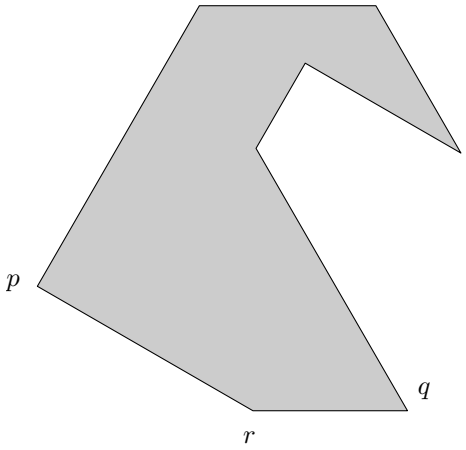
- with vertex snapping on, put origin at p with `F1`
- go to q and press `F2`. This puts the base direction from p to q.
- set angular snapping with `F8` and draw line.

Example 5: We want to draw the following "windmill". The angle of the sector and between sectors should be 30°.



- set vertex snapping, snap angle to 30°, reset axis system with `Shift-F1`,
- with automatic angular snapping, draw a horizontal segment pq.
- go to p, place origin and turn on angular snapping with `F1` and `F8`,
- duplicate segment with `d`, go to q and pick up q for rotation (with Ctrl and the middle mouse button). Rotate until segment falls on the next snap line.
- turn off angular snapping with `F8`. Choose arc mode, variant "center & two points".
- go to p, click for center. Go to q, click for first endpoint of arc, and at r for the second endpoint. Select all, and group.
- turn angular snapping on again. Duplicate sector, and rotate by 60° using angular snapping.
- duplicate and rotate four more times.

Example 6: We want to draw a c-oriented polygon, where the angles between successive segments are multiples of 30°. The automatic angular snapping mode makes this pretty easy, but there is a little catch: How do we place the ultimate vertex such that it is at the same time properly aligned to the penultimate and to the very first vertex?



- set snap angle to 30°, and turn on automatic angular snapping.
- click first vertex p and draw the polygon up to the penultimate vertex q.
- it remains to place r such that it is in a legal position both with respect to q and p. The automatic angular snapping mode ensures the position with respect to q. We will use angular snapping from p to get it right: Go near p and turn on vertex snapping. Press `F1` to place the origin at p and `F8` to turn on angular snapping. Now it is trivial to place r.

6 Stylesheets

The symbolic attributes appearing in an Ipe document are translated to absolute values for rendering by a *stylesheet* that is attached to the document. Documents can have multiple "cascaded" stylesheets, the sheets form a stack, and symbols are looked up from top to bottom. At the bottom of any stylesheet cascade is always the minimal *standard* style sheet, which is built into Ipe.

When you create a new empty document, it automatically gets a copy of this standard style sheet (which does little more than define the "normal" attribute for each kind of attribute). In addition, Ipe inserts a predefined list of stylesheets. The list of these stylesheets can be customized using an ipelet, using Ipe's command line options, and an environment variable. By default, a new document gets the stylesheet *basic* that comes with Ipe.

The stylesheet dialog (in the *Edit* menu under *Stylesheets*) allows you to inspect the cascade of stylesheets associated with your document, to add and remove stylesheets, and to change their order. You can also save individual stylesheets.

The stylesheets of your document also determine the symbolic choices you have in the Ipe user interface. If you feel that Ipe does not offer you the right choice of colors, pen widths, etc., you are ready to make your own style sheet! Ipe's *styles* directory contains a few examples to look at. The *colors.isy* stylesheet defines all the colors of the X11 color database - you could make a selection of these for your own use.

When a stylesheet is "added" to an Ipe document, the contents of the stylesheet file is copied into the Ipe document. Subsequent modification of the stylesheet file has no effect on the Ipe document. The right way to modify your stylesheet is to either "add" it again, and then to delete the *old* copy from your stylesheet cascade (the one further down in the list), or to use the *Update stylesheets* function in the *Edit* menu. This function assumes that the stylesheet file is in the same directory as the document and that the filename coincides with the name of the stylesheet (plus the extension *.isy*).

Removing or replacing a stylesheet can cause some of the symbolic attributes in your document to become undefined. This is not a disaster—Ipe will simply use some default value for any undefined symbolic attribute. To allow you to diagnose the problem, Ipe will show a warning listing all undefined symbolic attributes.

The style sheet is also responsible for determining the paper and frame size. Ipe's default paper size is the ISO standard A4. If you wish to use letter size paper instead, include this style sheet:

```
<ipestyle name="letterpaper">
  <layout paper="612 792" origin="0 0" frame="612 792"/>
</ipestyle>
```

Symbols. Style sheets can also contain *symbols*, such as marks and arrows, background patterns, or logos. These are named Ipe objects that can be referenced by the document. If your document's stylesheets define a symbol named *Background*, it will be displayed automatically on all pages. You can create and use symbols using the *Symbols* ipelet. Here is a (silly) example of a style sheet that defines such a background:

```
<ipestyle name="background">
<symbol name="Background" xform="yes">
<text pos="10 10" stroke="black" size="LARGE">
Background text
</text>
</symbol>
</ipestyle>
```

Note the use of the `xform` attribute—it ensures that the background is embedded only once into PDF document. This can make a huge difference if your background is a complicated object.

Symbols can be parameterized with a stroke color, fill color, pen size, and symbol size. This means that the actual value of these attributes is only set when the symbol is used in the document (not in the symbol definition). The name of a parameterized symbol must end with a pair of parentheses containing some of the letters "s" (stroke), "f" (fill), "p" (pen), "x" (symbol size), in this order. The symbol definition can then use the special attribute values `sym-stroke`, `sym-fill`, and `sym-pen`. A resizable symbol is automatically magnified by the symbol size set in the symbol reference.

You can also use a stylesheet to define additional mark shapes, arrow shapes, or tiling patterns.

Latex preamble. Stylesheets can also define a piece of LaTeX-preamble for your document. When your text objects are processed by LaTeX, the preamble used consists of the pieces on the style sheet cascade, from bottom to top, followed by the preamble set for the document itself.

Transparency. If you wish to use transparency in your document, you need to define opacity values in its stylesheet. The default stylesheet *basic.isy* does not define any opacity value, because documents using transparence cannot be saved in Postscript format. A minimal stylesheet defining an opacity value would be:

```
<ipestyle name="transparency">
<opacity name="50%" value="0.5"/>
</ipestyle>
```

Other stylesheet definitions that are meant for PDF presentations are discussed in the next section.

7 Presentations

An Ipe presentation is an Ipe PDF document that is presented using, for instance, Acrobat Reader and a video projector. Ipe has a number of features that make it easier to make such presentations.

You may want to have a look at IpePresenter, written by Dmitriy Morozov. IpePresenter shows the current slide in one window (which you can make full screen on the external display), while showing the current slide, the next slide, notes for the current page, as well as a timer on your own display.

The Ipe binary package for Windows already includes IpePresenter.

7.1 Presentation stylesheets

A presentation *must* use a dedicated stylesheet. Presentations must use much larger fonts than what is normal for a figure. Don't try to make use of the "LARGE" and "huge" textsizes, but use a stylesheet that properly defines "normal" to be a large textsize.

Ipe comes with a style sheet *presentation.isy* that can be used for presentations. To create a new presentation, you can simply say:

```
ipe -sheet presentation
```

Note that *presentation.isy* is meant to be used *instead* of *basic.isy* (not in addition to it).

This presentation stylesheet enlarges all standard sizes by a factor 2.8. Note the use of the `<textstretch>` element to magnify text:

```
<textstretch name="normal" value="2.8"/>
<textstretch name="large" value="2.8"/>
```

The text size you choose from the Ipe user interface (*"large"*, for instance) is in fact used for *two* symbolic attributes, namely `textsize` (where *large* maps to `\large`) and `textstretch` (where it maps to no stretch in the standard style sheet). By setting the text stretch, you can magnify fonts.

In addition, the `<layout>` element in this stylesheet redefines the paper size to be of the correct proportions for a projector, and defines a smaller area of the paper as the *frame*. The frame is the area that should be used for the contents. The *Insert text box* function, for instance, creates text objects that fill exactly the width of the frame.

The `<titlestyle>` element defines the style of the page *title* outside the frame. You can set the title for each page using the *Edit title & sections* function in the *Page* menu.

The LaTeX-preamble defined in the `<preamble>` element redefines the standard font shape to `cmss` (Computer Modern Sans Serif). Many people find sans-serif fonts easier to read on a screen. In addition, it redefines the list environments to use less spacing, and the text styles to not justify paragraphs (the `<textstyle>` elements).

If you wish to use the page transition effects of Acrobat Reader, you can define the effects in the stylesheet (using `<effect>` elements), and set them using *Edit effect* in the *View* menu.

7.2 Views

When making a PDF presentation with Acrobat Reader, one would often like to present a page incrementally. For instance, I would first like to show a polygon, then add its triangulation, and finally color the vertices. *Views* make it possible to do this nicely.

An Ipe document consists of several pages, each of which can consist of an arbitrary number of views. When saving as PDF, each view generates a separate PDF page (if you only look at the result in, say, Acrobat reader, you cannot tell whether two pages are actually two views of the same Ipe page or two different Ipe pages).

An Ipe page consists of a number of objects, a number of layers, and a number of views. Each object belongs to exactly one layer. A layer can be shown by any number of views—a view is really just a list of layers to be presented. In addition, a view keeps a record of the current active layer—this makes it easy to move around your views and edit them. Finally, views can specify a graphic effect to be used by the PDF viewer when proceeding to the following PDF page.

To return to our polygon triangulation example, let's create an empty page. We draw a polygon into the default layer "alpha." Now use the *New layer, new view* function (in the *Views* menu), and draw the triangulation into the new layer "beta." Note that the function not only created a new layer, but also a second view showing both "alpha" and "beta". Try moving back and forth between the two views (using the PageUp and PageDown keys). You'll see changes in the layer list on the left: in view 1, layer "alpha" is selected and active, in view 2, both layers are selected and "beta" is active. Create a third layer and view, and mark the vertices.

Save in PDF format, and voila, you have a lovely little presentation.

In presentations, one often has slides with mostly text. The textbox object is convenient for this, as one doesn't need to use the mouse to create it. To create a slide where several text items appear one by one, one only needs to press F10 to create a textbox, then Shift+Ctrl+I to make a new view, F10 again for the next textbox, and so on. Finally, one moves the textboxes vertically for the most pleasing effect (*Shift+Alt+Left Mouse* does a constrained vertical translation, or *Shift+Left Mouse* in *Translate* mode).

Note that all views of a page receive the same bounding box, containing all objects visible on some view, plus all objects in a layer named "BBOX" (even if that layer is not visible). This can be used to force a larger bounding box without adding a white rectangle or the like.

If you need independent bounding boxes for each view, create a layer named "VIEWBBOX". Any view in which this layer is visible will receive a bounding box computed for the objects visible in this view only.

7.3 Bookmarks

You can set a section title and a subsection title for each page of an Ipe document. Theses titles will be shown in the *bookmarks list* (right-click on a toolbar to make it visible). Double-clicking a title brings you directly to its page, making navigation of long documents much easier. The titles are also exported to PDF, and are visible in the bookmarks view of PDF viewers.

7.4 Gradient patterns

Gradient patterns allow to shade objects with continuously changing colors. This is often used for backgrounds, or to achieve the illusion of three-dimensional spheres or cylinders.

The intended use of gradients is to allow the creation of attractive symbols inside the style sheet, for backgrounds, as bullets in item lists (see next section), or simply to define attractive glassy-ball symbols and the like that can be used through the *Use symbol* ipelet.

The Ipe user interface does not offer any way of creating or editing gradients. If your stylesheet defines a gradient, then it is possible to fill a path object with this gradient, but getting the gradient coordinate system right is not trivial. (The trick is to draw the path object at gradient coordinates, and translate/rotate it to the final location afterwards.)

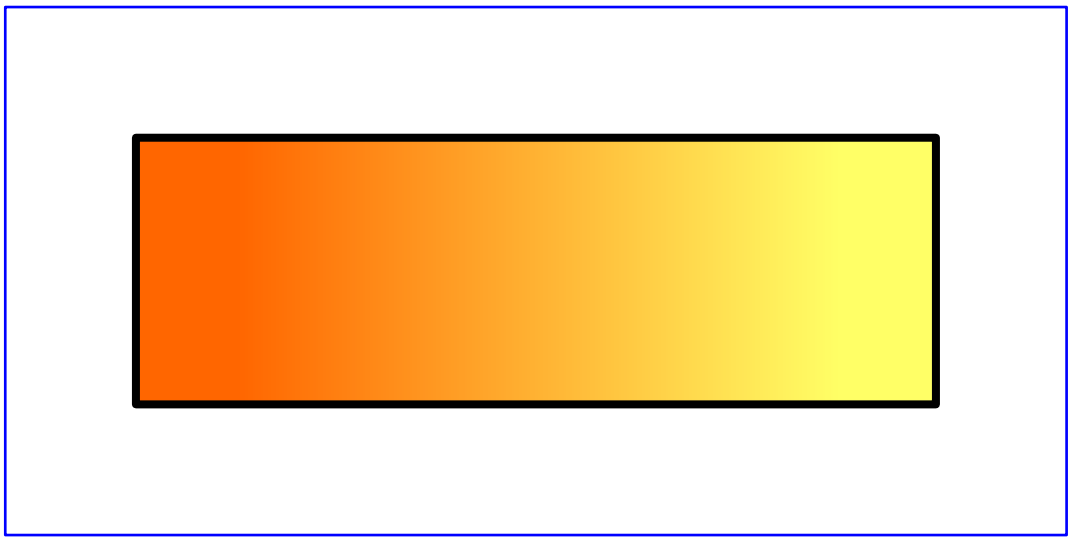
The definition of a linear (axial) gradient looks like this:

```
<gradient name="linear" type="axial" extend="yes" coords="75 0 325 0">
  <stop offset="0.05" color="1 0.4 0"/>
  <stop offset="0.95" color="1 1 0.4"/>
</gradient>
```

If used like this:

```
<path stroke="0" fill="1" gradient="linear" pen="3">
  50 50 m 350 50 l 350 150 l 50 150 l h
</path>
```

it will look like this:

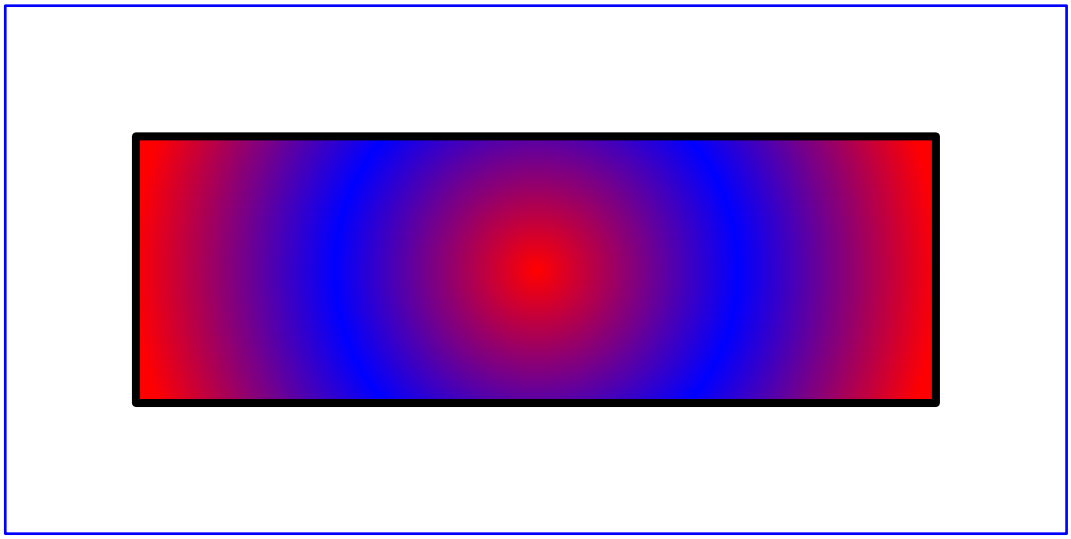


A radial gradient looks like this:

```
<gradient name="radial" type="radial" extend="yes"
     coords="200 100 0 200 100 150">
```

```
  <stop offset="0" color="1 0 0"/>
  <stop offset="0.5" color="0 0 1"/>
  <stop offset="1" color="1 0 0"/>
</gradient>
```

It will look like this:

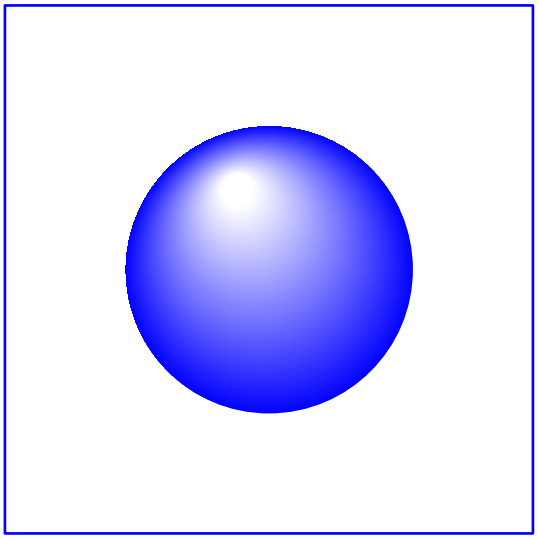


A common use of radial gradients is to define glassy balls like this:

```
<gradient name="ball" type="radial" coords="-4 10 2 0 0 18">
  <stop offset="0" color="1 1 1"/>
  <stop offset="1" color="0 0 1"/>
</gradient>
```

Note that the gradient is centered at *0 0*, so it needs to be moved to the location where it is used:

```
<path matrix="3 0 0 3 100 100" fill="1" gradient="ball">
  18 0 0 18 0 0 e
</path>
```



Normally, you would define a symbol looking like a glassy ball in your style sheet:

```
<ipestyle>
  <gradient name="ball" type="radial" coords="-4 10 2 0 0 18">
    <stop offset="0" color="1 1 1"/>
    <stop offset="1" color="0 0 1"/>
  </gradient>
  <symbol name="ball(x)" transformations="translations">
    <path fill="1" gradient="ball"> 18 0 0 18 0 0 e </path>
  </symbol>
</ipestyle>
```

The glassy ball can then be used in the document using the *Use symbol* ipelet. Note that `transformations="translations"` ensures that stretching your drawing does not change the glassy ball. Adding the `(x)` suffix to the symbol name allows you to resize the glassy ball by changing the symbol size from the properties (the same selector used to change the mark size).

For the precise syntax of the gradient definition see here. The easiest method of creating gradients, though, is to use an SVG editor such as *Inkscape* and to convert the SVG gradient to Ipe format using *Svgtoipe*.

7.5 Ipe symbols used from text objects

Presentations often make use of `itemize` environments. You can make these prettier in a number of ways:

You can color your bullets:

```
<preamble>
\def\labelitemi{\LARGE\textcolor{red}{$\bullet$}}
</preamble>
```

Enumeration numbers could be put in a colored box:

```
<preamble>
\newcommand{\labelenumi}{\fbox{\Roman{enumi}}}
</preamble>
```

You could use the Dingbats font for nice enumerations, for instance by putting `\usepackage{pifont}` in your preamble, and then having text objects with `\begin{dinglist}{43}` or `\begin{dingautolist}{172}` (or use 182, 192, 202 for various circled numbers).

You can mark items as "good" and "bad" using these "bullets":

Bad item: `\textcolor{red}{\ding{55}}`

Good item: `\textcolor{green}{\ding{52}}`

Finally, you can custom design your own bullets by creating an Ipe symbol for it. For instance:

```
<symbol name="bullet(sfpx)">
  <path matrix="2 0 0 2 0 0" pen="sym-pen" stroke="sym-stroke" fill="sym-fill">
    0 0 m -1.0 0.333 l -0.8 0 l -1.0 -0.333 l h</path>
</symbol>
<preamble>
  \def\labelitemi{\raisebox{0.5ex}{\hbox to 0.3em%
      {\ipesymbol{bullet(sfpx)}{blue}{yellow}{normal}}}}
</preamble>
```

Note the use of the `\ipesymbol{name}{stroke}{fill}{pen}` command. It allows you to use an Ipe symbol from inside a text object. The symbol is magnified proportionally to the ex-height of the current font at the position where it is used. (And so the symbol should be designed to be the correct size for a font of ex-height 1pt.)

In the following example, we redefine the bullet to be a blue glassy sphere:

```
<gradient name="ball" type="radial" coords="-4 10 2 0 0 18">
  <stop offset="0" color="1 1 1"/>
  <stop offset="1" color="0 0 1"/>
</gradient>
<symbol name="sphere">
  <path matrix="0.04 0 0 0.04 0 0" fill="blue" gradient="ball">
    18 0 0 18 0 0 e
  </path>
</symbol>
<preamble>
  \def\labelitemi{\raisebox{0.5ex}{\hbox to 0.3em{\ipesymbol{sphere}{}{}{}}}}
</preamble>
```

8 Advanced topics

8.1 Sharing Latex definitions with your Latex document

When using Ipe figures in a Latex document, it is convenient to have access to some of the definitions from the document.

Ipe comes with a Lua script *update-master* that makes this easy.

In your Latex document, say *master.tex*, surround the interesting definitions using `%%BeginIpePreamble` and `%%EndIpePreamble`, for instance like this:

```
%%BeginIpePreamble
\usepackage{amsfonts}
\newcommand{\R}{\mathbb{R}}
%%EndIpePreamble
```

Running the script as

```
ipescript update-master master.tex
```

extracts these definitions and saves them as a stylesheet *master-preamble.isy*. (This filename is fixed, and does not depend on the document name.)

Running this script as

```
ipescript update-master master.tex figures/*.ipe
```

creates the stylesheet *master-preamble.isy* as above. In addition, it looks at all the Ipe figures mentioned on the command line. The script adds the new stylesheet to each figure, or updates the stylesheet to the newest version (if the figure already contains a stylesheet named "master-preamble").

8.2 Writing ipelets

An ipelet is an extension to Ipe. Ipe 7 uses the scripting language Lua (in fact, most of the Ipe program itself is written in Lua), and loads ipelets written in Lua when it starts up. It is also possible to write ipelets in C++, using a small Lua wrapper that declares the methods available inside the ipelet.

Documentation about writing ipelets can be found in the Ipelib documentation.

8.3 Troubleshooting the LaTeX-conversion

Ipe converts text objects from their Latex source representation to a representation that can be rendered and included in Postscript and PDF by creating a Latex source file and running Pdflatex. This happens in a dedicated directory, which Ipe creates the first time it is used. The Latex source and output files are left in that directory and not deleted even when you close Ipe, to make it easy to solve problems with the Latex conversion process.

You can determine the directory used by Ipe using *Show configuration* in the *Help* menu. If you'd prefer to use a different directory, set the environment variable `IPELATEXDIR` before starting Ipe.

If Ipe fails to translate your text objects, and you cannot find the problem by looking at the log file displayed by Ipe (or Ipe doesn't even display the log file), you can terminate Ipe, go to the conversion directory, and run Pdflatex manually:

```
pdflatex ipetemp.tex
```

8.4 Unicode text

If you make figures containing text objects in languages other than English, you will need to enter accented characters, or characters from other scripts such as Greek, Hangul, Kana, or Chinese characters. Of course you can still use the LaTeX syntax `K\"onig` to enter the German word "König", but for larger runs of text it's more convenient to enter text in a script supported by your system. When Ipe writes the Pdflatex source file, it writes the text in UTF-8 encoded Unicode. You only have to make sure that Pdflatex can handle this file.

Instead of the solution below you may want to use Xetex for the LaTeX-conversion. It supports Unicode natively.

An easy solution, sufficient for German, French, and other languages for which support is already in a standard LaTeX-setup, is to add the line

```
\usepackage[utf8]{inputenc}
```

in your *Latex preamble* (set in the *Document properties* dialog, available on the *Edit* menu).

When setting this up, you have to keep in mind that Ipe can only handle scalable fonts, such as Postscript Type1 fonts. You'll have to choose a setup that uses such scalable fonts.

For instance, to use UTF-8 encoded Russian in LaTeX, it is sufficient to put this in the preamble:

```
\usepackage[utf8]{inputenc}
\usepackage[russian]{babel}
```

However, this will *not* work with Ipe: This setup uses Metafont fonts, which are included in the PDF output as bitmaps, and Ipe cannot use these fonts. In this case the solution is to install the *PsCyr* package, and the following preamble:

```
\usepackage[utf8]{inputenc}
\usepackage[russian]{babel}
\usepackage{pscyr}
```

8.5 Customizing Ipe

Since most of Ipe is writing in Lua, an interpreted language, much of Ipe's behavior can be changed without recompilation.

The main customization options are in the files *prefs.lua* (general settings), *shortcuts.lua* (keyboard shortcuts), and *mouse.lua* (mouse shortcuts). (Check the Lua code path in *Show configuration* in the *Help* menu if you can't locate the files.)

If you have installed Ipe for your personal use only (for instance under Windows), you can simply modify the original Lua file. In all other cases, you need to provide a small Lua ipelet that will change the setting you wish to change.

A small example is the following ipelet that changes a keyboard shortcut and the maximum zoom:

```
-----------------------------------------------------------------------
-- My customization ipelet: customize.lua
-----------------------------------------------------------------------
prefs.max_zoom = 100
shortcuts.insert_text_box = "I",
shortcuts.mode_splines = "Alt+Ctrl+I"
```

The ipelet needs to be placed with the extension *.lua* somewhere on the ipelet path (check *Show configuration* again). On Unix, the directory `$HOME/.ipe/ipelets` will do nicely. On Windows, you will have to set the environment variable IPELETPATH, see the next section.

8.6 Environment variables

Ipe, *ipetoipe*, and *iperender* respect the following environment variables:

IPELATEXDIR the directory where Ipe runs Latex.

IPELATEXPATH the directory that contains the *pdflatex* and *xelatex* commands. If not set, Ipe assumes the commands are on your path.

IPEDEBUG set to 1 for debugging output.

IPEANCIENTPDFTEX set this variable to use Pdftex versions older than 1.40.

IPETEXFORMAT if set, Ipe will not call pdflatex but pdftex requesting the pdflatex format (and similarly for xetex). This is needed to use cygwin's latex.

The Ipe program uses several additional environment variables:

EDITOR external editor to use for editing text objects.

IPESTYLES a list of directories, separated by semicolons on Windows and colons otherwise, where Ipe looks for stylesheets, for instance for the standard stylesheet *basic.isy*. You can write _ (a single underscore) for the system-wide stylesheet directory. If this variable is not set, the default consists of the system-wide stylesheet directory, plus *~/.ipe/styles* on Unix, plus *~/Library/Ipe/Styles* on OS X.

IPELETPATH a list of directories, separated by semicolons on Windows and colons otherwise, containing ipelets. You can write _ (a single underscore) for the system-wide ipelet directory. If this variable is not set, the default consists of the system-wide ipelet directory, plus *~/.ipe/ipelets* on Unix, plus *~/Library/Ipe/Ipelets* on OS X.

IPEICONDIR directory containing icons for the Ipe user interface.

IPEDOCDIR directory containing Ipe documentation.

IPELUAPATH path for searching for Ipe Lua code.

ipe.conf On Windows, Ipe allows you to set environment variables by writing the definitions in the file *ipe.conf* in the top level of the Ipe directory (the same place that contains the *readme.txt* and *gpl.txt* files). Each line of the file contains a setting for one environment variable, for instance like this:

```
IPEDEBUG=1
IPELATEXDIR=C:\latexrun
```

8.7 Running Ipe under Wine on Linux

Ipe itself works fine under Wine, but there is an issue: We don't want to create a new tex installation for Windows under Wine, we want to reuse the Linux tex installation!

So first we need to make the pdflatex program available to Wine, by putting a symbolic link in the simulated `C:` drive.

```
$ cd ~/.wine/drive_c/windows/
$ ln -s /usr/bin/pdflatex pdflatex.exe
```

The second problem is that Ipe is not able to wait for the completion of the pdflatex call—it starts pdflatex, and then immediately tries to read the pdflatex output, which of course fails. The solution is to make Ipe wait for a specified number of milliseconds before trying to read the pdflatex output.

You achieve this by creating a small text file called ipe.conf and placing it in the top-level Ipe directory (that is, the directory that contains *readme.txt* and *gpl.txt*). The contents of the file should be:

```
IPEWINE=1000
IPELATEXPATH=c:\windows
```

(You can define any other environment variable in the same file.)

8.8 Using cygwin latex on Windows

If you have cygwin on your Windows computer and wish to use the cygwin installation of Latex (rather than MikTeX or texlive), create a small text file called ipe.conf and place it in the top-level Ipe directory (that is, the directory that contains *readme.txt* and *gpl.txt*). The contents of the file should be:

```
IPETEXFORMAT=1
IPELATEXPATH=c:\cygwin\bin
```

(You'll need to check the exact path containing your cygwin binaries. On 64 bit cygwin, it's probably `c:\cygwin64\bin`.)

You can define any other environment variable in the same file.

You need the cygwin packages *texlive-collection-latex* and *texlive-collection-latexrecommended*.

Note that it's not necessary to add the cygwin path to your general Windows path.

A The Ipe file format

Ipe can store documents in several possible formats. Among them are standard PDF and Postscript, which can be read by any application capable of opening such files, such as Acrobat Reader, Xpdf, or Ghostview. (Ipe embeds its own information inside PDF and Postscript files. The way this is done is not documented here, and may change between releases of Ipe.)

There is one other Ipe file format, which is a pure XML implementation. Files stored in this format can be parsed with any XML-aware application, and you can create XML files for Ipe from your own applications.

A DTD for the Ipe format is available as ipe.dtd. For instance, you can use this to validate an Ipe document using

```
xmllint --valid --path <path-to-ipe.dtd> --noout <file.ipe>
```

The tags understood by Ipe are described informally in this section. Tags in the XML file can carry attributes other than the ones documented here. Ipe ignores all attributes it does't understand, and they will be lost if the document is saved again from Ipe. Ipe will complain about any XML elements not described here, with the exception that you can use elements whose name starts with "x-" freely to add your own information inside an Ipe file.

An Ipe XML file must contain exactly one `<ipe>` element, while an Ipe stylesheet file must contain exactly one `<ipestyle>` element (both types of files are allowed to start with an `<?xml>` tag, which is simply ignored by Ipe). An Ipe file may also contain a `<!DOCTYPE>` tag.

All elements are documented below.

A.1 The `<ipe>` element

Attributes

version (required) The value (a number, e.g. 70103 for Ipelib 7.1.3) indicates the earliest Ipelib version that can interpret the document. Ipe will refuse to load documents that require a version larger than its own, and may refuse to load documents that are too old (and which will have to be converted using a separate program).

creator (optional) indicates the program that created the file and is not interpreted by Ipe at all.

Contents

1. An `<info>` element (optional),
2. a `<preamble>` element (optional),
3. a series of `<bitmap>` and `<ipestyle>` elements (optional),
4. a series of `page` elements.

The `<ipestyle>` elements form a "cascade", with the *last* `<ipestyle>` element becoming the *top-level* style sheet. When symbolic names are looked up, the style sheets are checked from top to bottom. Ipe always appends the built-in standard style sheet at the bottom of the stack.

A.1.1 The `<info>` element

Attributes

title (optional) document title,

author (optional) document author,

subject (optional) document subject,

keywords (optional) document keywords,

pagemode (optional) the only value understood by Ipe is `fullscreen`, which causes the document to be opened in full screen mode in PDF readers.

created (optional) creation time in PDF format, e.g. "D:20030127204100".

modified (optional) modification time in PDF format,

numberpages (optional) if the value is `yes`, then Ipe will save PDF documents with visible page numbers on each page.

tex (optional) determines the TEX-engine used to translate your text. The possible values are `pdftex`, `xetex`, and `luatex`.

This element must be empty.

A.1.2 The `<preamble>` element

The contents of this element is LATEX source code, to be used as the LATEX preamble when running LATEX to process the text objects in the document. It should *not* contain a `\documentclass` command, but can contain `\usepackage` commands and macro definitions.

A.1.3 The `<bitmap>` element

Each `<bitmap>` element defines a bitmap to be used by `<image>` objects.

Attributes

id (required) the value must be an integer that will define the bitmap throughout the Ipe document,

width (required) integer width in pixels,

height (required) integer height in pixels,

ColorSpace (required) possible values are "DeviceGray", "DeviceRGB", and "DeviceCMYK",

BitsPerComponent (required) value must be 8,

ColorKey (optional) an RGB color in hexadecimal, indicating the transparent color (only supported for "DeviceRGB" color space),

length (required unless there is no filter) the number of bytes of image data,

Filter (optional) possible values are "FlateDecode" or "DCTDecode" to indicate a compressed image (the latter is used for JPEG images).

encoding (optional) possible value is "base64" to indicate that the image data is base64-encoded (not in hexadecimal).

The contents of the `<bitmap>` element is the image data, either base64-encoded or in hexadecimal format. White space between bytes is ignored. If no filter is specified, pixels are stored row by row, with rows padded to a full byte boundary.

Note that images with color maps are not supported, and such support is not planned. (The *Insert image* function does allow you to insert images with color maps, but they are stored as 24-bit images. Since the data is compressed, this does not seriously increase the image data size.)

A.2 The <page> element

Attributes

title (optional) title of this page (displayed at a fixed location in a format specified by the style sheet),

section (optional) Title of document section starting with this page. If the attribute is not present, this page continues the section of the previous page. If the attribute is present, but its value is an empty string, then the contents of the `title` attribute is used instead.

subsection (optional) Title of document subsection starting with this page. If the attribute is not present, this page continues the subsection of the previous page. If the attribute is present, but its value is an empty string, then the contents of the `title` attribute is used instead.

marked (optional) The page is marked for printing unless the value of this attribute is `no`.

Contents

1. An optional `<notes>` element,
2. a possibly empty sequence of `<layer>` elements,
3. a possibly empty sequence of `<view>` elements,
4. a possibly empty sequence of Ipe object elements.

If a page contains no layer element, Ipe automatically adds a default layer named "alpha", visible and editable.

If a page contains no view element, a single view where all layers are visible is assumed.

A.2.1 The <notes> element

This element has no attributes. Its contents is plain text, containing notes for this page.

A.2.2 The <layer> element

Attributes

name (required) Name of the layer. It must not contain white space.

edit (optional) The value should be `yes` or `no` and indicates whether the user can select and modify the contents of the layer in the Ipe user interface (of course the user can always modify the setting of the attribute).

The layer element must be empty.

A.2.3 The <view> element

Attributes

layers (required) The value must be a sequence of layer names defined in this page, separated by white space.

active (required) The layer that is the active layer in this view.

effect (optional) The symbolic name of a graphics effect to be used during the PDF page transition. The effect must be defined in the style sheet.

marked (optional) The view is marked for printing if the value of this attribute is `yes`.

The view element must be empty.

A.3 Ipe object elements

Common attributes

layer (optional) Only allowed on "top-level" objects, that is, objects directly inside a `<page>` element. The value indicates into which layer the object goes. If the attribute is missing, the object goes into the same layer as the preceding object. If the first object has no layer attribute, it goes into the layer defined first in the page, or the default "alpha" layer.

matrix (optional) A sequence of six real numbers, separated by white space, indicating a transformation matrix for all coordinates inside the element (including embedded elements if this is a `<group>` element). A missing `matrix` attribute is interpreted as the identity matrix.

pin (optional) Possible values are `yes` (object is fixed on the page), `h` (object is pinned horizontally, but can move in the vertical direction), and `v` (the opposite). The default is no pinning.

transformations (optional) This attribute determines how objects can be deformed by transformations. Possible values are *affine* (the default), *rigid*, and *translations*.

Color attribute values A color attribute value is either a symbolic name defined in one of the style sheets of the document, one of the predefined names "black" or "white", a single real number between 0 (black) and 1 (white) indicating a gray level, or three real numbers in the range $[0, 1]$ indicating the red, green, and blue component (in this order), separated by white space.

Path construction operators Graphical shapes in Ipe are described using a series of "path construction operators" with arguments. This generalizes the PDF path construction syntax.

Each operator follows its arguments. The operators are

- `m` (moveto) (1 point argument): begin new subpath.
- `l` (lineto) (1 point argument): add straight segment to subpath.
- `c` (cubic B-spline) (n point arguments): add a uniform cubic B-spline with $n + 1$ control points (the current position plus the n arguments). If $n = 3$, this is equivalent to a single cubic Bézier spline, if $n = 2$ it is equivalent to a single quadratic Bézier spline.
- `q` (deprecated) (2 point arguments): identical to 'c'.
- `e` (ellipse) (1 matrix argument): add a closed subpath consisting of an ellipse, the ellipse is the image of the unit circle under the transformation described by the matrix.
- `a` (arcto) (1 matrix argument, 1 point argument): add an elliptic arc, on the ellipse describe by the matrix, from current position to given point.
- `s` (deprecated) (n point arguments): add an "old style" uniform cubic B-spline as used by Ipe up to version 7.1.6.
- `u` (closed spline) (n point arguments): add a closed subpath consisting of a closed uniform B-spline with n control points,
- `h` (closepath) (no arguments): close the current subpath. No more segments can be added to this subpath, so the next operator (if there is one) must start a new subpath.

Paths consisting of more than one closed loop are allowed. A subpath can consist of any mix of straight segments, elliptic arcs, and B-splines.

A.3.1 The `<group>` element

The `<group>` element allows to group objects together, so that they appear as one in the user interface.

Attributes

clip (optional) The value is a sequence of path construction operators, forming a clipping path for the objects inside the group.

The contents of the `<group>` element is a series of Ipe object elements.

A.3.2 The `<image>` element

Attributes

bitmap (required) Value is an integer referring to a bitmap defined in a `<bitmap>` element in the document,

rect (required) Four real coordinates separated by white space, in the order x_1, y_1, x_2, y_2, indicating two opposite corners of the image in Ipe coordinates).

The image element is normally empty. However, it is allowed to omit the `bitmap` attribute. In this case, the `<image>` must carry all the attributes of the `<bitmap>` element, with the exception of `id`. The element contents is then the bitmap data, as described for `<bitmap>`.

A.3.3 The `<use>` element

The `<use>` element refers to a symbol (an Ipe object) defined in the style sheet. The attributes `stroke`, `fill`, `pen`, and `size` make sense only when the symbol accepts these parameters.

Attributes

name (required) The name of a `symbol` defined in a style sheet of the document.

pos (optional) Position of the symbol on the page (two real numbers, separated by white space). This is the location of the origin of the symbol coordinate system. The default is the origin.

stroke (optional) A stroke color (used whereever the symbol uses the symbolic color "sym-stroke"). The default is black.

fill (optional) A fill color (used whereever the symbol uses the symbolic color "sym-fill"). The default is white.

pen (optional) A line width (used whereever the symbol uses the symbolic value "sym-pen"). The default is "normal".

size (optional) The size of the symbol, either a symbolic size (of type "symbol size"), or an absolute scaling factor. The default is 1.0.

The `<use>` element must be empty.

A.3.4 The `<text>` element

Attributes

stroke (optional) The stroke color. If the attribute is missing, black will be used.

type (required) Possible values are *label* and *minipage*.

size (optional) The font size—either a symbolic name defined in a style sheet, or a real number. The default is "normal".

pos (required) Two real numbers separated by white space, defining the position of the text on the paper.

width (required for minipage objects, optional for label objects) The width of the object in points.

height (optional) The total height of the object in points.

depth (optional) The depth of the object in points.

valign (optional) Possible values are *top* (default for a minipage object), *bottom* (default for a label object), *center*, and *baseline*.

halign (optional, label only) Possible values are *left*, *right*, and *center*. *left* is the default. This determines the position of the reference point with respect to the text box.

style (optional, minipage only) Selects a LaTeX "style" to be used for formatting the text, and must be a symbolic name defined in a style sheet. The standard style sheet defines the styles "normal", "center", "itemize", and "item". If the attribute is not present, the "normal" style is applied.

opacity (optional) Opacity of the element. This must be a symbolic name. The default is 1.0, meaning fully opaque.

The dimensions are recomputed by Ipe when running LaTeX, with the exception of `width` for minipage objects whose width is fixed.

The contents of the `<text>` element must be a legal LaTeX fragment that can be interpreted by LaTeX inside `\hbox`, possibly using the macros or packages defined in the preamble.

A.3.5 The `<path>` element

Attributes

stroke (optional) The stroke color. If the attribute is missing, the shape will not be stroked.

fill (optional) The fill color. If the attribute is missing, the shape will not be filled.

dash (optional) Either a symbolic name defined in a style sheet, or a dash pattern in PDF format, such as "[3 1] 0" for "three pixels on, one off, starting with the first pixel". If the attribute is missing, a solid line is drawn.

pen (optional) The line width, either symbolic (defined in a style sheet), or as a single real number. The default value is "normal".

cap (optional) The *line cap* setting of PDF as an integer. If the argument is missing, the setting from the style sheet is used.

join (optional) The *line join* setting of PDF as an integer. If the argument is missing, the setting from the style sheet is used.

fillrule (optional) Possible values are `wind` and `eofill`, selecting one of two algorithms for determining whether a point lies inside a filled object. If the argument is missing, the setting from the style sheet is used.

arrow (optional) The value consists of a symbolic name, say "triangle" for an arrow type (a symbol with name "arrow/triangle(spx)"), followed by a slash and the size of the arrow. The size is either a symbolic name (of type "arrowsize") defined in a style sheet, or a real number. If the attribute is missing, no arrow is drawn.

rarrow (optional) Same for an arrow in the reverse direction (at the beginning of the first subpath).

opacity (optional) Opacity of the element. This must be a symbolic name. The default is 1.0, meaning fully opaque.

tiling (optional) A tiling pattern to be used to fill the element. The default is not to tile the element. If the element is not filled, then the tiling pattern is ignored.

gradient (optional) A gradient pattern to be used to fill the element. If the element is not filled, then the gradient pattern is ignored. (The fill color is only used for rendering where gradients are not available, for instance currently in Postscript.) If `gradient` is set, then `tiling` is ignored.

The contents of the `<path>` element is a sequence of path construction operators. The entire shape will be stroked and/or filled with a single stroke and fill operation.

A.4 The `<ipestyle>` element

Attributes

name (optional) The name serves to identify the style sheet informally, and can be used to automatically update the style sheet from a file with the matching name.

The contents of the `<ipestyle>` element is a series of style definition elements, in no particular order. These elements are described below.

A.4.1 The `<symbol>` element

Attributes

name (required) The name identifies the symbol and must be unique in the style sheet. For parameterized symbols, the name must end with the pattern "(s?f?p?x?)", where "s" stands for stroke, "f" for fill, "p" for pen, and "x" for size.

transformations (optional) As for objects.

xform (optional) If this attribute is set, a PDF XForm will be created for this symbol when saving or exporting to PDF. It implies `transformations="translations"`, and will be ignored if any of the symbol parameters (that is, stroke, fill, pen, or size) are used. Setting this attribute will cause the PDF output to be significantly smaller for a complicated symbol that is used often (for instance, a complicated background used on every page).

The contents of the `<symbol>` element is a single Ipe object.

A.4.2 The `<preamble>` element

See the `<preamble>` elements inside `<ipe>` elements.

A.4.3 The `<textstyle>` element

Attributes

name (required) The symbolic name (to be used in the `style` attribute of `<text>` elements),

begin (required) LaTeX code to be placed before the text of the object when it is formatted,

end (required) LaTeX code to be placed after the text of the object when it is formatted.

A.4.4 The `<layout>` element

It defines the layout of the frame on the paper and the paper size.

Attributes

paper (required) The size of the paper.

origin (required) The lower left corner of the frame in the paper coordinate system.

frame (required) The size of the frame.

skip (optional) The default paragraph skip between textboxes.

crop (optional) If the value of `crop` is `yes`, Ipe will create a `CropBox` attribute when saving to PDF.

A.4.5 The `<titlestyle>` element

It defines the appearance of the page title on the page.

Attributes

pos (required) The position of the title reference point in the frame coordinate system.

color (required) The color of the title.

size (required) The title font size (same as for `<text>` elements).

halign (optional) The horizontal alignment (same as for `<text>` elements).

valign (optional) The vertical alignment (same as for `<text>` elements).

A.4.6 The `<pagenumberstyle>` element

It defines the appearance of page numbers on the page.

Attributes

pos (required) The position of the page number on the page.

color (required) The color of the page number as an absolute color.

size (required) The font size as a number.

A.4.7 The `<textpad>` element

It defines padding around text objects for the computation of bounding boxes. The four required attributes are `left`, `right`, `top`, and `bottom`.

A.4.8 The `<pathstyle>` element

It defines the default setting for path objects.

Attributes

cap (optional) Same as for `<path>` elements.

join (optional) Same as for `<path>` elements.

fillrule (optional) Same as for `<path>` elements.

A.4.9 The `<opacity>` element

The `opacity` element defines a possible opacity value (also known as an alpha-value). All opacity values used in a document must be defined in the style sheet.

Attributes

name (required) A symbolic name, to be used in the `opacity` attribute of a `text` or `path` element.

value (required) An absolute value for the opacity, between 0.001 and 1.000. A value of 1.0 implies that the element is fully opaque.

A.4.10 The `<gradient>` element

The `gradient` element defines a gradient pattern.

Attributes of `<gradient>`

name (required) The symbolic name (to be used in the `gradient` attribute of `<path>` elements).

type (required) Possible values are `axial` and `radial`.

extend (optional) `yes` or `no` (the default). Indicates whether the gradient is extended beyond the boundaries.

coords (required) For axial shading: the coordinates of the endpoints of the axis (in the order `x1 y1 x2 y2`). For radial shading: the center and radius of both circles (in the order `cx1 cy1 r1 cx2 cy2 r2`).

matrix (optional) A transformation that transforms the gradient coordinate system into the coordinate system of the path object using the gradient. The default is the identity matrix.

The contents of the `<gradient>` element are `<stop>` elements defining the color stops of the gradient. There must be at least two stops. Stops must be defined in increasing offset order. It is not necessary that the first offset is 0.0 and the last one is 1.0.

Attributes of `<stop>`

offset (required) Offset of the color stop (a number between 0.0 and 1.0).

color (required) Color at this color stop (three numbers). Symbolic names are not allowed.

A.4.11 The `<tiling>` element

The `tiling` element defines a tiling pattern. Only very simple patterns that hatch the area with a line are supported.

Attributes

name (required) The symbolic name (to be used in the `tiling` attribute of `<path>` elements).

angle (required) Slope of the hatching line in degrees, between -90 and +90 degrees.

width (required) Width of the hatching line.

step (required) Distance from one hatching line to the next.

Here, `width` and `step` are measured in the y-direction if the absolute value of `angle` is less than 45 degrees, and in the y-direction otherwise.

A.4.12 The `<effect>` element

The `effect` element defines a graphic effect to be used during a PDF page transition. Acrobat Reader supports these effects, but not all PDF viewers do.

Attributes

name (required) The symbolic name (to be used in the `effect` attribute of `<view>` elements).

duration (required) Value must be a real number, indicating the duration of display in seconds.

transition (required) Value must be a real number, indicating the duration of the transition effect in seconds.

effect (required) a number indicated the desired effect. The value must be an integer between 0 and 16 (see `ipe::Effect::TEffect` for the exact meaning).

A.4.13 Other style definition elements

The remaining style definition elements are:

- `<color>` Defines a symbolic color. The value must be an absolute color, that is either a single gray value (between 0 and 1), or three components (red, green, blue) seperated by space.
- `<dashstyle>` Defines a symbolic dashstyle. The value must be a correct dashstyle description, e.g. `[3 5 2 5] 0`.
- `<pen>` Defines a symbolic pen width. The value is a single real number.
- `<textsize>` Defines a symbolic text size. The value is a piece of LaTeX source code selecting the desired font size.
- `<textstretch>` Defines a symbolic text stretch factor. The symbolic name is shared with `<textsize>` elements. The value is a single real number.
- `<symbolsize>` Defines a symbolic size for symbols. The value is a single real number, and indicates the scaling factor used for the symbol.
- `<arrowsize>` Defines a symbolic size for arrows. The value is a single real number.
- `<gridsize>` Defines a grid size. The symbolic name cannot actually be used by objects in the document — it is only used to fill the grid size selector in the user interface.
- `<anglesize>` Defines an angular snap angle. The symbolic name cannot actually be used by objects in the document — it is only used to fill the angle selector in the user interface.

Common attributes

name (required) A symbolic name, which must start with a letter 'a' to 'z' or 'A' to 'Z'.

value (required) A legal absolute value for the type of attribute.

B Using Ipe figures in Latex

If—like many Latex users nowadays—you are a user of Pdflatex you can include Ipe figures in PDF format in your Latex documents directly.

The standard way of including PDF figures is using the `graphicx` package. If you are not familiar with it, here is a quick overview. In the preamble of your document, add the declaration:

```
\usepackage{graphicx}
```

One useful attribute to this declaration is `draft`, which stops LaTeX from actually including the figures—instead, a rectangle with the figure filename is shown:

```
\usepackage[draft]{graphicx}
```

To include the figure "figure1.pdf, you use the command:

```
\includegraphics{figs/figure1}
```

Note that it is common *not* to specify the file extension ".pdf". The command `\includegraphics` has various options to scale and rotate the figure. For instance, to scale the same figure to 50%, use:

```
\includegraphics[scale=0.5]{figs/figure1}
```

To scale such that the width of the figure becomes 5 cm:

```
\includegraphics[width=5cm]{figs/figure1}
```

Instead, one can specify the required height with `height`.

Here is an example that scales a figure to 200% and rotates it by 45 degrees counter-clockwise. Note that the scale argument should be given *before* the `angle` argument.

```
\includegraphics[scale=2,angle=45]{figs/figure1}
```

Let's stress once again that these commands are the standard commands for including PDF figures in a LaTeX document. Ipe files neither require nor support any special treatment. If you want to know more about the LaTeX packages for including graphics and producing colour, check the `grfguide.tex` document that is probably somewhere in your TeX installation.

There is a slight complication here: Each page of a PDF document can carry several "bounding boxes", such as the *MediaBox* (which indicates the paper size), the *CropBox* (which indicates how the paper will by cut), or the *ArtBox* (which indicates the extent of the actual contents of the page). Ipe automatically saves, for each page, the paper size in the *MediaBox*, and a bounding box for the drawing in the *ArtBox*. Ipe also puts the bounding box in the *CropBox* unless this has been turned off by the stylesheet.

Now, when including a PDF figure, Pdflatex will (by default) first look at the CropBox, and, if that is not set, fall back on the MediaBox. It does not inspect the ArtBox, and so it is important that you use the correct stylesheet for the kind of figure you are making—with cropping for figures to be included, without cropping for presentations (as otherwise Acrobat Reader will not display full pages—Acrobat Reader actually crops each page to the CropBox).

If you have a recent version of Pdflatex (1.40 or higher), you can actually ask Pdflatex to inspect the ArtBox by saying `\pdfpagebox5` in your Latex file's preamble.

If you are still using the "original" Latex, which compiles documents to DVI format, you need figures in Encapsulated Postscript (EPS) format (the "Encapsulated" means that there is only a single Postscript page and that it contains a bounding box of the figure). Some publishers may also require that you submit figures in EPS format, rather than in PDF.

Ipe allows you to export your figure in EPS format, either from the Ipe program (*File* menu, *Export as EPS*), or by using the command line tool *iperender* with the `-eps` option. Remember to keep a copy of your original Ipe figure! Ipe cannot read the exported EPS figure, you will not be able to edit thema any further.

Including EPS figures works exactly like for PDF figures, using `\includegraphics`. In fact you can save all your figures in both EPS and PDF format, so that you can run both Latex and Pdflatex on your document—when including figures, Latex will look for the EPS variant, while Pdflatex will look for the PDF variant. (Here it comes in handy that you didn't specify the file extension in the `\includegraphics` command.)

It would be cumbersome to have to export to EPS every time you modify and save an Ipe figure in PDF format. What you should do instead is to write a shell script or batch file that calls iperender to export to EPS.

On the other hand, if you *only* use Pdflatex, you might opt to exploit a feature of Pdflatex: You can keep all the figures for a document in a single, multi-page Ipe document, with one figure per page. You can then include the figures one by one into your document by using the `page` argument of `\includegraphics`.

For example, to include page 3 from the PDF file "figures.pdf" containing several figures, you could use

```
\includegraphics[page=3]{figures}
```

C The command line programs

C.1 Ipe

Ipe supports the following command line options:

`-sheet` ***style sheet name*** Adds the designated style sheet to any newly created documents.

`-show-configuration` With this option, Ipe will display the current configuration options on stdout, and terminate.

In addition, you can specify the name of an Ipe file to open on the command line.

C.2 Ipetoipe: converting Ipe file formats

The auxiliary program *ipetoipe* converts between the different Ipe file formats:

```
ipetoipe ( -xml | -pdf ) { <options> } infile [ outfile ]
```

The first argument determines the format of the output file. If no output filename is provided, Ipe will try to guess it by appending one of the extensions "ipe" or "pdf" to the input file's basename.

For example, the command line syntax

```
ipetoipe -pdf figure1.ipe
```

converts *figure1.ipe* to *figure1.pdf*.

Ipetoipe understands the following options:

`-export`
: No Ipe markup is included in the resulting output file. Ipe will not be able to open a file created that way, so make sure you keep your original!

`-markedview` (PDF only)
Only the marked views of marked Ipe pages will be created in PDF format. If all views of a marked page are unmarked, the last view is exported. This is convenient to make handouts for slides.

`-pages` **from-to** (PDF only)
Restrict exporting to PDF to this page range. This implies the `-export` option.

`-view` **page-view**
Only export this single view from the document. This implies the `-export` option.

`-runlatex` Run Latex even for XML output. This has the effect of including the dimensions of each text object in the XML file.

`-nozip` Do not compress streams in PDF output.

C.3 Iperender: exporting to a bitmap, EPS, or SVG

The program *iperender* exports a page of the document to a bitmap in PNG format, to a figure in Encapsulated Postscript (EPS), or to scalable vector graphics in SVG format. (Of course the result contains no Ipe markup, so make sure you keep your original!) For instance, the following command line

```
iperender -png -page 3 -resolution 150 presentation.pdf pres3.png
```

converts page 3 of the Ipe document `presentation.pdf` to a bitmap, with resolution 150 pixels per inch.

C.4 Ipeextract: extract XML stream from Ipe file

Ipeextract extracts the XML stream from an PDF or EPS file made by Ipe 6 or 7 and saves it in a file. It will work even if Ipe cannot actually parse the file, so you can use this tool to debug problems where Ipe fails to open your document.

```
ipeextract infile [ outfile ]
```

If not provided, the outfile is guessed by appending "xml" to the infile's basename.

C.5 Ipe6upgrade: convert Ipe 6 files to Ipe 7 file format

Ipe6upgrade takes as input a file created by any version of Ipe 6, and saves in the format of Ipe 7.0.0.

```
ipe6upgrade infile [ outfile ]
```

If not provided, the outfile is guessed by adding the extension "ipe" to the infile's basename.

To reuse an Ipe 6 document in EPS or PDF format, you first run "ipeextract", which extracts the XML stream inside the document and saves it as an XML file. The Ipe 6 XML document can then be converted to Ipe 7 format using "ipe6upgrade".

If your old figure is *figure.pdf*, then the command

```
ipeextract figure.pdf
```

will save the XML stream as *figure.xml*. Then run

```
ipe6upgrade figure.xml
```

which will save your document in Ipe 7 format as *figure.ipe*. All contents of the original document should have been preserved.

C.6 Ipescript: running Ipe scripts

Ipescript runs an Ipe script written in the Lua language with bindings for the Ipe objects, such as the script "update-master". Ipescript automatically finds the script in Ipe's script directories. On Unix, you can place your own scripts in *$HOME/.ipe/scripts*.

The Ipe distribution contains the following scripts:

- *update-master*, explained earlier Section 8.1;
- *add-style* to add a stylesheet to Ipe figures;
- *update-styles* to update the stylesheets in Ipe figures (in the same way that Ipe does it using the "Update stylesheets" function).

C.7 Importing other formats

Svgtoipe: Importing SVG figures The auxiliary program *svgtoipe* converts an SVG figure to Ipe format. It cannot handle all SVG features (many SVG features are not supported by Ipe anyway), but it works for gradients.

svgtoipe is not part of the Ipe source distribution. You can download it separately.

Pdftoipe: Importing Postscript and PDF You can convert arbitrary Postscript or PDF files into Ipe documents, making them editable. The auxiliary program *pdftoipe* converts (pages from) a PDF file into an Ipe XML-file. (If your source is Postscript, you have to first convert it to PDF using Acrobat Distiller or *ps2pdf*.) Once converted to XML, the file can be opened from Ipe as usual.

The conversion process should handle any graphics in the PDF file fine, but doesn't do very well on text—Ipe's text model is just too different.

pdftoipe is not part of the Ipe source distribution. You can download and build it separately.

Ipe5toxml: convert Ipe 5 files to Ipe 6 file format If you still have figures that were created with Ipe 5, you can use *ipe5toxml* to convert them to Ipe 6 format. You can then use *ipe6upgrade* to convert them to Ipe 7 format.

ipe5toxml is not part of the Ipe distribution, but available as a separate download.

Figtoipe: Importing FIG figures The auxiliary program *figtoipe* converts a figure in FIG format into an Ipe XML-file. This is useful if you used to make figures with Xfig before discovering Ipe, of if your co-authors made figures for your article with Xfig (converting them will have the added benefit of forcing your co-authors to learn to use Ipe). Finally, there are quite a number of programs that can export to FIG format, and *figtoipe* effectively turns that into the possibility of exporting to Ipe.

However, *figtoipe* is not quite complete. The drawing models of FIG and Ipe are also somewhat different, which makes it impossible to properly render some FIG files in Ipe. Ipe does not support depth ordering independent of grouping, pattern fill, and Postscript fonts. You may therefore have to edit the file after conversion.

figtoipe is not part of the Ipe distribution. You can download and build it separately. *figtoipe* is now maintained by Alexander Bürger.

D History and acknowledgments

The name "Ipe" is older than the program itself. When I made figures for my papers using Idraw in 1992, I was annoyed that I had to store two versions of each figure: one with Latex text, one with

Postscript information. I came up with a file format that I called "Ipe", for "Integrated Picture Environment", and which was at the same time legal Latex source code and a legal Postscript file.

When I wrote the first version of Ipe at Utrecht University in the summer of 1993, it created this file format directly, and inherited the name. The first versions of Ipe (Ipe 2.0 up to 4.1) were based on my experiences with Idraw, XFig, and Jean-Pierre Merlet's JPDraw, used IRIS-GL and Mark Overmars' FORMS library, and run on SGI workstations only.

Due to popular demand, I spent two weeks in the summer of 1994 to teach myself Motif and to rewrite Ipe to run under the X window system. Unfortunately, two weeks were really not enough, and the 1994 X-version of Ipe was somewhat of a hack. I didn't have time to port the code that displayed bitmaps on the screen, it crashed on both monochrome and truecolor (24-bit) displays, and was in general quite unmaintainable.

These versions of Ipe were supported by the Netherlands' Organization for Scientific Research (NWO), and I would never have started working on it without Geert-Jan Giezeman's PLAGEO library. For testing, support, and inspiration in that original period, I'm grateful to Mark de Berg, Maarten Pennings, Jules Vleugels, Vincenzo Ferrucci, and Anil Rao. Many students of the department at Utrecht University served as alpha-testers (who apparently referred to Ipe as "the cute little core-dumper").

I gave a presentation about Ipe at the Dagstuhl Workshop on Computational Geometry in 1995, and made a poster presentation at the ACM Symposium on Computational Geometry in Vancouver in the same year. Both served to create a small but faithful community of Ipe addicts within the Computational Geometry community.

Ipe proved itself invaluable to me over the years, especially when we used it to make all the illustrations in our book "Computational Geometry: Theory and Applications" (Springer 1997, with Mark de Berg, Marc van Kreveld, and Mark Overmars). Nevertheless, the problems were undeniable: It was hard to compile Ipe on other C++ compilers and it only worked on 8-bit displays. It was only due to the efforts of Ipe fans such as Tycho Strijk, Robert-Paul Berretty, Alexander Wolff, and Sariel Har-Peled that the 1994 version of Ipe continued to be used until 2003.

I was teaching myself C++ while writing the first version of Ipe, and it showed—Ipe 5 was full of elementary object-oriented design mistakes. When teaching C++ to second-year students at Postech in 1996 I started to think about a clean rewrite of Ipe. My first notes on such a rewrite stem from evenings spent at a hotel in Machida, close to IBM Tokyo in July 1996 (the idea at that time was to embed Ipe into Emacs!). It proved impossible, though, to do a full rewrite next to teaching and research, and nothing really happened until the Dagstuhl Workshop on Computational Geometry in 2001, where Christian Knauer explained to me how to use Pdflatex to create presentations. I realized that PDF was ideally suited for a new version of Ipe.

Ipe 5 figures were at the same time Latex and Postscript files, and required special handling to be included into Latex documents, which sometimes required a bit of explaining when talking to co-authors or publishers. While editing a figure, Ipe 5 kept a Ghostscript window open that would show what the figure looked like after processing by Latex.

Several developments that had happened between 1993 and 2001 allowed me to use a completely new approach: First, Hàn Thê Thàn's Pdflatex takes Latex source and directly produces a PDF file with a PDF representation of the text and all necessary fonts. Second, Derek Noonburg's Xpdf contained an open-source PDF parser that I could use to parse this PDF representation and to extract the processed text and fonts. Third, all relevant Latex fonts are now available as scalable Type1 fonts, and so it is possible to embed Latex text and formulas in figures that may still need to be scaled later. Finally, the Ghostscript window was no longer necessary as Ipe could use the beautiful Freetype library to directly display the text on-screen as it will appear on paper.

Directly after the Dagstuhl workshop I implemented a proof-of-concept: I defined the Ipe XML format (there was no question that Ipe 6 would have to be able to communicate in XML, of course), wrote "ipe5toxml" (reusing my old Ipe parsing code) and a program that runs Pdflatex, parses its PDF output, extracts text objects and font data, and creates a PDF file for the whole Ipe figure.

All that remained to be done was to rewrite the user interface. Mark de Berg and the TU

Eindhoven made it possible for me to take some time off from teaching and research. The final design changes were made during the Second McGill-INRIA Workshop on Computational Geometry in Computer Graphics at McGill's Bellairs Research Institute in February 2003, and much inspiration was due to the atmosphere at the workshop and the magnificient cooking by Gwen, Bellair's chef. An early preview of Ipe 6.0 was "formally" released at the Dagstuhl Workshop on Computational Geometry in March 2003, to celebrate the Dagstuhl influence on Ipe.

Other than the file format, there weren't really that many changes to Ipe's functionality between Ipe 5 and Ipe 6. René van Oostrum insisted that no self-respecting drawing program can do without style sheets and layers. Views allow you to incrementally build up a page in a PDF presentation.

I also revised the interface to ipelets (which used to be called "Iums" in the good old days when people still thought that "applets" were small apples)—it is now based on dynamically loaded libraries (a technology that was still somewhat poorly understood in the early nineties, at least by me).

And, of course, there was a Windows version of Ipe 6. Who would have thought that ten years earlier!

There were many releases of Ipe 6.0, all of them called "previews", because I never considered that I had reached a stable state. A number of experimental features were tried and either built into Ipe or discarded. Ipe 6 migrated from Qt 2 and Qt 3 to Qt 4, a somewhat painful process due to a number of annyoing Qt bugs that cost me a lot of time.

When in 2007 I discovered the fantastic Cairo library for rendering, I immediately decided to switch Ipe to use this: a small dedicated library with a nice API to do the rendering, instead of the buggy monster that was Qt. The Cairo API fit Ipe so well that I could write a Cairo painter for Ipe in an hour or so. Cairo supports Freetype directly, instead of Ipe having to render each glyph into a bitmap that is then blit onto the canvas.

I made the huge mistake of announcing on the Ipe discussion list that Ipe 6.0 preview 28 was the last version of Ipe 6, and that there would soon be a new version, Ipe 7. I should have known that this was impossible during a time where I advised several graduate students, taught several new courses, and went through the tenure process. I had to release several bugfix releases of Ipe 6 while really wanting to work on Ipe 7.

However, the delay left me with enough time to carefully think about another change I wanted to make: It would be nice if Ipe embedded a scripting language that could be used to write simple ipelets without compilation. I looked at Scheme/Guile, Python, and Lua, and finally decided for Lua: a small, elegant, stable language with a tiny footprint, easily embedded with a very nice C interface.

In 2009, I had my first sabbatical ever, which I spent in the group of Ulrik Brandes at the University of Konstanz. Here I finally had the time to work on Ipe 7, and I'm very grateful to Ulrik and all members of his group for the wonderful time I had in Konstanz. Next to the two big changes mentioned above, Ipe 7 introduced tiling patterns, gradients, clipping paths, transparency, user-definable arrows and marks, and SVG output.

I wanted to avoid Qt in Ipe 7 as it had caused me quite a bit of pain during the life of Ipe 6, but it was hard to find a good replacement that would allow Ipe to run on Linux, Windows, and Macs. During the Korean Workshop on Computational Geometry organized by Tetsuo Asano at Hakusan seminar house in June 2009, I discussed using Ipe on tablet PCs with Vida Dujmovic, Jit Bose, and Stefan Langerman. It is their fault that Ipe 7 comes with a tablet input tool, and finally Stefan and Sébastien Collette convinced me that there isn't really an alternative to Qt that has the same support for tablets and Macs. So Ipe 7 is still using Qt, but in a much more restricted way than before, and hopefully much less sensitive to bugs in Qt.

E Copyright

Ipe is "free," this means that everyone is free to use it and free to redistribute it on certain conditions. Ipe is not in the public domain; it is copyrighted and there are restrictions on its distribution as follows:

[4] at `http://www.gnu.org/copyleft/gpl.html`

Contents