Making Pictures With GNU PIC

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ABSTRACT

The **pic** language is a **troff** extension that makes it easy to create and alter box-and-arrow diagrams of the kind frequently used in technical papers and textbooks. This paper is both an introduction to and reference for *gpic*(1), the implementation distributed by the Free Software Foundation for use with *groff*(1). It also catalogs other implementations and explains the differences among them.

1. Introduction to PIC

1.1. Why PIC?

The **pic** language provides an easy way to write procedural box-and-arrow diagrams to be included in **troff** documents. The language is sufficiently flexible to be quite useful for state charts, Petri-net diagrams, flow charts, simple circuit schematics, jumper layouts, and other kinds of illustration involving repetitive uses of simple geometric forms and splines. Because these descriptions are procedural and object-based, they are both compact and easy to modify.

The phrase "GNU pic" may refer to either of two **pic** implementations distributed by the Free Software Foundation and intended to accept the same input language. The *gpic*(1) implementation is for use with the *groff*(1) implementation of **troff**. The *pic2plot*(1) implementation runs standalone and is part of the **plotutils** package. Because both implementations are widely available in source form for free, they are good bets for writing very portable documentation.

1.2. PIC Versions

The original 1984 pre-*ditroff*(1) version of **pic** is long obsolete. The rewritten 1991 version is still available as part of the Documenter's Work Bench module of System V.

Where differences between Documenter's Work Bench (1991) **pic** and GNU **pic** need to be described, original **pic** is referred to as "DWB pic". Details on the history of the program are given at the end of this document.

The **pic2plot** program does not require the rest of the *groff*(1) toolchain to render graphics. It can display **pic** diagrams in an X window, or generate output plots in a large number of other formats. These formats include: PNG, PBM, PGM, PPM, GIF, SVG, Adobe Illustrator format, idraw-editable Postscript, the WebCGM format for Web-based vector graphics, the format used by the **xfig** drawing editor, the Hewlett-Packard PCL 5 printer language, the Hewlett-Packard Graphics Language (by default, HP-GL/2), the ReGIS (remote graphics instruction set) format developed by DEC, Tektronix format, and device-independent GNU graphics metafile format.

In this document, *gpic*(1) and *pic2plot*(1) extensions are marked as such.

2. Invoking PIC

Every **pic** description is a little program describing drawing actions. The **[gtn]roff**-dependent versions compile the program by *pic*(1) into *gtroff*(1) macros; the *pic2plot*(1) implementation uses a plotting library to draw the picture directly. Programs that process or display *gtroff*(1) output need not know or care that parts of the image began life as **pic** descriptions.

The *pic*(1) program tries to translate anything between **.PS** and **.PE** markers, and passes through everything else. The normal definitions of **.PS** and **.PE** in the *ms* macro package and elsewhere have also the side-effect of centering the **pic** output on the page.

2.1. PIC Error Messages

If you make a mistake in **pic** input such that the program cannot interpret what you mean, *gpic*(1) issues a diagnostic message in the format prescribed by the GNU Coding Standards. A typical error message looks like

```
pic:file:nnn: syntax error before 'token'
pic:file:nnn: giving up on this picture
```

where *file* is the name of the file being processed, *nnn* is a line number within that file, and *token* is a symbol in the **pic** language (often a keyword) near (usually just after) the error location.

3. Basic PIC Concepts

Pictures are described procedurally, as collections of objects connected by motions. Normally, **pic** tries to string together objects left-to-right in the sequence they are described, joining them at visually natural points. Here is an example illustrating the flow of data in **pic** processing:

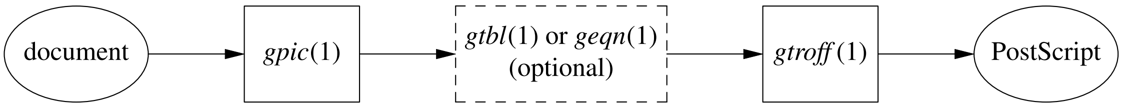


Figure 3-1: Flow of **pic** data

This was produced from the following **pic** program:

```
.PS
ellipse "document";
arrow;
box width 0.6 "\fIgpic\/\fP(1)"
arrow;
box width 1.1 "\fIgtbl\/\fP(1) or \fIgeqn\/\fP(1)" "(optional)" dashed;
arrow;
box width 0.6 "\fIgtroff\/\fP(1)";
arrow;
ellipse "PostScript"
.PE
```

This little program illustrates several **pic** basics. Firstly, we see how to invoke three object types; ellipses, arrows, and boxes. We see how to declare text lines to go within an object (and that text can have font changes in it). We see how to change the line style of an object from solid (the default) to dashed. And we see that a box can be made wider than its default size to accommodate more text (we'll discuss this facility in detail in the next section).

We also get to see **pic**'s simple syntax. Statements are ended by newlines or semicolons. String quotes are required around all text arguments, whether or not they contain spaces. In general, the order of command arguments and modifiers like “width 1.2” or “dashed” doesn't matter, except that the order of text arguments is significant.

Here are all but two of the basic **pic** objects at their default sizes:

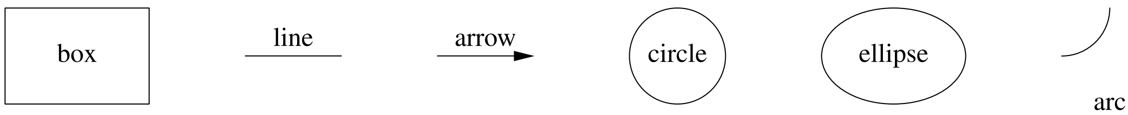


Figure 3-2: Basic **pic** objects

The missing simple object types are *spline* and *polygon*. There is also a way to collect objects into *block composites* which allows you to treat the whole group as a single object (resembling a box) for many purposes. We'll describe all of these later on.

The box, ellipse, circle, and block composite objects are *closed*; lines, arrows, arcs and splines are *open*. Polygons are a special case drawn using the syntax of open objects, but with most of the attributes of closed objects. This distinction is often important in explaining command modifiers.

Figure 3-2 was produced by the following **pic** program, which introduces some more basic concepts:

```
.PS
box "box";
move;
line "line" "";
move;
arrow "arrow" "";
move;
circle "circle";
move;
ellipse "ellipse";
move;
arc; down; move; "arc"
.PE
```

The first thing to notice is the *move* command, which moves a default distance (1/2 inch) in the current movement direction.

Secondly, see how we can also decorate lines and arrows with text. The line and arrow commands each take two arguments here, specifying text to go above and below the object. If you wonder why one argument would not do, contemplate the output of **arrow "ow!"**:

Figure 3-3: Text centered on an arrow

When a command takes one text string, **pic** tries to place it at the object's geometric center. As you add more strings, **pic** treats them as a vertical block to be centered. The program

```
line "1";
line "1" "2";
line "1" "2" "3";
line "1" "2" "3" "4";
line "1" "2" "3" "4" "5";
```

for example, gives you this:

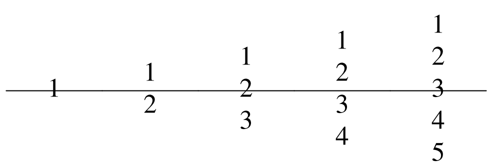


Figure 3-4: Effects of multiple text arguments

The last line of Figure 3-2's program, '**arc; down; move; "arc"**', describing the captioned arc, introduces several new ideas. Firstly, we see how to change the direction in which objects are joined. Had we written **arc; move; "arc"**, omitting **down** the caption would have been joined to the top of the arc, like this:

Figure 3-5: Result of **arc; move; "arc"**

This is because drawing an arc changes the default direction to the one its exit end points at. To reinforce this point, consider:

Figure 3-6: Result of **arc cw; move; "arc"**

All we've done differently here is specify "cw" for a clockwise arc ("ccw" specifies counter-clockwise direction). Observe how it changes the default direction to down, rather than up.

Another good way to see this via with the following program:

```
line; arc; arc cw; line
```

which yields:

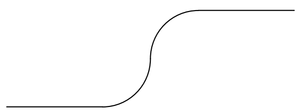


Figure 3-7: Result of **line; arc; arc cw; line**

Notice that we did not have to specify "up" for the second arc to be joined to the end of the first.

Finally, observe that a string, alone, is treated as text to be surrounded by an invisible box of a size either specified by width and height attributes or by the defaults **textwid** and **textht**. Both are initially zero (because we don't know the default font size).

4. Sizes and Spacing

Sizes are specified in inches. If you don't like inches, it's possible to set a global style variable **scale** that changes the unit. Setting **scale = 2.54** effectively changes the internal unit to centimeters (all other size variable values are scaled correspondingly).

4.1. Default Sizes of Objects

Here are the default sizes for **pic** objects:

Object	**Default Size**
box	0.75" wide by 0.5" high
circle	0.5" diameter
ellipse	0.75" wide by 0.5" high
arc	0.5" radius
line	0.5" long
arrow	0.5" long

The simplest way to think about these defaults is that they make the other basic objects fit snugly into a default-sized box.

pic2plot(1) does not necessarily emit a physical inch for each virtual inch in its drawing coordinate system. Instead, it draws on a canvas 8 virtual inches by 8 virtual inches wide. If its output page size is “letter”, these virtual inches will map to real ones. Specifying a different page size (such as, say, “a4”) will scale virtual inches so they are output as one eighth of the page width. Also, *pic2plot*(1) centers all images by default, though the **−n** option can be used to prevent this.

4.2. Objects Do Not Stretch!

Text is rendered in the current font with normal troff line spacing. Boxes, circles, and ellipses do *not* automatically resize to fit enclosed text. Thus, if you say **box "this text far too long for a default box"** you’ll get this:

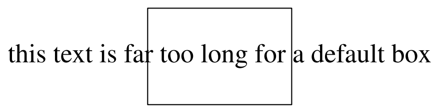


Figure 4-1: Boxes do not automatically resize

which is probably not the effect you want.

4.3. Resizing Boxes

To change the box size, you can specify a box width with the “width” modifier:

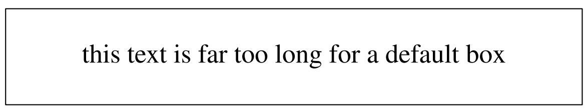


Figure 4-2: Result of **box width 3 "text far too long"**

This modifier takes a dimension in inches. There is also a “height” modifier that changes a box’s height. The **width** keyword may be abbreviated to **wid**; the **height** keyword to **ht**.

4.4. Resizing Other Object Types

To change the size of a circle, give it a **rad[ius]** or **diam[eter]** modifier; this changes the radius or diameter of the circle, according to the numeric argument that follows.

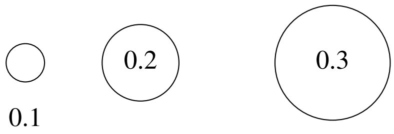


Figure 4-3: Circles with increasing radii

The **move** command can also take a dimension, which just tells it how many inches to move in the current direction.

Ellipses are sized to fit in the rectangular box defined by their axes, and can be resized with **width** and **height** like boxes.

You can also change the radius of curvature of an arc with **rad[ius]** (which specifies the radius of the circle of which the arc is a segment). Larger values yield flatter arcs.

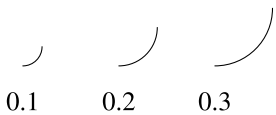


Figure 4-4: **arc rad** with increasing radii

Observe that because an arc is defined as a quarter circle, increasing the radius also increases the size of the arc's bounding box.

4.5. The 'same' Keyword

In place of a dimension specification, you can use the keyword **same**. This gives the object the same size as the previous one of its type. As an example, the program

```
.PS
box; box wid 1 ht 1; box same; box
.PE
```

gives you

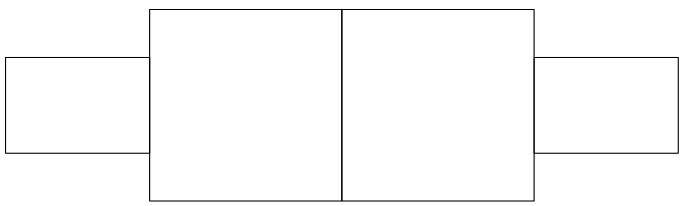
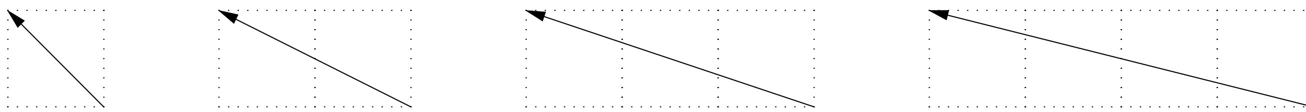


Figure 4-5: The **same** keyword

5. Generalized Lines and Splines

5.1. Diagonal Lines

It is possible to specify diagonal lines or arrows by adding multiple **up**, **down**, **left**, and **right** modifiers to the line object. Any of these can have a multiplier. To understand the effects, think of the drawing area as being gridded with standard-sized boxes.



arrow up left 0.5 **arrow up left 1** **arrow up left 1.5** **arrow up left 2**

Figure 5-1: Diagonal arrows (dotted boxes show the implied 0.5-inch grid)

5.2. Multi-Segment Line Objects

A “line” or “arrow” object may actually be a path consisting of any number of segments of varying lengths and directions. To describe a path, connect several line or arrow commands with the keyword **then**.

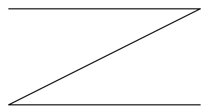
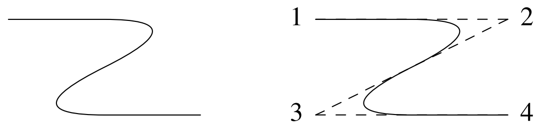


Figure 5-2: **line right 1 then down .5 left 1 then right 1**

If a path starts with **then**, the first segment is assumed to be into the current direction, using the default length.

5.3. Spline Objects

If you start a path with the **spline** keyword, the path vertices are treated as control points for a spline curve fit.



The spline curve... ...with tangents displayed

Figure 5-3: **spline right 1 then down .5 left 1 then right 1**

You can describe many natural-looking but irregular curves this way. For example:

spline right then up then left then down ->; **spline left then up right then down right ->;**

Figure 5-4: Two more spline examples

Note the arrow decorations. Arrowheads can be applied naturally to any path-based object, line or spline. We’ll see how in the next section.

5.4. Polygon Objects

GNU **gpic** supports arbitrary polygons constructed with the same syntax as multi-segment lines. The final line segment connecting back to the starting point is included automatically and should be omitted.

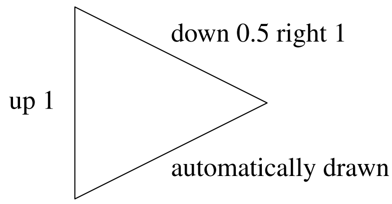


Figure 5-5: **polygon up 1 then down 0.5 right 1**

Polygons are decorated like closed objects as described in the next section.

6. Decorating Objects

6.1. Text Special Effects

All **pic** implementations support the following font-styling escapes within text objects:

\fR, \f1 Set Roman style (the default)

\fI, \f2 Set Italic style

\fB, \f3 Set Bold style

\fP Revert to previous style; only works one level deep, does not stack.

In the **pic** implementations that are preprocessors for a toolchain that include **[gtn]roff**, text objects may also contain **[gtn]roff** vertical- and horizontal-motion escapes such as \h or \v. Troff special glyphs are also available. All \-escapes will be passed through to the postprocessing stage and have their normal effects. The base font family is set by the **[gtn]roff** environment at the time the picture is rendered.

pic2plot replaces **[gtn]roff** horizontal- and vertical-motion escapes with \-escapes of its own. Troff special glyphs are not available, but in most back ends Latin-1 special characters and a square-root radical will be. See the **pic2plot** documentation for full details.

6.2. Dashed Objects

We've already seen that the modifier **dashed** can change the line style of an object from solid to dashed. GNU **gpic** permits you to dot or dash ellipses, circles, and arcs (and splines in TEX mode only); some versions of DWB may only permit dashing of lines and boxes. It's possible to change the dash interval by specifying a number after the modifier.

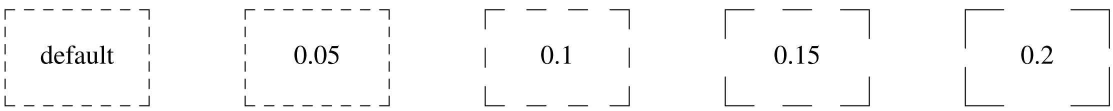


Figure 6-1: Dashed objects

6.3. Dotted Objects

Another available qualifier is **dotted**. GNU **gpic** permits you to dot or dash ellipses, circles, and arcs (and splines in TEX mode only); some versions of DWB may only permit dashing of lines and boxes. It too can be suffixed with a number to specify the interval between dots:

Figure 6-2: Dotted objects

6.4. Rounding Box Corners

It is also possible, in GNU **gpic** only, to modify a box so it has rounded corners:

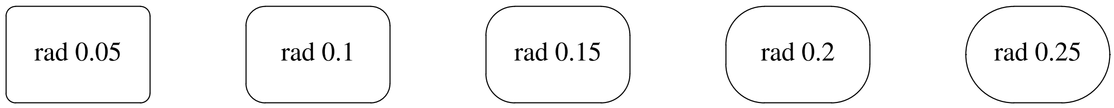


Figure 6-3: **box rad** with increasing radius values

Radius values higher than half the minimum box dimension are silently truncated to that value.

6.5. Slanted Boxes

GNU **gpic** supports slanted boxes:

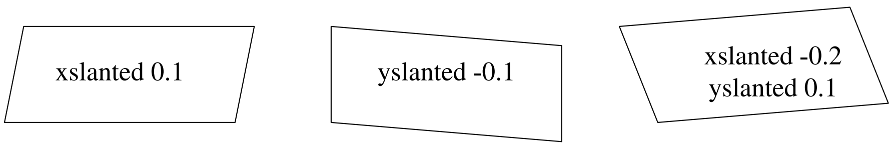


Figure 6-4: Various slanted boxes.

The **xslanted** and **yslanted** attributes specify the x and y offset, respectively, of the box's upper right corner from its default position.

6.6. Arrowheads

Lines and arcs can be decorated as well. Any line or arc (and any spline as well) can be decorated with arrowheads by adding one or more as modifiers:

Figure 6-5: Double-headed line made with **line <- ->**

In fact, the **arrow** command is just shorthand for **line ->**. And there is a double-head modifier <->, so the figure above could have been made with **line <->**.

Arrowheads have a **width** attribute, the distance across the rear; and a **height** attribute, the length of the arrowhead along the shaft.

Arrowhead style is controlled by the style variable **arrowhead**. The DWB and GNU versions interpret it differently. DWB defaults to open arrowheads and an **arrowhead** value of 2; the Kernighan paper says a value of 7 makes solid arrowheads. GNU **gpic** defaults to solid arrowheads and an **arrowhead** value of 1; a value of 0 produces open arrowheads. Note that solid arrowheads are always filled with the current outline color.

6.7. Line Thickness

It's also possible to change the line thickness of an object (this is a GNU extension, DWB **pic** doesn't support it). The default thickness of the lines used to draw objects is controlled by the **linethick** variable. This gives the thickness of lines in points. A negative value means use the default thickness: in TEX output mode, this means use a thickness of 8 milliinches; in TEX output mode with the **-c** option, this means use the line thickness specified by **.ps** lines; in troff output mode, this means use a thickness proportional to the pointsize. A zero value means draw the thinnest possible line supported by the output device. Initially it has a value of -1. There is also a **thickness** attribute (which can be abbreviated to **thick**). For example, **circle thickness 1.5** would draw a circle using a line with a thickness of 1.5 points. The thickness of lines is not affected by the value of the **scale** variable, nor by any width or height given in the **.PS** line.

6.8. Invisible Objects

The modifier **invis[ible]** makes an object entirely invisible. This used to be useful for positioning text in an invisible object that is properly joined to neighboring ones. Newer DWB versions and GNU **pic** treat stand-alone text in exactly this way.

6.9. Filled Objects

It is possible to fill boxes, circles, ellipses, and polygons. The modifier **fill[ed]** accomplishes this. You can suffix it with a fill value; the default is given by the style variable **fillval**.

DWB **pic** and **gpic** have opposite conventions for fill values and different defaults. DWB **fillval** defaults to 0.3 and smaller values are darker; GNU **fillval** uses 0 for white and 1 for black.

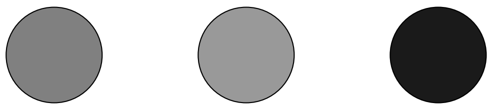


Figure 6-6: **circle fill; move; circle fill 0.4; move; circle fill 0.9;**

GNU **gpic** makes some additional guarantees. A fill value greater than 1 can also be used: this means fill with the shade of gray that is currently being used for text and lines. Normally this is black, but output devices may provide a mechanism for changing this. The invisible attribute does not affect the filling of objects. Any text associated with a filled object is added after the object has been filled, so that the text is not obscured by the filling.

6.10. Colored Objects

As a GNU extension, three additional modifiers are available to specify colored objects. **outline** sets the color of the outline, **shaded** the fill color, and **color** sets both. All three keywords expect a suffix specifying the color. Example:

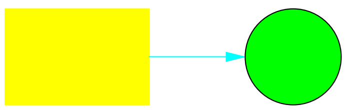


Figure 6-7: **box color "yellow"; arrow color "cyan"; circle shaded "green" outline "black";**

Alternative spellings are **colour**, **colored**, **coloured**, and **outlined**.

Predefined color names for *[gtn]roff*-based **pic** implementations are defined in the device macro files, for example `ps.tmac`; additional colors can be defined with the **.defcolor** request (see the manual page of GNU *troff*(1) for more details). Currently, color support is not available at all in TEX mode.

The *pic2plot*(1) carries with its own set of color names, essentially those recognized by the X window system with "grey" accepted as a variant of "gray".

pic assumes that at the beginning of a picture both glyph and fill color are set to the default value.

7. More About Text Placement

By default, text is centered at the geometric center of the object it is associated with. The modifier **ljust** causes the left end to be at the specified point (which means that the text lies to the right of the specified place!), the modifier **rjust** puts the right end at the place. The modifiers **above** and **below** center the text one half line space in the given direction.

Text attributes can be combined:

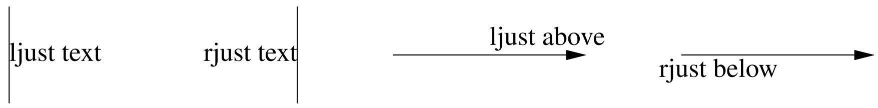


Figure 7-1: Text attributes

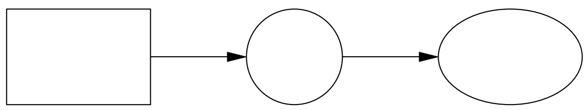
What actually happens is that *n* text strings are centered in a box that is **textwid** wide by **textht** high. Both these variables are initially zero (that is **pic**'s way of not making assumptions about *[tg]roff*(1)'s default point size).

In GNU **gpic**, objects can have an **aligned** attribute. This only works if the postprocessor is **grops** or **gropdf**. Any text associated with an object having the **aligned** attribute is rotated about the center of the object so that it is aligned in the direction from the start point to the end point of the object. Note that this attribute has no effect for objects whose start and end points are coincident.

8. More About Direction Changes

We've already seen how to change the direction in which objects are composed from rightward to downward. Here are some more illustrative examples:

right; box; arrow; circle; arrow; ellipse



left; box; arrow; circle; arrow; ellipse

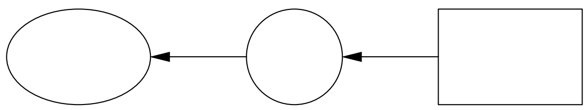


Figure 8-1: Effects of different motion directions (right and left)

down; box; arrow; circle; arrow; ellipse; **up; box; arrow; circle; arrow; ellipse;**

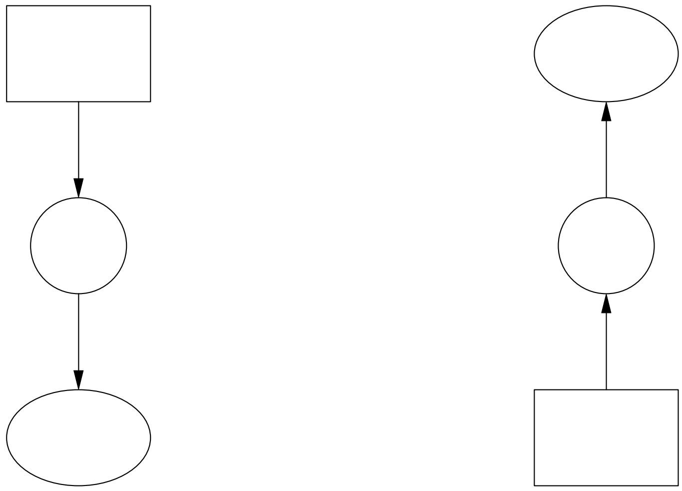


Figure 8-2: Effects of different motion directions (up and down)

Something that may appear surprising happens if you change directions in the obvious way:

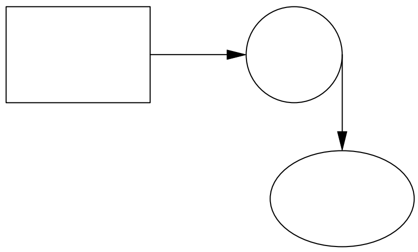


Figure 8-3: **box; arrow; circle; down; arrow; ellipse**

You might have expected that program to yield this:

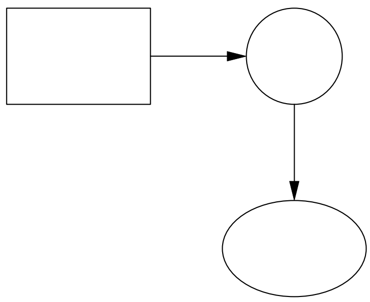


Figure 8-4: More intuitive?

But, in fact, to get Figure 8.3 you have to do this:

```
.PS
box;
arrow;
circle;
move to last circle .s;
down;
arrow;
ellipse
.PE
```

Why is this? Because the exit point for the current direction is already set when you draw the object. The second arrow in Figure 8.2 dropped downward from the circle's attachment point for an object to be joined to the right.

The meaning of the command **move to last circle .s** should be obvious. In order to see how it generalizes, we'll need to go into detail on two important topics; locations and object names.

9. Naming Objects

The most natural way to name locations in **pic** is relative to objects. In order to do this, you have to be able to name objects. The **pic** language has rich facilities for this that try to emulate the syntax of English.

9.1. Naming Objects By Order Of Drawing

The simplest (and generally the most useful) way to name an object is with a **last** clause. It needs to be followed by an object type name; **box**, **circle**, **ellipse**, **line**, **arrow**, **spline**, **""**, or **[]** (the last type refers to a *composite object* which we'll discuss later). So, for example, the **last circle** clause in the program attached to Figure 9.1.3 refers to the last circle drawn.

More generally, objects of a given type are implicitly numbered (starting from 1). You can refer to (say) the third ellipse in the current picture with **3rd ellipse**, or to the first box as **1st box**, or to the fifth text string (which isn't an attribute to another object) as **5th ""**.

Objects are also numbered backward by type from the last one. You can say **2nd last box** to get the second-to-last box, or **3rd last ellipse** to get the third-to-last ellipse.

In places where *n***th** is allowed, **`***expr***'th** is also allowed. Note that **'th** is a single token: no space is allowed between the **'** and the **th**. For example,

```
for i = 1 to 4 do {
   line from `i'th box.nw to `i+1'th box.se
}
```

9.2. Naming Objects With Labels

You can also specify an object by referring to a label. A label is a word (which must begin with a capital letter) followed by a colon; you declare it by placing it immediately before the object drawing command. For example, the program

```
.PS
A: box "first" "object"
move;
B: ellipse "second" "object"
move;
arrow right at A .r;
.PE
```

declares labels **A** and **B** for its first and second objects. Here's what that looks like:

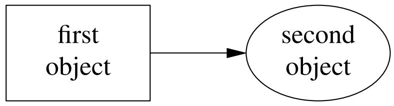


Figure 9-1: Example of label use

The **at** statement in the fourth line uses the label **A** (the behavior of **at** is explained in the next section). We'll see later on that labels are most useful for referring to block composite objects.

Labels are not constants but variables (you can view colon as a sort of assignment). You can say something like **A: A + (1,0);** and the effect is to reassign the label **A** to designate a position one inch to the right of its old value.

10. Describing locations

The location of points can be described in many different ways. All these forms are interchangeable as for as the **pic** language syntax is concerned; where you can use one, any of the others that would make semantic sense are allowed.

The special label **Here** always refers to the current position.

10.1. Absolute Coordinates

The simplest is absolute coordinates in inches; **pic** uses a Cartesian system with (0,0) at the lower left corner of the virtual drawing surface for each picture (that is, X increases to the right and Y increases upward). An absolute location may always be written in the conventional form as two comma-separated numbers surrounded by parentheses (and this is recommended for clarity). In contexts where it creates no ambiguity, the pair of X and Y coordinates suffices without parentheses.

It is a good idea to avoid absolute coordinates, however. They tend to make picture descriptions difficult to understand and modify. Instead, there are quite a number of ways to specify locations relative to **pic** objects and previous locations.

Another possibility of surprise is the fact that **pic** crops the picture to the smallest bounding box before writing it out. For example, if you have a picture consisting of a small box with its lower left corner at (2,2) and another small box with its upper right corner at (5,5), the width and height of the image are both 3 units and not 5. To get the origin at (0,0) included, simply add an invisible object to the picture, positioning the object's left corner at (0,0).

10.2. Locations Relative to Objects

The symbol **Here** always refers to the position of the last object drawn or the destination of the last **move**.

Alone and unqualified, a **last circle** or any other way of specifying a closed-object or arc location refers as a position to the geometric center of the object. Unqualified, the name of a line or spline object refers to the position of the object start.

Also, **pic** objects have quite a few named locations associated with them. One of these is the object center, which can be indicated (redundantly) with the suffix **.center** (or just **.c**). Thus, **last circle .center** is equivalent to **last circle**.

10.2.1. Locations Relative to Closed Objects

Every closed object (box, circle, ellipse, or block composite) also has eight compass points associated with it;

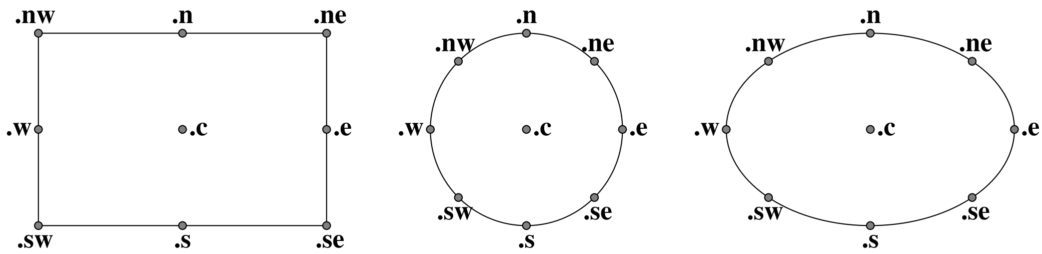


Figure 10-1: Compass points

these are the locations where eight compass rays from the geometric center would intersect the figure. So when we say **last circle .s** we are referring to the south compass point of the last circle drawn. The explanation of Figure 8-3's program is now complete.

(In case you dislike compass points, the names **.top**, **.bottom**, **.left** and **.right** are synonyms for **.n**, **.s**, **.e**, and **.w** respectively; they can even be abbreviated to **.t**, **.b**, **.l** and **.r**).

The names **center**, **top**, **bottom**, **left**, **right**, **north**, **south**, **east**, and **west** can also be used (without the leading dot) in a prefix form marked by **of**; thus, **center of last circle** and **top of 2nd last ellipse** are both valid object references. Finally, the names **left** and **right** can be prefixed with **upper** and **lower** which both have the obvious meaning.

Arc objects also have compass points; they are the compass points of the implied circle.

Non-closed objects (line, arrow, or spline) have compass points too, but the locations of them are completely arbitrary. In particular, different **pic** implementations return different locations.

10.2.2. Locations Relative to Open Objects

Every open object (line, arrow, arc, or spline) has three named points: **.start**, **.center** (or **.c**), and **.end**. They can also be used without leading dots in the **of** prefix form. The center of an arc is the center of its circle, but the center of a line, path, or spline is halfway between its endpoints.

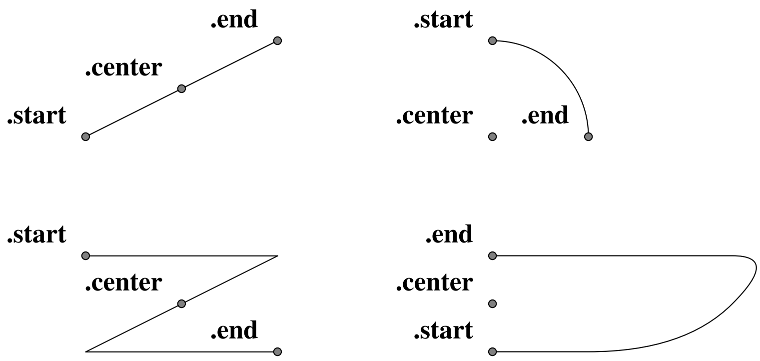


Figure 10-2: Special points on open objects

10.2.2.1. Locations Relative to Polygons

Polygons have three types of reference points: *vertices* (**.vertex**, **.ver**, **.v**), *midpoints* of edges between the vertices (**.midpoint**, **.mid**), and a *center* (**.center**, **.c**). Reference points can be used without leading dots in the **of** prefix form. The center of a polygon is the centroid, and may give unexpected results for non-simple polygons.

GNU **pic** numbers vertices and midpoints in drawing order starting from **1**. Express them in the forms **.v** *expr* or **.v** \`*expr*'. The latter is required when the vertex/point expression is followed by an additional expression, as **pic** otherwise attempts to reduce them to a single expression. For example,

```
for i = 1 to n do {
   circle rad 0.05 fill 1 at last polygon.vi
}
circle rad 0.05 fill 1 at last polygon.mid `1' + (0.0,0.1)
```

would draw a dot 0.1i above the mid-point of the first edge at the default scale, and one at each vertex for a polygon with n vertices.

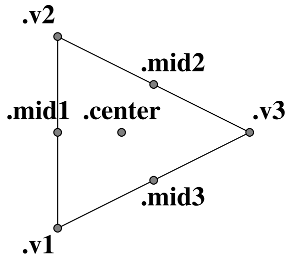


Figure 10-3: Special points on polygons

10.3. Ways of Composing Positions

Once you have two positions to work with, there are several ways to combine them to specify new positions.

10.3.1. Vector Sums and Displacements

Positions may be added or subtracted to yield a new position (to be more precise, you can only add a position and an expression pair; the latter must be on the right side of the addition or subtraction sign). The result is the conventional vector sum or difference of coordinates. For example, **last box .ne + (0.1, 0)** is a valid position. This example illustrates a common use, to define a position slightly offset from a named one (say, for captioning purposes).

10.3.2. Interpolation Between Positions

A position may be interpolated between any two positions. The syntax is '*fraction* **of the way between** *position1* **and** *position2*'. For example, you can say **1/3 of the way between Here and last ellipse .ne**. The fraction may be in numerator/denominator form or may be an ordinary number (values are *not* restricted to [0,1]). As an alternative to this verbose syntax, you can say '*fraction* **<***position1* **,** *position2***>**'; thus, the example could also be written as **1/3 <Here, last ellipse>**.

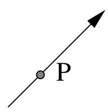


Figure 10-3: **P: 1/3 of the way between last arrow .start and last arrow .end**

This facility can be used, for example, to draw double connections.

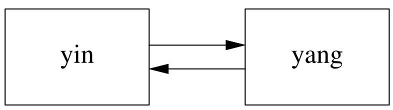


Figure 10-4: Doubled arrows

You can get Figure 10-4 from the following program:

```
.PS
A: box "yin"; move;
B: box "yang";
arrow right at 1/4 <A.e,A.ne>;
arrow left  at 1/4 <B.w,B.sw>;
.PE
```

Note the use of the short form for interpolating points.

10.3.3. Projections of Points

Given two positions p and q, the position (p, q) has the X coordinate of p and the Y coordinate of q. This can be helpful in placing an object at one of the corners of the virtual box defined by two other objects.

Figure 10-5: Using (x, y) composition

10.4. Using Locations

There are four ways to use locations; **at**, **from**, **to**, and **with**. All four are object modifiers; that is, you use them as suffixes to a drawing command.

The **at** modifier says to draw a closed object or arc with its center at the following location, or to draw a line/spline/arrow starting at the following location.

The **to** modifier can be used alone to specify a move destination. The **from** modifier can be used alone in the same way as **at**.

The **from** and **to** modifiers can be used with a **line** or **arc** command to specify start and end points of the object. In conjunction with named locations, this offers a very flexible mechanism for connecting objects. For example, the following program

```
.PS
box "from"
move 0.75;
ellipse "to"
arc cw from 1/3 of the way \
    between last box .n and last box .ne to last ellipse .n;
.PE
```

yields:

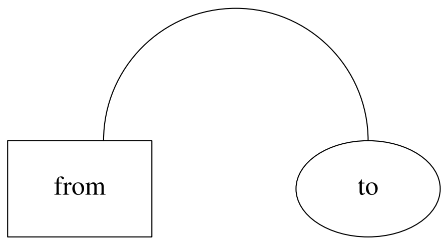


Figure 10-6: A tricky connection specified with English-like syntax

The **with** modifier allows you to identify a named attachment point of an object (or a position within the object) with another point. This is very useful for connecting objects in a natural way. For an example, consider these two programs:

box wid 0.5 ht 0.5; box wid 0.75 ht 0.75

box wid 0.5 ht 0.5;
box wid 0.75 ht 0.75 with .sw at last box .se;

Figure 10-7: Using the **with** modifier for attachments

10.5. The 'chop' Modifier

When drawing lines between circles that don't intersect them at a compass point, it is useful to be able to shorten a line by the radius of the circle at either or both ends. Consider the following program:

```
.PS
circle "x"
circle "y" at 1st circle - (0.4, 0.6)
circle "z" at 1st circle + (0.4, -0.6)
arrow from 1st circle to 2nd circle chop
arrow from 2nd circle to 3rd circle chop
arrow from 3rd circle to 1st circle chop
.PE
```

It yields the following:

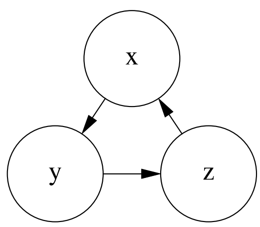


Figure 10-8: The **chop** modifier

Notice that the **chop** attribute moves arrowheads rather than stepping on them. By default, the **chop** modifier shortens both ends of the line by **circlerad**. By suffixing it with a number you can change the amount of chopping.

If you say **line ... chop** *r1* **chop** *r2* with *r1* and *r2* both numbers, you can vary the amount of chopping at both ends. You can use this in combination with trigonometric functions to write code that deals with more complex intersections.

11. Object Groups

There are two different ways to group objects in **pic**; *brace grouping* and *block composites*.

11.1. Brace Grouping

The simpler method is simply to group a set of objects within curly bracket or brace characters. On exit from this grouping, the current position and direction are restored to their value when the opening brace was encountered.

11.2. Block Composites

A block composite object is created a series of commands enclosed by square brackets. The composite can be treated for most purposes like a single closed object, with the size and shape of its bounding box. Here is an example. The program fragment

```
A: [
    circle;
    line up 1 at last circle .n;
    line down 1 at last circle .s;
    line right 1 at last circle .e;
    line left 1 at last circle .w;
    box dashed with .nw at last circle .se + (0.2, -0.2);
    Caption: center of last box;
]
```

yields the block in figure 11-1, which we show both with and without its attachment points. The block's location becomes the value of **A**.

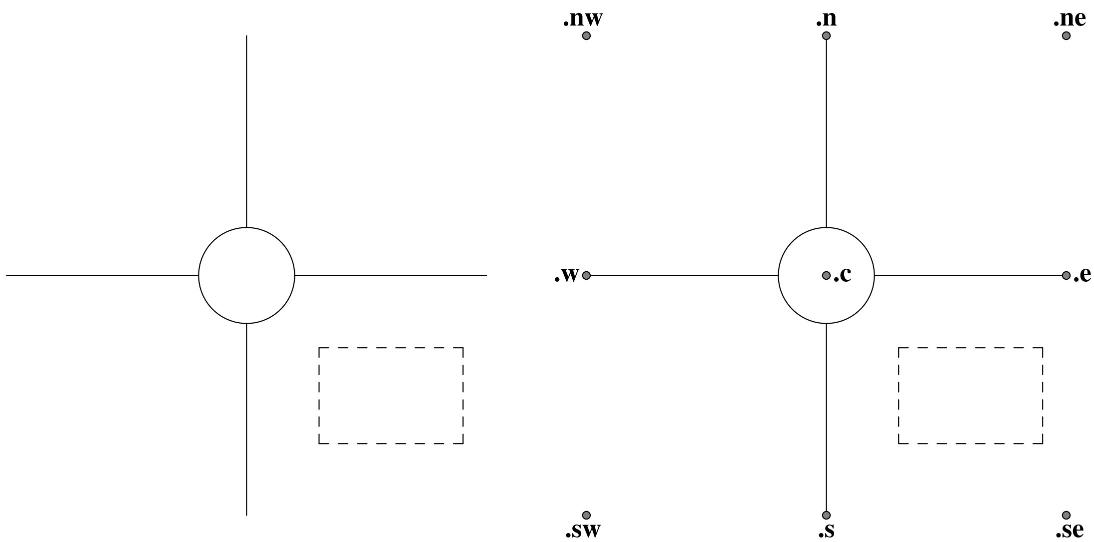


Figure 11-1: A sample composite object

To refer to one of the composite's attachment points, you can say (for example) **A .s**. For purposes of object naming, composites are a class. You could write **last [] .s** as an equivalent reference, usable anywhere a location is needed. This construction is very important for putting together large, multi-part diagrams.

Blocks are also a variable-scoping mechanism, like a *groff*(1) environment. All variable assignments done inside a block are undone at the end of it. To get at values within a block, write a name of the block followed by a dot, followed by the label you want. For example, we could refer the center of the box in the above composite as **last [] .Caption** or **A.Caption**.

This kind of reference to a label can be used in any way any other location can be. For example, if we added **"Hi!" at A.Caption** the result would look like this:

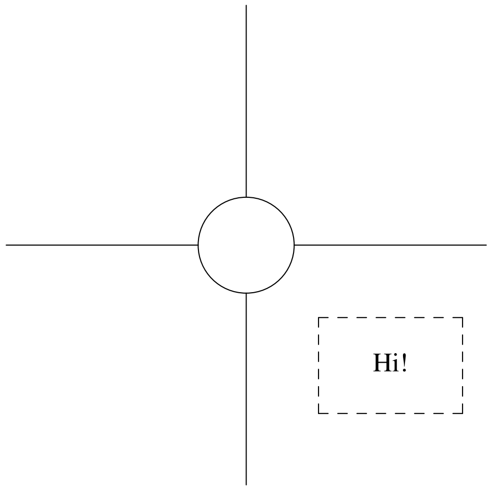


Figure 11-2: Adding a caption using interior labeling

You can also use interior labels in either part of a **with** modifier. This means that the example composite could be placed relative to its caption box by a command containing **with A.Caption at**.

Note that both width and height of the block composite object are always positive:

box wid -0.5 ht 0.5; box wid 0.75 ht 0.75 **[box wid -0.5 ht 0.5]; box wid 0.75 ht 0.75**

Figure 11-3: Composite block objects always have positive width and height

Blocks may be nested. This means you can use block attachment points to build up complex diagrams hierarchically, from the inside out. Note that **last** and the other sequential naming mechanisms don't look inside blocks, so if you have a program that looks like

```
.PS
P: [box "foo"; ellipse "bar"];
Q: [
     [box "baz"; ellipse "quxx"]
     "random text";
   ]
arrow from 2nd last [];
.PE
```

the arrow in the last line is attached to object **P**, not object **Q**.

In DWB **pic**, only references one level deep into enclosed blocks were permitted. GNU **gpic** removes this restriction.

The combination of block variable scoping, assignability of labels and the macro facility that we'll describe later on can be used to simulate functions with local variables (just wrap the macro body in block braces).

12. Style Variables

There are a number of global style variables in **pic** that can be used to change its overall behavior. We've mentioned several of them in previous sections. They're all described here. For each variable, the default is given.

Style Variable	Default	What It Does
boxht	0.5	Default height of a box
boxwid	0.75	Default width of a box
lineht	0.5	Default length of vertical line
linewid	0.75	Default length of horizontal line
linethick	-1	Default line thickness
arcrad	0.25	Default radius of an arc
circlerad	0.25	Default radius of a circle
ellipseht	0.5	Default height of an ellipse
ellipsewid	0.75	Default width of an ellipse
moveht	0.5	Default length of vertical move
movewid	0.75	Default length of horizontal move
textht	0	Default height of box enclosing a text object
textwid	0	Default width of box enclosing a text object
arrowht	0.1	Length of arrowhead along shaft
arrowwid	0.05	Width of rear of arrowhead
arrowhead	1	Enable/disable arrowhead filling
dashwid	0.05	Interval for dashed lines
maxpswid	8.5	Maximum width of picture
maxpsht	11	Maximum height of picture
scale	1	Unit scale factor
fillval	0.5	Default fill value

Any of these variables can be set with a simple assignment statement. For example:

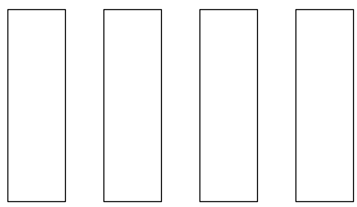


Figure 12-1: **boxht=1; boxwid=0.3; movewid=0.2; box; move; box; move; box; move; box;**

In GNU **pic**, setting the **scale** variable re-scales all size-related state variables so that their values remain equivalent in the new units.

The command **reset** resets all style variables to their defaults. You can give it a list of variable names as arguments (optionally separated by commas), in which case it resets only those.

State variables retain their values across pictures until reset.

13. Expressions, Variables, and Assignment

A number is a valid expression, of course (all numbers are stored internally as floating-point). Decimal-point notation is acceptable; in GNU **gpic**, scientific notation in C's 'e' format (like `5e−2`) is accepted.

Anywhere a number is expected, the language also accepts a variable. Variables may be the built-in style variable described in the last section, or new variables created by assignment.

DWB **pic** supports only the ordinary assignment via **=**, which defines the variable (on the left side of the equal sign) in the current block if it is not already defined there, and then changes the value (on the right side) in the current block. The variable is not visible outside of the block. This is similar to the C programming language where a variable within a block shadows a variable with the same name outside of the block.

GNU **gpic** supports an alternate form of assignment using **:=**. The variable must already be defined, and the value is assigned to that variable without creating a variable local to the current block. For example, this

```
x=5
y=5
[
  x:=3
  y=3
]
print x " " y
```

prints **3 5**.

You can use the height, width, radius, and x and y coordinates of any object or corner in expressions. If **A** is an object label or name, all the following are valid:

```
A.x                   # x coordinate of the center of A
A.ne.y                # y coordinate of the northeast corner of A
A.wid                 # the width of A
A.ht                  # and its height
2nd last circle.rad   # the radius of the 2nd last circle
```

Note the second expression, showing how to extract a corner coordinate.

Basic arithmetic resembling those of C operators are available; **+**, *****, **-**, **/**, and **%**. So is ^ for exponentiation. Grouping is permitted in the usual way using parentheses. GNU **gpic** allows logical operators to appear in expressions; **!** (logical negation, not factorial), **&&**, **||**, **==**, **!=**, **>=**, **<=**, **<**, **>**.

Various built-in functions are supported: **sin**(*x*), **cos**(*x*), **log**(*x*), **exp**(*x*), **sqrt**(*x*), **max**(*x*,*y*), **atan2**(*x*,*y*), **min**(*x*,*y*), **int**(*x*), **rand**(), and **srand**(). Both **exp** and **log** are base 10; **int** does integer truncation; **rand**() returns a random number in [0-1), and **srand**() sets the seed for a new sequence of pseudo-random numbers to be returned by **rand**() (**srand**() is a GNU extension).

GNU **gpic** also documents a one-argument form or rand, **rand**(*x*), which returns a random number between 1 and *x*, but this is deprecated and may be removed in a future version.

The function **sprintf**() behaves like a C *sprintf*(3) function that only takes %%, %e, %E, %f, %g, and %G conversion specifications.

14. Macros

You can define macros in **pic**, with up to 32 arguments (up to 16 on EBCDIC platforms). This is useful for diagrams with repetitive parts. In conjunction with the scope rules for block composites, it effectively gives you the ability to write functions.

The syntax is

define *name* **{** *replacement text* **}**

This defines *name* as a macro to be replaced by the replacement text (not including the braces). The macro may be called as

name(*arg1, arg2, . . . argn*)

The arguments (if any) are substituted for tokens **$1**, **$2** . . . **$n** appearing in the replacement text.

As an example of macro use, consider this:

```
.PS
# Plot a single jumper in a box, $1 is the on-off state.
define jumper { [
    shrinkfactor = 0.8;
    Outer: box invis wid 0.45 ht 1;

    # Count on end ] to reset these
    boxwid = Outer.wid * shrinkfactor / 2;
    boxht  = Outer.ht  * shrinkfactor / 2;

    box fill (!$1) with .s at center of Outer;
    box fill ($1)  with .n at center of Outer;
] }

# Plot a block of six jumpers.
define jumperblock {
    jumper($1);
    jumper($2);
    jumper($3);
    jumper($4);
    jumper($5);
    jumper($6);

    jwidth  = last [].Outer.wid;
    jheight = last [].Outer.ht;

    box with .nw at 6th last [].nw wid 6*jwidth ht jheight;

    # Use {} to avoid changing position from last box draw.
    # This is necessary so move in any direction works as expected
    {"Jumpers in state $1$2$3$4$5$6" at last box .s + (0,-0.2);}
}

# Sample macro invocations.
jumperblock(1,1,0,0,1,0);
move;
jumperblock(1,0,1,0,1,1);
.PE
```

It yields the following:

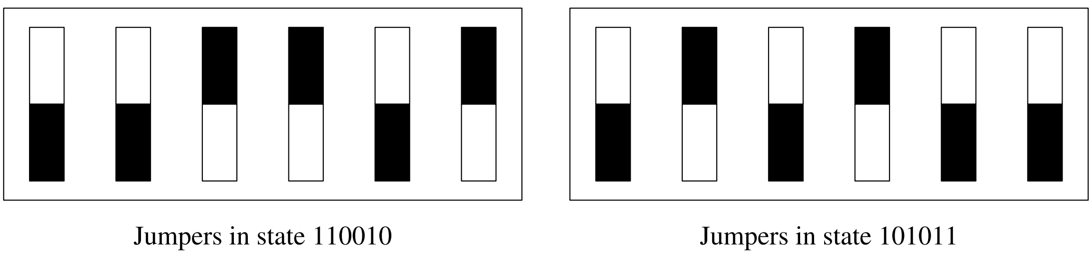


Figure 14-1: Sample use of a macro

This macro example illustrates how you can combine [], brace grouping, and variable assignment to write true functions.

One detail the example above does not illustrate is the fact that macro argument parsing is not token-oriented. If you call **jumper(1)**, the value of $1 is **" 1 "**. You could even call **jumper(big string)** to give $1 the value

"big string".

If you want to pass in a coordinate pair, you can avoid getting tripped up by the comma by wrapping the pair in parentheses.

Macros persist through pictures. To undefine a macro, say **undef** *name*; for example,

```
undef jumper
undef jumperblock
```

would undefine the two macros in the jumper block example.

15. Import/Export Commands

Commands that import or export data between **pic** and its environment are described here.

15.1. File and Table Insertion

The statement

`copy` *filename*

inserts the contents of *filename* in the **pic** input stream. Any **.PS/.PE** pair in the file is ignored. You can use this to include pre-generated images.

A variant of this statement replicates the **copy thru** feature of *grap*(1). The call

`copy` *filename* `thru` *macro*

calls *macro* (which may be either a name or replacement text) on the arguments obtained by breaking each line of the file into blank-separated fields. The macro may have up to 9 arguments. The replacement text may be delimited by braces or by a pair of instances of any character not appearing in the rest of the text.

If you write

`copy thru` *macro*

omitting the filename, lines to be parsed are taken from the input source up to the next **.PE**.

In either of the last two **copy** commands, GNU **gpic** permits a trailing '**until** *word*' clause to be added which terminates the copy when the first word matches the argument (the default behavior is therefore equivalent to **until .PE**).

Accordingly, the command

```
.PS
copy thru % circle at ($1,$2) % until "END"
1 2
3 4
5 6
END
box
.PE
```

is equivalent to

```
.PS
circle at (1,2)
circle at (3,4)
circle at (5,6)
box
.PE
```

15.2. Debug Messages

The command **print** accepts any number of arguments, catenates their output forms, and writes the result to standard error. Each argument must be an expression, a position, or a text string.

15.3. Escape to Post-Processor

If you write

command *arg . . .*

pic concatenates the arguments and pass them through as a line to troff or TEX. Each *arg* must be an expression, a position, or text. This has a similar effect to a line beginning with `.` or `\`, but allows the values of variables to be passed through.

For example,

```
.PS
x = 14
command ".ds string x is " x "."
.PE
\*[string]
```

prints

```
x is 14.
```

15.4. Executing Shell Commands

The command

`sh {` *anything. . .* `}`

macro-expands the text in braces, then executes it as a shell command. This could be used to generate images or data tables for later inclusion. The delimiters shown as {} here may also be two copies of any one character not present in the shell command text. In either case, the body may contain balanced {} pairs. Strings in the body may contain balanced or unbalanced braces in any case.

16. Control-flow constructs

The **pic** language provides conditionals and looping. For example,

```
pi = atan2(0,-1);
for i = 0 to 2 * pi by 0.1 do {
     "-" at (i/2, 0);
     "." at (i/2, sin(i)/2);
     ":" at (i/2, cos(i)/2);
}
```

which yields this:

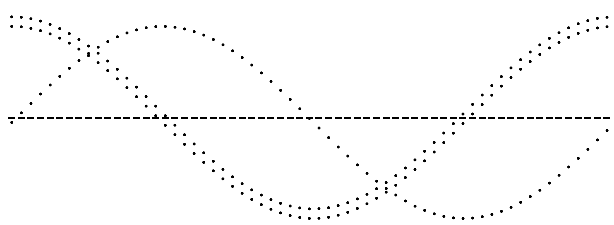


Figure 16-1: Plotting with a **for** loop

The syntax of the **for** statement is:

for *variable* **=** *expr1* **to** *expr2* [**by** [*]*expr3*] **do** *X body X*

The semantics are as follows: Set *variable* to *expr1*. While the value of *variable* is less than or equal to *expr2*, do *body* and increment *variable* by *expr3*; if **by** is not given, increment *variable* by 1. If *expr3* is prefixed by ***** then *variable* is multiplied instead by *expr3*. The value of *expr3* can be negative for the additive case; *variable* is then tested whether it is greater than or equal to *expr2*. For the multiplicative case, *expr3* must be greater than zero. If the constraints aren't met, the loop isn't executed. *X* can be any character not occurring in *body*; or the two *X*s may be paired braces (as in the **sh** command).

The syntax of the **if** statement is as follows:

if *expr* **then** *X if-true X* [**else** *Y if-false Y*]

Its semantics are as follows: Evaluate *expr*; if it is non-zero then do *if-true*, otherwise do *if-false*. *X* can be any character not occurring in *if-true*. *Y* can be any character not occurring in *if-false*.

Eithe or both of the *X* or *Y* pairs may instead be balanced pairs of braces ({ and }) as in the **sh** command. In either case, the *if-true* may contain balanced pairs of braces. None of these delimiters are seen inside strings.

All the usual relational operators my be used in conditional expressions; **!** (logical negation, not factorial), **&&**, **||**, **==**, **!=**, **>=**, **<=**, **<**, **>**.

String comparison is also supported using **==** and **!=**. String comparisons may need to be parenthesized to avoid syntactic ambiguities.

17. Interface To [gt]roff

The output of **pic** is **[gt]roff** drawing commands. The GNU *gpic*(1) command warns that it relies on drawing extensions present in *groff*(1) that are not present in *troff*(1).

17.1. Scaling Arguments

The DWB *pic*(1) program accepts one or two arguments to **.PS**, which is interpreted as a width and height in inches to which the results of *pic*(1) should be scaled (width and height scale independently). If there is only one argument, it is interpreted as a width to scale the picture to, and height is scaled by the same proportion.

GNU **gpic** is less general; it accepts a single width to scale to, or a zero width and a maximum height to scale to. With two non-zero arguments, it scales to the maximum height.

17.2. How Scaling is Handled

When **pic** processes a picture description on input, it passes **.PS**, **.PE**, **.PF**, and **.PY** through to the postprocessor. The **.PS** gets decorated with two numeric arguments which are the X and Y dimensions of the picture in inches. The post-processor can use these to reserve space for the picture and center it.

The GNU incarnation of the **ms** macro package, for example, includes the following definitions:

```
.de PS
.br
.sp \\n[DD]u
.ie \\n[.$]<2 .@error bad arguments to PS (not preprocessed with pic?)
.el \{\
.    ds@need (u;\\$1)+1v
.    in +(u;\\n[.l]-\\n[.i]-\\$2/2>?0)
.\}
..
.de PE
.par@reset
.sp \\n[DD]u+.5m
..
```

Equivalent definitions of these and of **.PF** and **.PY** are supplied by GNU *pic*(1) if you use the −mpic option; this should make it usable with macro packages other than *ms*.

If **.PF** is used instead of **.PE**, the **troff** position is restored to what it was at the picture start (Kernighan notes that the F stands for “flyback”). GNU *pic*(1) supports **.PY** as a synonym of **.PF** to work around a name space collision with the *mm* macro package, which uses the same name for a page footer management macro. Use **.PF** preferentially unless a similar problem faces your document.

The invocation

.PS < *file*

causes the contents of *file* to replace the **.PS** line. This feature is deprecated; use '**copy** *file*' instead.

17.3. PIC and [gt]roff commands

By default, input lines that begin with a period are passed to the postprocessor, embedded at the corresponding point in the output. Messing with horizontal or vertical spacing is an obvious recipe for bugs, but point size and font changes are usually safe.

Point sizes and font changes are also safe within text strings, as long as they are undone before the end of string.

The enablement of output line filling by **[gt]roff** is preserved across pictures.

17.4. PIC and EQN

The Kernighan paper notes that there is a subtle problem with complicated equations inside **pic** pictures; they come out wrong if *eqn*(1) has to leave extra vertical space for the equation. If your equation involves more than subscripts and superscripts, you must add to the beginning of each equation the extra information **space 0**. He gives the following example:

```
arrow
box "$space 0 {H( omega )} over {1 - H( omega )}$"
arrow
```

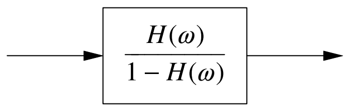


Figure 17-1: Equations within pictures

17.5. Absolute Positioning of Pictures

A **pic** picture is positioned vertically by troff at the current position. The topmost position possible on a page is not the paper edge but a position which is one baseline lower so that the first row of glyphs is visible. To make a picture really start at the paper edge you have to make the baseline-to-baseline distance zero, this is, you must set the vertical spacing to 0 (using **.vs**) before starting the picture.

18. Interface to TeX

TeX mode is enabled by the **–t** option. In TeX mode, pic defines a vbox called **\graph** for each picture; the name can be changed with the pseudo-variable **figname** (which is actually a specially parsed command). You must yourself print that vbox using, for example, the command

```
\centerline{\box\graph}
```

Actually, since the vbox has a height of zero (it is defined with \vtop) this produces slightly more vertical space above the picture than below it;

```
\centerline{\raise 1em\box\graph}
```

would avoid this.

To make the vbox having a positive height and a depth of zero (as used e.g. by LaTeX's `graphics.sty`), define the following macro in your document:

```
\def\gpicbox#1{%
  \vbox{\unvbox\csname #1\endcsname\kern 0pt}}
```

Now you can simply say **\gpicbox{graph}** instead of \box\graph.

You must use a TEX driver that supports the **tpic** specials, version 2.

Lines beginning with **** are passed through transparently; a **%** is added to the end of the line to avoid unwanted spaces. You can safely use this feature to change fonts or to change the value of **\baselineskip**. Anything else may well produce undesirable results; use at your own risk. Lines beginning with a period are not given any special treatment.

The TEX mode of *pic*(1) does *not* translate **troff** font and size changes included in text strings!

Here an example how to use **figname**.

```
.PS
figname = foo;
...
.PE

.PS
figname = bar;
...
.PE

\centerline{\box\foo \hss \box\bar}
```

Use this feature sparsingly and only if really needed: A different name means a new box register in TEX, and the maximum number of box registers is only 256. Also be careful not to use a predefined TEX or LATEX macro name as an argument to **figname** since this inevitably causes an error.

19. Obsolete Commands

GNU *gpic*(1) has a command

plot *expr* ["*text*"]

This is a text object which is constructed by using *text* as a format string for sprintf with an argument of *expr*. If *text* is omitted a format string of **"%g"** is used. Attributes can be specified in the same way as for a normal text object. Be very careful that you specify an appropriate format string; **pic** does only very limited checking of the string. This is deprecated in favour of **sprintf**.

20. Some Larger Examples

Here are a few larger examples, with complete source code. One of our earlier examples is generated in an instructive way using a for loop:

```
.PS
# Draw a demonstration up left arrow with grid box overlay
define gridarrow
{
    move right 0.1
    [
        {arrow up left $1;}
        box wid 0.5 ht 0.5 dotted with .nw at last arrow .end;
        for i = 2 to ($1 / 0.5) do
        {
            box wid 0.5 ht 0.5 dotted with .sw at last box .se;
        }
        move down from last arrow .center;
        [
            sprintf("\fBarrow up left %g\fP", $1)
        ]
    ]
    move right 0.1 from last [] .e;
}
gridarrow(0.5);
gridarrow(1);
gridarrow(1.5);
gridarrow(2);
undef gridarrow
.PE
```

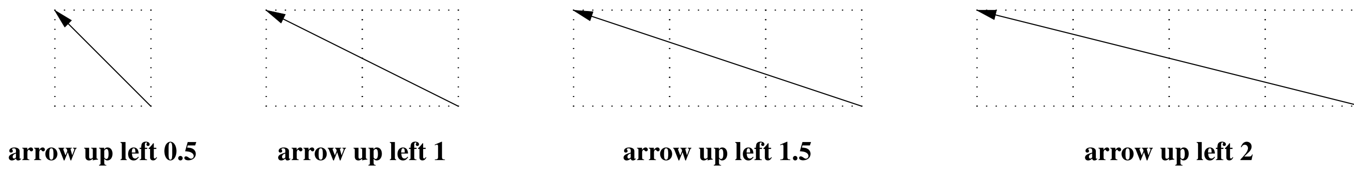


Figure 20-1: Diagonal arrows (dotted boxes show the implied 0.5-inch grid)

Here’s an example concocted to demonstrate layout of a large, multiple-part pattern:

```
.PS
define filter {box ht 0.25 rad 0.125}
lineht = 0.25;
Top: [
    right;
    box "\fBms\fR" "sources";
    move;
    box "\fBHTML\fR" "sources";
    move;
    box "\fBlinuxdoc-sgml\fP" "sources" wid 1.5;
    move;
    box "\fBTexinfo\fP" "sources";

    line down from 1st box .s lineht;
    A: line down;
    line down from 2nd box .s; filter "\fBhtml2ms\fP";
    B: line down;
    line down from 3rd box .s; filter "\fBformat\fP";
    C: line down;
    line down from 4th box .s; filter "\fBtexi2roff\fP";
    D: line down;
]
move down 1 from last [] .s;
Anchor: box wid 1 ht 0.75 "\fBms\fR" "intermediate" "form";
arrow from Top.A.end to Anchor.nw;
arrow from Top.B.end to 1/3 of the way between Anchor.nw and Anchor.ne;
arrow from Top.C.end to 2/3 of the way between Anchor.nw and Anchor.ne;
arrow from Top.D.end to Anchor.ne
{
    # PostScript column
    move to Anchor .sw;
    line down left then down ->;
    filter "\fBpic\fP";
    arrow;
    filter "\fBeqn\fP";
    arrow;
    filter "\fBtbl\fP";
    arrow;
    filter "\fBgroff\fP";
    arrow;
    box "PostScript";

    # HTML column
    move to Anchor .se;
    line down right then down ->;
    A: filter dotted "\fBpic2img\fP";
    arrow;
    B: filter dotted "\fBeqn2html\fP";
    arrow;
    C: filter dotted "\fBtbl2html\fP";
    arrow;
    filter "\fBms2html\fP";
    arrow;
    box "HTML";

    # Nonexistence caption
    box dashed wid 1 at B + (2,0) "These tools" "don't yet exist";
    line chop 0 chop 0.1 dashed from last box .nw to A.e ->;
    line chop 0 chop 0.1 dashed from last box .w  to B.e ->;
```

```
    line chop 0 chop 0.1 dashed from last box .sw to C.e ->;
}
.PE
```

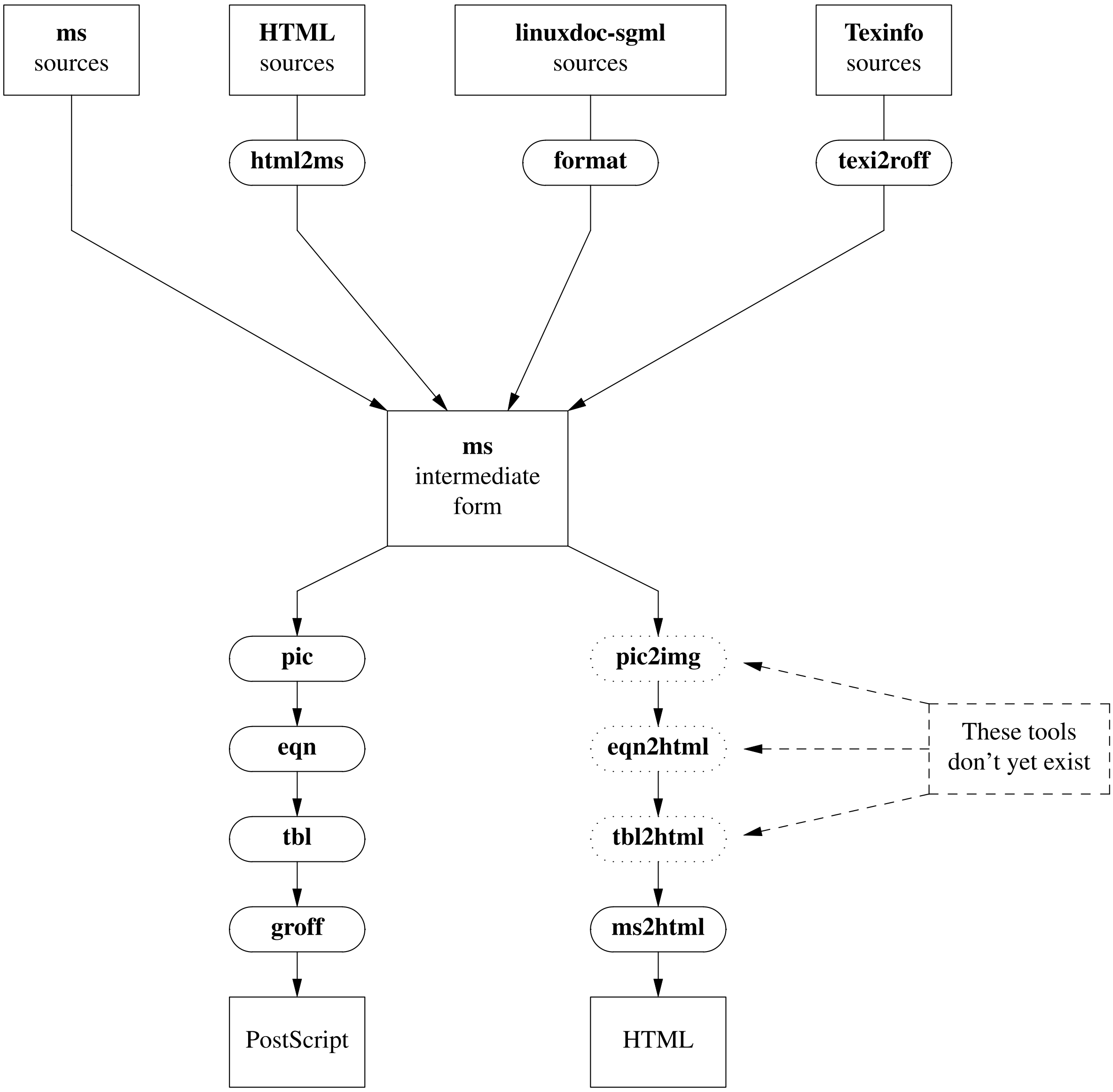


Figure 20-2: Hypothetical production flow for dual-mode publishing

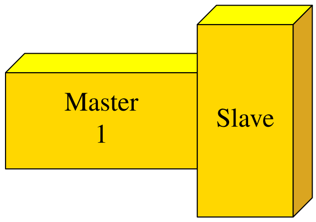


Figure 20-3: Three-dimensional Boxes

Here the source code for figure 20-3:

```
.PS
# a three-dimensional block
#
# tblock(<width>, <height>, <text>)

define tblock { [
  box ht $2 wid $1 \
      color "gold" outlined "black" \
      xslanted 0 yslanted 0 \
      $3;
  box ht .1 wid $1 \
      color "yellow" outlined "black" \
      xslanted .1 yslanted 0 \
      with .sw at last box .nw;
  box ht $2 wid .1 \
      color "goldenrod" outlined "black" \
      xslanted 0 yslanted .1 \
      with .nw at 2nd last box .ne;
] }

tblock(1, .5, "Master" "1");
move -.1
tblock(.5, 1, "Slave");
.PE
```

Here is a flow chart with source code to demonstrate how a polygon attaches to other objects:

```
.PS
down;
h = 0.25;
w = 0.375;
l = 0.75;
r = 0.1;
box rad r fill 0.3 outlined "green";
"Start" at last box;
arrow down l from last box.s;
polygon \
    down h right w \
    then down h left w \
    then up h left w \
    with .v1 at last arrow.end \
    fill 0.3 outlined "blue";
"Done?" at last polygon.c;
arrow down l from last polygon.v3 " Yes" ljust;
box rad r fill 0.3 outlined "green";
"End" at last box.c;
move to last polygon.v2;
line right "" "No";
arrow up l - h/2 then left lineht + w;
.PE
```

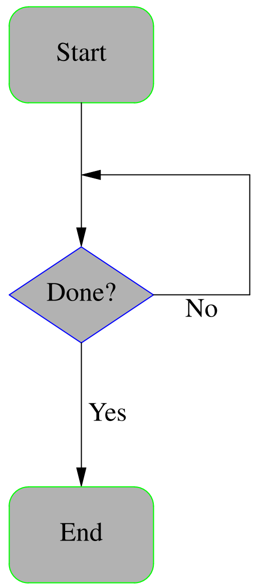


Figure 20-3: Flowchart for demonstrating polygon attachment

21. PIC Reference

This is an annotated grammar of **pic**.

21.1. Lexical Items

In general, **pic** is a free-format, token-oriented language that ignores whitespace outside strings. But certain lines and constructs are specially interpreted at the lexical level:

A comment begins with **#** and continues to **\n** (comments may also follow text in a line). A line beginning with a period or backslash may be interpreted as text to be passed through to the post-processor, depending on command-line options. An end-of-line backslash is interpreted as a request to continue the line; the backslash and following newline are ignored.

Here are the grammar terminals:

INT A positive integer.

NUMBER
: A floating point numeric constant. May contain a decimal point or be expressed in scientific notation in the style of *printf*(3)'s %e escape. A trailing 'i' or 'I' (indicating the unit 'inch') is ignored.

TEXT
: A string enclosed in double quotes. A double quote within TEXT must be preceded by a backslash. Instead of TEXT you can use

```
sprintf ( TEXT [, <expr> ...] )
```

except after the 'until' and 'last' keywords, and after all ordinal keywords ('th' and friends).

VARIABLE
: A string starting with a character from the set [a-z], optionally followed by one or more characters of the set [a-zA-Z0-9_]. (Values of variables are preserved across pictures.)

LABEL
: A string starting with a character from the set [A-Z], optionally followed by one or more characters of the set [a-zA-Z0-9_].

COMMAND-LINE
: A line starting with a command character ('.' in groff mode, '\' in TEX mode).

BALANCED-TEXT
: A string either enclosed by '{' and '}' or with *X* and *X*, where *X* doesn't occur in the string.

BALANCED-BODY
: Delimiters as in BALANCED-TEXT; the body is interpreted as '⟨**command**⟩**...**'.

FILENAME
: The name of a file. This has the same semantics as TEXT.

MACRONAME
: Either VARIABLE or LABEL.

21.2. Semi-Formal Grammar

Tokens not enclosed in ⟨⟩ are literals, except:

1. **\n** is a newline.
2. Three dots is a suffix meaning 'replace with 0 or more repetitions of the preceding element(s).
3. An enclosure in square brackets has its usual meaning of 'this clause is optional'.
4. Square-bracket-enclosed portions within tokens are optional. Thus, 'h[eigh]t' matches either 'height' or 'ht'.

If one of these special tokens has to be referred to literally, it is surrounded with single quotes.

The top-level **pic** object is a picture.

```
<picture> ::=
  .PS [NUMBER [NUMBER]]\n
  <statement> ...
  .PE \n
```

The arguments, if present, represent the width and height of the picture, causing **pic** to attempt to scale it to the given dimensions in inches. In no case, however, the X and Y dimensions of the picture exceed the values of the style variables **maxpswid** and **maxpsheight** (which default to the normal 8.5i by 11i page size).

If the ending '.PE' is replaced by '.PF' or '.PY', the page vertical position is restored to its value at the time '.PS' was encountered. Another alternate form of invocation is '.PS <FILENAME', which replaces the '.PS' line with a file to be interpreted by **pic** (but this feature is deprecated).

The '.PS', '.PE', '.PF', and '.PY' macros to perform centering and scaling are normally supplied by the post-processor.

In the following, either '|' or a new line starts an alternative.

```
<statement> ::=
  <command> ;
  <command> \n

<command> ::=
  <primitive> [<attribute>]
  LABEL : [;] <command>
  LABEL : [;] <command> [<position>]
  { <command> ... }
  VARIABLE [:] = <any-expr>
  figname = MACRONAME
  up | down | left | right
  COMMAND-LINE
  command <print-arg> ...
  print <print-arg> ...
  sh BALANCED-TEXT
  copy FILENAME
  copy [FILENAME] thru MACRONAME [until TEXT]
  copy [FILENAME] thru BALANCED-BODY [until TEXT]
  for VARIABLE = <expr> to <expr> [by [*] <expr>] do BALANCED-BODY
  if <any-expr> then BALANCED-BODY [else BALANCED-BODY]
  reset [VARIABLE [[,] VARIABLE ...]]

<print-arg> ::=
  TEXT
  <expr>
  <position>
```

The current position and direction are saved on entry to a
'{ ... }' construction and restored on exit from it.

Note that in 'if' constructions, newlines can only occur in BALANCED-BODY. This means that

```
if
{ ... }
else
{ ... }
```

fails. You have to use the braces on the same line as the keywords:

```
if {
...
} else {
...
}
```

This restriction doesn't hold for the body after the 'do' in a 'for' construction.

At the beginning of each picture, 'figname' is reset to the vbox name 'graph'; this command has only a meaning in TeX mode. While the grammar rules allow digits and the underscore in the value of 'figname', TeX normally accepts uppercase and lowercase letters only as box names (you have to use '\csname' if you really need to circumvent this limitation).

```
<any-expr> ::=
  <expr>
  <text-expr>
  <any-expr> <logical-op> <any-expr>
  ! <any-expr>

<logical-op> ::=
  == | != | && | '||'

<text-expr> ::=
  TEXT == TEXT
  TEXT != TEXT
```

Logical operators are handled specially by **pic** since they can deal with text strings also. **pic** uses *strcmp*(3) to test for equality of strings; an empty string is considered as 'false' for '&&' and '||'.

```
<primitive> ::=
  box                     # closed object — rectangle
  circle                  # closed object — circle
  ellipse                 # closed object — ellipse
  polygon                 # closed object — polygon
  arc                     # open object — quarter-circle
  line                    # open object — line
  arrow                   # open object — line with arrowhead
  spline                  # open object — spline curve
  move
  TEXT TEXT ...           # text within invisible box
  plot <expr> TEXT        # formatted text
  '[' <command> ... ']'
```

Drawn objects within '[...]' are treated as a single composite object with a rectangular shape (that of the bounding box of all the elements). Variable and label assignments within a block are local to the block. Current direction of motion is restored to the value at start of block upon exit. Position is *not* restored (unlike '{ }'); instead, the current position becomes the exit position for the current direction on the block's bounding box.

```
<attribute> ::=
  h[eigh]t <expr>          # set height of closed figure
  wid[th] <expr>           # set width of closed figure
  rad[ius] <expr>          # set radius of circle/arc
  diam[eter] <expr>        # set diameter of circle/arc
  up [<expr>]              # move up
  down [<expr>]            # move down
  left [<expr>]            # move left
  right [<expr>]           # move right
  from <position>          # set from position of open figure
  to <position>            # set to position of open figure
  at <position>            # set center of open figure
  with <path>              # fix corner/named point at specified location
  with <position>          # fix position of object at specified location
  by <expr-pair>           # set object's attachment point
  then                     # sequential segment composition
  dotted [<expr>]          # set dotted line style
  dashed [<expr>]          # set dashed line style
  thick[ness] <expr>       # set thickness of lines
  chop [<expr>]            # chop end(s) of segment
  '->' | '<-' | '<->'      # decorate with arrows
  invis[ible]              # make primitive invisible
  solid                    # set solid line style
  fill[ed] [<expr>]        # fill closed figure with optional density
  xscaled <expr>           # slant box into x direction
  yscaled <expr>           # slant box into y direction
  colo[u]r[ed] TEXT        # set fill and outline color for figure
  outline[d] TEXT          # set outline color for figure
  shaded TEXT              # set fill color for figure
  same                     # copy size of previous object
  cw | ccw                 # set orientation of curves
  ljust | rjust            # adjust text horizontally
  above | below            # adjust text vertically
  aligned                  # align parallel to object
  TEXT TEXT ...            # text within object
  <expr>                   # motion in the current direction
```

Missing attributes are supplied from defaults; inappropriate ones are silently ignored. For lines, splines, and arcs, height and width refer to arrowhead size.

The ‘at’ primitive sets the center of the current object. The ‘with’ attribute fixes the specified feature of the given object to a specified location. (Note that ‘with’ is incorrectly described in the Kernighan paper.)

The ‘by’ primitive is not documented in the tutorial portion of the Kernighan paper, and should probably be considered unreliable.

The primitive ‘arrow’ is a synonym for ‘line ->’.

Text is normally an attribute of some object, in which case successive strings are vertically stacked and centered on the object’s center by default. Standalone text is treated as though placed in an invisible box.

A text item consists of a string or sprintf-expression, optionally followed by positioning information. Text (or strings specified with ‘sprintf’) may contain font changes, size changes, and local motions, provided those changes are undone before the end of the current item. Text may also contain \-escapes denoting special characters. The base font and specific set of escapes supported is implementation dependent, but supported escapes always include the following:

\fR, \f1   Set Roman style (the default)

\fI, \f2 Set Italic style

\fB, \f3 Set Bold style

\fP Revert to previous style; only works one level deep, does not stack.

Color names are dependent on the pic implementation, but in all modern versions color names recognized by the X window system are supported.

A position is an (x,y) coordinate pair. There are lots of different ways to specify positions:

```
<position> ::=
  <position-not-place>
  <place>
  ( <position> )

<position-not-place> ::=
  <expr-pair>
  <position> + <expr-pair>
  <position> - <expr-pair>
  ( <position> , <position> )
  <expr> [of the way] between <position> and <position>
  <expr> ’<’ <position> , <position> ’>’

<expr-pair> ::=
  <expr> , <expr>
  ( expr-pair )

<place> ::=
  <label>
  <label> <corner>
  <label> <reference-point>
  <corner> [of] <label>
  <reference-point> of <label>
  Here

<label> ::=
  LABEL [. LABEL ...]
  <nth-primitive>

<corner> ::=
  .n | .e | .w | .s
  .ne | .se | .nw | .sw
  .c[enter] | .start | .end
  .t[op] | .b[ot[tom]] | .l[eft] | .r[ight]
  left | right | <top-of> | <bottom-of>
  <north-of> | <south-of> | <east-of> | <west-of>
  <center-of> | <start-of> | <end-of>
  upper left | lower left | upper right | lower right

<reference-point> ::=
  .v[er[tex]] <expr>
  .v[er[tex]] ` <expr> '
  .mid[point] <expr>
  .mid[point] ` <expr> '

<xxx-of> ::=
  xxx                        # followed by ‘of’
```

```
<nth-primitive> ::=
  <ordinal> <object-type>
  [<ordinal>] last <object-type>

<ordinal> ::=
  INT th
  INT st | INT nd | INT rd
  ` <any-expr> 'th

<object-type> ::=
  box
  circle
  ellipse
  polygon
  arc
  line
  arrow
  spline
  '[]'
  TEXT
```

As Kernighan notes, “since barbarisms like **1th** and **3th** are barbaric, synonyms like **1st** and **3rd** are accepted as well.” Objects of a given type are numbered from 1 upward in order of declaration; the **last** modifier counts backward.

The “'th” form (which allows you to select a previous object with an expression, as opposed to a numeric literal) is not documented in DWB’s *pic*(1).

The ⟨*xxx*-of⟩ rule is special: The lexical parser checks whether *xxx* is followed by the token ‘of’ without eliminating it so that the grammar parser can still see ‘of’. Valid examples of specifying a place with corner and label are thus

```
A .n
.n of A
.n A
north of A
```

while

```
north A
A north
```

both cause a syntax error. (DWB **pic** also allows the weird form ‘A north of’.)

Here the special rules for the ‘with’ keyword using a path:

```
<path> ::=
  <relative-path>
  ( <relative-path> , <relative-path> )

<relative-path> ::=
  <corner>
  . LABEL [. LABEL ...] [<corner>]
```

The following style variables control output:

Style Variable	**Default**	**What It Does**
boxht	0.5	Default height of a box
boxwid	0.75	Default width of a box
lineht	0.5	Default length of vertical line
linewid	0.75	Default length of horizontal line
linethick	-1	Default line thickness
arcrad	0.25	Default radius of an arc
circlerad	0.25	Default radius of a circle
ellipseht	0.5	Default height of an ellipse
ellipsewid	0.75	Default width of an ellipse
moveht	0.5	Default length of vertical move
movewid	0.75	Default length of horizontal move
textht	0	Default height of box enclosing a text object
textwid	0	Default width of box enclosing a text object
arrowht	0.1	Length of arrowhead along shaft
arrowwid	0.05	Width of rear of arrowhead
arrowhead	1	Enable/disable arrowhead filling
dashwid	0.05	Interval for dashed lines
maxpswid	8.5	Maximum width of picture
maxpsht	11	Maximum height of picture
scale	1	Unit scale factor
fillval	0.5	Default fill value

Any of these can be set by assignment, or reset using the **reset** statement. Style variables assigned within '[ ]' blocks are restored to their beginning-of-block value on exit; top-level assignments persist across pictures. Dimensions are divided by **scale** on output.

All **pic** expressions are evaluated in floating point; units are always inches (a trailing 'i' or 'I' is ignored). Expressions have the following simple grammar, with semantics very similar to C expressions:

```
<expr> ::=
  VARIABLE
  NUMBER
  <place> <place-attribute>
  <expr> <op> <expr>
  - <expr>
  ( <any-expr> )
  ! <expr>
  <func1> ( <any-expr> )
  <func2> ( <any-expr> , <any-expr> )
  rand ( )

<place-attribute>
 .x | .y | .h[eigh]t | .wid[th] | .rad

<op> ::=
  + | - | * | / | % | ^ | '<' | '>' | '<=' | '>='

<func1> ::=
  sin | cos | log | exp | sqrt | int | rand | srand

<func2> ::=
  atan2 | max | min
```

Both **exp** and **log** are base 10; **int** does integer truncation; and **rand()** returns a random number in [0-1).

There are **define** and **undef** statements which are not part of the grammar (they behave as pre-processor macros to the language). These may be used to define pseudo-functions.

define *name* **{** *replacement-text* **}**

This defines *name* as a macro to be replaced by the replacement text (not including the braces). The macro may be called as

name(*arg1, arg2, . . ., argn*)

The arguments (if any) are substituted for tokens $1, $2 . . . $n appearing in the replacement text. To undefine a macro, say **undef** *name*, specifying the name to be undefined.

22. History and Acknowledgements

Original **pic** was written to go with Joseph Ossanna's original *troff*(1) by Brian Kernighan, and later re-written by Kernighan with substantial enhancements (apparently as part of the evolution of *troff*(1) into *ditroff*(1) to generate device-independent output).

The language had been inspired by some earlier graphics languages including **ideal** and **grap**. Kernighan credits Chris van Wyk (the designer of **ideal**) with many of the ideas that went into **pic**.

The **pic** language was originally described by Brian Kernighan in Bell Labs Computing Science Technical Report #116 (you can obtain a PostScript copy of the revised version, [1], by sending a mail message to *netlib@research.att.com* with a body of 'send 116 from research/cstr'). There have been two revisions, in 1984 and 1991.

The document you are reading effectively subsumes Kernighan's description; it was written to fill in lacunæ in the exposition and integrate in descriptions of the GNU *gpic*(1) and *pic2plot*(1) features.

The GNU **gpic** implementation was written by James Clark ⟨*jjc@jclark.com*⟩.

The GNU **pic2plot** implementation is based on James Clark's parser code and maintained by Robert Maier, principal author of **plotutils**.

23. Bibliography

1. Kernighan, B. W. **PIC — A Graphics Language for Typesetting (Revised User Manual)**. Bell Labs Computing Science Technical Report #116, December 1991.

2. Van Wyk, C. J. **A high-level language for specifying pictures**. *ACM Transactions On Graphics* 1,2 (1982) 163-182.