Drawing with dpic

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1 Introduction

This document is meant for persons using dpic to produce diagrams for LaTeX documents or web files. You are assumed to have basic knowledge of the pic language as described for the original Documenter's Workbench (ATT) pic or the current GNU pic (gpic) processor. For an introduction to the language, elementary examples, sample pictures, and other details, consult a gpic manual [4] or pic manual [3]. For the most part, dpic accepts gpic input but there are minor differences. The outputs of gpic and dpic are quite different but both can serve as preprocessors that create diagrams for inclusion in LaTeX documents.

The pic language is particularly suited for easily creating line diagrams such as electric circuits, and many persons use a package of macros called Circuit_macros along with the m4 macro processor. The pic language itself allows macro definitions, and both pic and m4 macros will be described.

Dpic usage will be reviewed, some programming examples that illustrate dpic extensions of the pic language will be given, then a summary of the differences among pic translators will be given, particularly the differences between gpic and dpic.

There had better be a disclaimer: The temptation to change the pic language has been resisted most of the time so that valid diagrams can be processed with minimal changes using the original Documenter's Workbench (ATT) pic, with gpic, or dpic. There are exceptions, of course: embedded word-processor commands principally, but also minor differences in defaults for valid pic input, a few gpic constructs that dpic does not implement directly, and some dpic extensions. For details, see Section 5.

2 Dpic usage

In the following, items in square brackets "[,]" are optional and items separated by a vertical line "|" are choices. To produce .tex output (for LaTeX, PSTricks, TikZ-PGF, mfpic processing):

```
  dpic [options] file.pic > file.tex
```

or

```
  cat file.pic | dpic [options] > file.tex
```

To produce other formats:

```
  dpic -[e|f|g|h|m|p|r|s|t|v|x|z] file.pic > file.[tex|eps|mp|fig|svg]
```

2.1 Options

Dpic accepts the following options:

(none)	Latex drawing commands
`-e`	pict2e output
`-f`	Postscript output with psfrag strings
`-g`	TikZ-PGF output
`-h`	write out these options and quit
`-m`	mfpic output
`-p`	PSTricks output
`-r`	raw Postscript output
`-s`	MetaPost output
`-t`	eepicemu output
`-v`	svg output
`-x`	xfig 3.2 output
`-z`	safe mode (`sh`, `copy`, and print to file disabled)

The `-p` option produces output for postprocessing by PSTricks, and is useful for many purposes. Similarly, the `-g` option produces output for postprocessing by TikZ-PGF and makes pdf production via pdflatex a one-step process.

Mfpic and MetaPost output is provided for compatibility.

The `-r` option produces Postscript `eps` files, in which font changes or typesetting must be done explicitly. The `-f` option writes Postscript strings in psfrag format for tex or latex typesetting.

The `-v` option produces svg for including figures in web documents or for further processing by the Inkscape graphics editor, for which svg is the native format. There are two possibilities.

Either the svg output is used directly as a web document, in which case as for Postscript, text formatting must be handled explicitly.

The other possibility for svg output is that, for example, an svg library of elements is drawn by dpic, and Inkscape used to place and connect copies of the elements. Then Inkscape can export the graphics as eps for processing by LaTeX or as pdf for processing by pdflatex. Inkscape will also export a tex file from which labels can be formatted and overlaid on the imported eps or pdf.

In all cases, arbitrary postprocessor commands (that is, arbitrary PSTricks, SVG, Postscript, or other commands) can be inserted into the dpic output from the source. This adds considerable power for manipulating diagram elements at the expense of integrating them into normal dpic output.

The `-z` option disables the commands that access external files. These commands can be permanently disabled by the use of a compile-time option.

The file Examples.txt contains a minimal example of each of these options except `-z`. Consult the appropriate manual for processing mfpic, PSTricks, MetaPost, pgf, or psfrag output.

Invoking dpic without options produces basic LaTeX drawing commands by default. LaTeX line slopes, for example, are very limited and you must ensure that lines and arrows are drawn only at acceptable slopes. Dpic sets the maximum slope integer to be 6 for LaTeX, 453 for eepic, and 1000 for pict2e. To see the effect of the slope limitations, process the following:

```
.PS
rtod = 180/atan2(0,-1)
for theta = 0 to 360 by 2 do {
  line from 0,0 to cos(theta/rtod),sin(theta/rtod)
  }
line from 0,0 to 2,0
line from 0,0 to 0,2
.PE
```

2.2 Lexical error messages

Lexical error messages are generated automatically, and state the lexical value that was found and what was expected. Some non-obvious lexical values are:

`<EOF>`	end of input

`<ERROR>`	an error is considered valid input during error recovery
`<NL>`	new line or `;`
`<corner>`	a compass corner or `.c`, `.start`, `.end`
`<envvar>`	environmental variable
`<func1>`	numerical function of 1 argument
`<func2>`	numerical function of 2 arguments
`<param>`	`.ht`, `.wid`, `.rad`, `.diam`
`<primitiv>`	`box`, `circle`, `ellipse`, `arc`, `line`, `arrow`, `move`, `spline`

3 Dpic programming

Pic is a simple language with a good ratio of power to complexity, so surprisingly sophisticated diagrams can be produced in several areas of application. Arbitrary postprocessor commands can be output and several of the postprocessors are powerful drawing languages in their own right, so it can be argued that dpic has all the power of these languages. However, if you find yourself writing extensive postprocessor code then you might ask why you are not programming exclusively in that language.

Pic is very suitable for line diagrams, and recent language extensions allow for basic color. Elaborate fills and cropping are the domain of the postprocessors, but can be included easily with the use of macros.

The following sections are intended to help you become familiar with dpic language features. Some of these details are exclusive to dpic and are not described in the GNU manual, for example, but are discussed in Section 5 of this document.

3.1 Blocks

The basic planar objects in pic are `box`, `circle`, and `ellipse`, the placing of which is done according to the current drawing direction or by explicit placement such as

`box at` *position*

which places the object so that its center is at *position*.

A block, or composite object, is a group of elements enclosed by square brackets, such as

`Q: [ B: [A: arc]; circle ]`.

The block is placed by default as if it were a box, and its resulting compass corners `Q.n`, `Q.sw`, … will be defined. The position `Q` will be the center of the block.

3.1.1 Positioning blocks

An entire block can be positioned by specifying the location of one of its defined points. A defined point is one of the following.

1. A compass corner `.center`, `.n`, `.ne`, … of the block
2. A defined point of a labeled object or position within the block, preceded by a dot, e.g.,
   ```
   Q: [ B: [A: arc]; circle ] with .B.A.ne at position
   ```
3. A defined point of an enumerated object in the block, preceded by a dot (but make sure there is a space after the dot if it is followed by a number), e.g.,
   ```
   Q: [ B: [A: arc]; circle ] with . 1st circle at position
   ```
   Even better, put braces around the ordinal value, which can now be any expression, e.g.,
   ```
   ... with .{10-9}th circle at ...
   ```
4. A displacement `(x,y)` from the lower left corner of the block, e.g.,
   ```
   Q: [ B: [A: arc]; circle ] with (0.5,0.2) at position
   ```

Reference to a defined point is recursive, as the second example above shows, and may correspond to drilling down through several block layers.

3.1.2 Defining scope

Variables defined within a block are accessible only within the block itself or its sub-blocks. Thus, the statement `x = 5` creates the variable `x` and assigns it a value. If the statement is `x := 5` then `x` must already have been defined either in the block or in a scope containing the block. Limiting the scope to a block avoids name conflicts.

Macro definitions are not local to blocks, however, so care must be taken to avoid conflicts with macro names or variables defined within macros.

As shown in the previous subsection, locations inside a block are accessible from outside, but the values of variables are not; thus, an error results from

```
Q: [ v = 5 ]; y = Q.v
```

Variable values can be exported, if you must, using the following trick:

```
Q: [ v = 5; w = 6
  Origin: (0,0); Export: (v,w) ]
v = Q.Export.x - Q.Origin.x
w = Q.Export.y - Q.Origin.y
```

This method works because all locations inside the block will be translated by the same amount no matter where the block is positioned. Their differences therefore remain constant, with one exception: if the dpic `scaled` *x* construct has been employed, the trick has to be modified as shown:

```
  s = 0.7
  Q: [ v = 5; w = 6
    Origin: (0,0); Export: (v,w) ] scaled s
  v = (Q.Export.x - Q.Origin.x)/s
  w = (Q.Export.y - Q.Origin.y)/s
```

3.2 Dpic Macros

Macros can be used to turn the basic dpic language into a powerful tool for producing line drawings. A macro serves to

- specialize the pic language in order to draw components from an application area
- abbreviate long sequences of repetitive commands
- substitute particular values in commands by the use of macro arguments
- provide conditional text replacement depending on the value of its arguments
- provide recursive looping

The pic language includes basic macro facilities, but the m4 macro processor [2, 5] makes a good companion to the language, so both will be mentioned.

General-purpose macro definitions can be stored in files external to the diagram source and read in automatically. In particular, the author has written a package called Circuit_macros for drawing electric circuits and other diagrams using dpic and m4 [1], from which examples will be taken.

A dpic macro is defined by the statement

`define` *name* `{` *contents* `}`

where *name* may begin with a lowercase or uppercase letter. Then any separate appearance of *name* in the following lines is replaced by the characters between the defining braces, including newlines. If the name is given arguments of the form

name(*x*, *y*, *z*, …)

then, in the macro body, `$`*n* expands to the nth argument, which may be nul, if at least one argument has been defined and *n* is a positive integer. Otherwise `$`*n* is not evaluated.

Dpic skips white space immediately preceding macro arguments, so that, for example,

```
  name( x,
   y, z )
```

is equivalent to

```
name(x,y,z )
```

In a macro invocation, the arguments are separated by commas. An argument may contain commas if they are contained within strings or `()` parentheses. A double quote character within a string must be preceded by a backslash. Thus, for example, the macro

```
name(ABc"\"t,"(,DE,F))
```

has one argument.

In a dpic macro, the value of `$+` is the number of arguments given to the macro on invocation. Thus if *x* is a macro name, the values of `$+` when the macro is invoked as *x*, *x*`()`, *x*`(8)`, *x*`(8,9)`, and *x*`(,,)` are respectively 0, 1, 1, 2, and 3.

3.2.1 Finding roots

A root finder is a powerful tool for determining where lines or curves intersect in diagrams, and can be implemented using a macro. Consider the trivial example in which we wish to find the root of $x^2 - 1$ between 0 and 2. First, we define a macro called `bisect` by reading in a library file containing definitions, using a command such as

```
copy "filename"
```

or by writing a definition such as given below, which employs the method of bisection, a suitably robust (but not particularly fast) algorithm. We define the two-argument macro corresponding to the function of which we want to calculate the root:

```
define parabola { $2 = ($1)^2 - 1 }
```

In general, many statements might be required to calculate the function, but the essential statement is to assign the function value to the name given by the second argument. Then we call the `bisect` macro using a command such as

```
bisect( parabola, 0, 2, 1e-8, x )
```

where the second and third arguments define the search interval, the fourth argument specifies the solution precision, and the fifth argument is the name of the variable to be set to the root. A basic version of `bisect` is given by

```
define bisect {
  x_m = $2; x_M = $3
  x_c = (x_m+x_M)/2
  if (abs(x_m-x_M) <= $4) then { $5 = x_c } else {
     $1(x_m,f_m)
     $1(x_c,f_c)
     if (sign(f_c)==sign(f_m)) then { bisect($1,x_c,x_M,$4,$5) } \
     else { bisect($1,x_m,x_c,$4,$5) } }
  }
```

This macro repeatedly calls `parabola` and then itself, halving the search interval until it is smaller than the prescribed precision. The Circuit_macros library version operates essentially as above but avoids name clashes by appending the value of the first argument to the internal names.

3.2.2 Composing statements

Dpic macro arguments can be expanded almost anywhere. Suppose that circles `A` and `B` have been defined, with intersections at positions `AB` and `BA` found using the macro `cintersect` from Circuit_macros, for example. Then the boundary of the region within both circles might be drawn using the macro shown, invoked as `lozenge(A,B)`:

```
define lozenge {
  arc from $1$2 to $2$1 with .c at $2
  arc from $2$1 to $1$2 with .c at $1 }
```

3.2.3 Branching

Pic has a basic if-statement of the form
  `if` *expression* `then {` *if-true* `} else {` *if-false* `}`
but lacks a case statement. Multiple branches can be defined by nested `if` statements but there is another way that uses the dpic statement
  `exec` *string*
which executes the contents of *string* as if it were the current input line. Since
  `sprintf("`*format*`",`*expression*`,`...`)`
behaves like a string, consider the macro definition
```
  define case { exec sprintf("$%g",floor($1+0.5)+1); }
```
This macro adds 1 to its rounded first argument to determine which alternative among the remaining arguments should be executed; thus
```
  case(2,
    print "A",
    print "B")
```
executes the second alternative (the third argument) and prints B. In the definition of `case`, the semicolon or a newline is necessary to prevent dpic from leaving the macro before performing the `exec` statement.

3.3 M4 macros

M4 is a simple but powerful macro language originally distributed with Unix systems [2], but free versions are now available for other operating systems. The use of this language requires an extra processing step, but the power and flexibility of the macros easily make up for it. The macro definitions are read before the text to be processed, typically by a system command such as

```
  m4 library.m4 diagram.m4 | dpic -g > diagram.tex
```

An m4 macro is defined as follows:

```
  define(‘name’,‘contents’)
```

so that distinct occurrences of *name* will be replaced by *contents* in the following text. This basic description is a vast simplification of the power that results from conditional substitution, loops, recursion, file inclusion, integer arithmetic, shell commands, and multiple input and output streams. The online manual [5] is a good source of details.

A general rule might be that floating point computation is in the domain of dpic macros but text substitution is often better done in m4 macros.

When m4 reads text, it strips off pairs of single quotes: thus, `‘text’` becomes `text`. If `text` is read again, as when it is a macro argument, for example, then the process is repeated. The single quotes serve to delay the evaluation of macros within `text`, as in macro definitions described above. Therefore, to avoid m4 changing dpic macro definitions or LaTeX, enclose them in single quote pairs.

Some simple applications of m4 macros are illustrated in the subsections that follow.

3.3.1 Branching

As an illustration of m4 macros, suppose that commands that are specific to the postprocessor must be generated. Then the macro

```
  ifpgf(‘pgf-specific commands’,‘other commands’)
```

for example, should expand to its first argument if pgf is to be the postprocessor, otherwise it should expand to the second argument. To implement this, `ifpgf` is defined in the statement

```
  define(‘ifpgf’,‘ifelse(m4postprocessor,pgf,‘$1’,‘$2’)’)
```

which tests for equality of the character sequences `m4postprocessor` and `pgf`. However, if `m4postprocessor` is the name of a macro, it is replaced by the macro text before the test is performed, and if the macro text is `pgf`, then the first argument of `ifpgf` is evaluated. In the Circuit_macros package, m4 is required to read a postprocessor-specific file before anything else, and that file contains the required definition of `m4postprocessor`.

The built-in macro `ifelse` can have multiple branches, as illustrated below:

```
  ifelse(m4postprocessor,pstricks,‘PSTricks code’,
m4postprocessor,pgf,`TikZ PGF code',
m4postprocessor,mfpic,`Mfpic code',
m4postprocessor,mpost,`MetaPost code',
m4postprocessor,xfig,`Xfig code',
m4postprocessor,postscript,`Postscript code',
m4postprocessor,svg,`SVG code',
`default code')
```

3.3.2 Perpendiculars

The Circuit_macros `vperp` macro illustrates how m4 macros can extend the pic language. The purpose is to generate a pair of values representing the unit vector perpendicular to a given line, say.

```
define(`vperp',
 `define(`m4pdx',`(`$1'.end.x-`$1'.start.x)')dnl
  define(`m4pdy',`(`$1'.end.y-`$1'.start.y)')dnl
  -m4pdy/vlength(m4pdx,m4pdy),m4pdx/vlength(m4pdx,m4pdy)')
```

The macro can be invoked as `vperp(A)` where `A` is the name of a line. Another invocation might be `vperp(last line)`. First, two macros (beginning with `m4` to avoid name clashes) are defined as the x-distance dx and y-distance dy of the end of the line from the start. The macro evaluates to the pair $-dy/\sqrt{(dx)^2 + (dy)^2}$, $dx/\sqrt{(dx)^2 + (dy)^2}$, where the denominators are calculated by the macro `vlength`.

3.3.3 Setting directions

The pic language defines the concept of the current drawing direction, which is limited to `up`, `down`, `left`, and `right`. Two-terminal circuit elements, for example, might have to be drawn in any direction, which calls for the ability to define diagrams without knowing their orientation and to rotate the result at will. This capability can be added to the basic pic language by judicious use of macros.

First, instead of defining positions in the usual way, such as in
```
  line from (x1,y1) to (x2,y2)
```
for example, let us agree to write
```
  line from vec_(x1,y1) to vec_(x2,y2)
```
where `vec_(x1,y1)` evaluates to
```
  (a*x1 + b*y1, c*x1 + d*y1)
```
Then if `a` and `d` are `cos(theta)`, `b` is `-sin(theta)`, and `c` is `sin(theta)`, this transformation

corresponds to rotating the argument vector by an angle `theta`. To produce relative coordinates, the macro `rvec_(x,y)` evaluates to

```
  Here + vec_(x,y),
```

so writing

```
  line to rvec_(x1,y1)
```

draws a line from the current position `Here` to a point `(x1,y1)` defined with respect to rotated coordinates.

The Circuit_macros package makes extensive use of versions of the above two macros. The angle and transformation constants are set using macros

`Point_(`*degrees*`)` and `point_(`*radians*`)`,

which have angles as arguments.

This usage is illustrated by the macro `lbox`, which draws a pic-like box oriented in the current direction. It can be defined as

```
define(‘lbox’,
 ‘define(‘m4bwd’,ifelse(‘$1’,,boxwid,‘($1)’))dnl
  define(‘m4bht’,ifelse(‘$2’,,boxht,‘($2)’))dnl
  line from rvec_(m4bwd,0) to rvec_(m4bwd,m4bht/2) \
    then to rvec_(0,m4bht/2) \
    then to rvec_(0,-m4bht/2) \
    then to rvec_(m4bwd,-m4bht/2) \
    then to rvec_(m4bwd,0) ‘$3’ ’)
```

The macro is invoked as `lbox(`*width*`, `*height*`, `*type*`)`; for example,

```
  Point_(20); lbox(,,fill 0.9)
```

draws a light gray-filled box of default size at an angle of 20 degrees from the horizontal. In the macro, the width and height of the box are first defined, using default values if the first and second arguments are not given. Then a line is drawn to outline the box, and the `fill 0.9` argument is appended to the line command to fill the box. A slightly more elaborate version that encloses the box in `[, ]` brackets is given by the Circuit_macros `rotbox` macro.

3.4 Subscripts

Dpic allows variables and capitalized labels to have subscripts; thus `x` and `x[4]` are distinct variable names, and can be employed in expressions as usual. Similarly, `P` and `P[3]` are distinct labels.

3.4.1 Assigning an array of numbers

We can assign an array of numbers to subscripted variables using statements such as

```
  x[1] = 47
  x[2] = 63
  ⋮
```

and so on, but generating the subscripts is inconvenient, particularly when these statements are obtained by editing a data file. One way of entering the data is to employ the m4 macro definition

```
  define(`inx',`define(`m4x',ifdef(`m4x',`incr(m4x)',1))m4x')
```

Then, writing

```
  x[inx] = 47
  x[inx] = 63
  ⋮
```

and processing with m4 automatically generates the required subscripts. The macro sets `m4x` to 1 if it is not yet defined, otherwise it increments `m4x`, and then it evaluates to `m4x`. On completion of the assignments, `m4x` has the value of the last subscript.

Another way of assigning variables to a subscripted variable is by the definition

```
  define array {
    for i=2 to $+ do { exec sprintf("$1[%g] = $%g",i-1,i); } }
```

which equates the subscripted first argument to the values in argument 2, 3, ... so that, for example,

```
  array(x,9,-4,7,4.2,0,0,7.9,0,0,10,11,12,13,14,10)
```

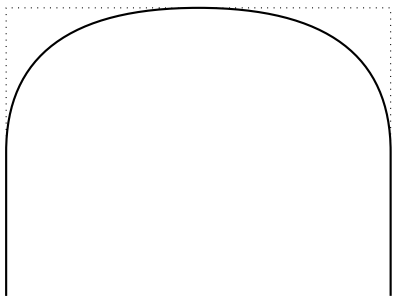
assigns the second to sixteenth arguments to `x[1]` to `x[15]` respectively.

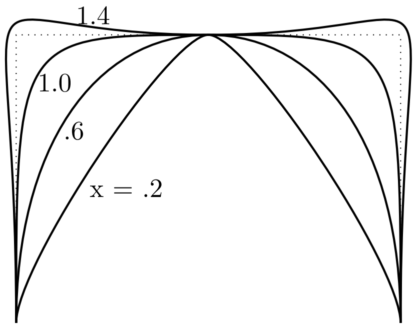
Dpic does not define vector operations, but it is easy to define macros for them, for example, to define 3-dimensional vectors, transform them, and to project them onto a drawing plane.

3.5 Splines

Dpic implements standard pic splines by default, as in the figure, which shows the result of the command

```
  spline up 1.5 then right 2 then down 1.5
```





A straight line is drawn along the first half of the first segment and the last half of the last segment. The curve is tangent to the centres of intermediate segments. The dpic result of including an expression after `spline`, as in

```
  spline x up 1.5 then right 2 then down 1.5
```

is shown on the right of the figure, as the tension parameter `x` varies from 0.2 to 1.4. The curve begins at the start of the first segment and terminates at the end of the last segment. The tension parameter can be varied to assist in fitting a multisegment spline to a curve. It turns out, for example, that the optimum tension for approximating a circle using four splines is the value 0.551784.

3.5.1 Curve fitting

Splines are drawn with respect to control points, but only pass through the first and last point. Suppose that a sequence of points `X[0]`, `X[1]`, ... `X[n]` has been given, and a spline is to be found to pass through each of them. The control points `P[0]`, `P[1]`, ... `P[n]` have to be calculated. These points satisfy the following equations:

```
  P[0] = X[0]
  P[i-1]/8 + P[i]*3/4 + P[i+1]/8 = X[i] for i = 1 to n-1
  P[n] = X[n]
```

The Circuit_macros `fitcurve` macro performs the required calculations and draws the spline to pass through the given points.

3.6 Postprocessor commands and color

Arbitrary postprocessor commands can be interspersed with pic statements to achieve effects such as gradient fills, clipping, and transformations. There are two ways of passing commands into dpic output.

Dpic lines beginning with the backslash `\` are passed through to the output without modification. This method works well for TeX statements, LaTeX statements, and commands to postprocessors that rely on the TeX macro processing.

The second method that does not require a command to start with a backslash is the form
  `command "`*text*`"`
or
  `command sprintf("`*format*`",`*expression*`,...)`
both of which pass the contents of the string into the output stream without the enclosing quotes.

Both of the above methods add considerable power to the pic language, but there are two issues. The first is that if a postprocessor transformation changes the size of a drawn element, the pic processor will not know the new sizes unless they are explicitly calculated. The second is that if the same operation is to be performed by postprocessors, then designing a macro that has identical effect using any of a variety of postprocessors can be challenging.

The Circuit_macros library contains several routines that produce equivalent or nearly equivalent results for several postprocessors. It is probably a good rule to stick with one or two postprocessors such as Tikz-pgf or PSTricks.

3.6.1 Color

From version 18, gpic allows coloured lines and filled objects as follows, and dpic allows them where the postprocessor supports them:
  object `outlined` *string*
  object `shaded` *string*
  object `colored` *string*
where *string* specifies a colour compatible with the postprocessor. For planar objects, the third case is equivalent to
  object `outlined` *string* `shaded` *string*
For the linear objects line, arrow, spline, dpic treats
  `colored` *string*
to be the same as
  `outlined` *string*
but fill can be added by explicitly writing
  `outlined` *string* `shaded` *string*

The original pic language does not include the `outlined` or `shaded attributes`. Current processors recognize these but know nothing about color except as strings attached to drawing elements. What the string should be depends on the postprocessor.

3.6.2 Filling with color

Basic pic shapes such as boxes, circles, and ellipses can be colored and filled using, for example,
`ellipse shaded "`*color*`" outlined "`*color*`"`
and, if the two colors are the same, this can be abbreviated as
`ellipse colored "`*color*`"`
where the color strings are compatible with the postprocessor. For example, the definitions

```
define(`gold_',`1,0.84,0')
ifelse(m4postprocessor,pstricks,
 `command "\definecolor{`gold'}{rgb}{gold_}"',
m4postprocessor,pgf,
 `command "\definecolor{`gold'}{rgb}{gold_}"',
m4postprocessor,mpost,
 `define(`gold',`(gold_)')',
m4postprocessor,postscript,
 `define(`gold',`1 0.84 0')')
```

allow the command
`circle shaded "gold"`
to work for the three different postprocessors specified plus direct postscript output.

More elaborate options can also be invoked. For example, with PSTricks output the sequence

```
  box shaded "lightgray,fillstyle=hlines*,linecolor=blue,
  hatchwidth=0.5pt,hatchsep=5pt,hatchcolor=red,hatchangle=45"
```

produces a hatched multicoloured fill and is equivalent to

```
  command "\pscustom[fillcolor=lightgray,fillstyle=hlines*,linecolor=blue,"
  command "hatchwidth=0.5pt,hatchsep=5pt,hatchcolor=red,hatchangle=45]{%"
    box
  command "}%"
```

One limitation of the pic language is that it lacks the concept of a path composed of different basic curves such as lines, splines, and arcs. The language was never explicitly designed to draw filled objects of arbitrary shape. Dpic, however, extends the `shaded` and `outlined` directives to linear objects such as lines or splines. (This implementation is incomplete for some output formats.) Consider, for example, the following macro:

```
define slantbox { [
  w = $1 ; h = $2 ; xs = $3 ; ys = $4
  NE: (w+xs,h+ys)/2 ; SE: (w-xs,-h+ys)/2
  SW: (-w-xs,-h-ys)/2 ; NW: (-w+xs,h-ys)/2
  N: 0.5 between NW and NE ; E: 0.5 between NE and SE
  S: 0.5 between SE and SW ; W: 0.5 between SW and NW
  C: 0.5 between SW and NE
  line $5 from N to NE then to SE then to SW then to NW then to N
  ] }
```

This macro implements a version of the `xslanted` and `yslanted` attributes recently introduced for gpic boxes, for example

```
  box wid 0.1 ht 0.5 xslanted 0 yslanted 0.1 \
    shaded "Dandelion" outlined "black"
```

The `slantbox` macro defines the implied compass corners `N`, `S`, `NE`, ... Its fifth argument can be used to fill or otherwise specify the line. For example, the command

```
  slantbox(0.1,0.5,0,0.1,shaded "Dandelion" outlined "black")
```

is equivalent to the gpic example. The above macro can be easily modified to produce arbitrary polygons, for example. The color `Dandelion` is automatically defined for PSTricks by the LaTeX line

```
  \usepackage[dvipsnames]{pstricks}
```

For TikZ-PGF, try

```
  \usepackage[usenames,dvipsnames]{xcolor}
  \usepackage{tikz}
```

4 SVG and Postscript output

The `-r` (raw Postscript), `-v` (SVG), and `-x` (xfig) options of dpic produce output that is not intended to be processed by LaTeX.

4.1 Bounding boxes

The Postscript and SVG produced by dpic `-r` and dpic `-v` respectively deserve attention because the output is not always meant to be imported into LaTeX or printed on paper. In particular, the bounding box of the diagram is not always know exactly or even defined exactly, since it can depend on the context in which the diagram is to be used. Different line widths, mitred joints, splines, colored output, over-painting, arbitrary text, arbitrary Postscript or svg, and other complications are also allowed within a diagram; consequently dpic can only provide an estimate of the exact bounding box.

There is apparently no reliable way to know the exact bounding box of arbitrary SVG text, so dpic uses an approximation and text placement on diagrams may have to be adjusted by hand.

Truncated text: The dpic `textht` environmental variable often gives dpic a good estimate of the actual height of embedded text, but the width of the text is more difficult to estimate. Consequently, text is often truncated by the figure bounding box at the left or right edge of the figure. Setting the width of strategic strings by hand, e.g. `"string" wid 0.75` often serves as a quick cure in specific cases, but cannot be done automatically. Otherwise, strategic `move` commands can be used to enlarge the bounding box as illustrated at the end of the discussion below.

Postscript bounding boxes: For a while, the dpic `%%BoundingBox` output line simply gave the nominal bounding box determined by line ends and other control points. The use of dpic in server mode has induced a change that correctly defines the bounding box for very basic diagrams. More explicitly, consider

```
.PS
box with .sw at 0,0
.PE
```

which draws a box with southwest corner line centres intersecting at Postscript coordinates 0,0 and northeast intersection at 54,36. Dpic `-r` augments this nominal bounding box by half of the last `linethick` value (default `linethick` is 0.8 pt) in the outermost diagram scope to produce the Postscript bounding-box definitions

```
%%BoundingBox: -1 -1 55 37
%%HiResBoundingBox: -0.4 -0.4 54.4 36.4
```

The `%%BoundingBox` line contains integer values that enclose the high-resolution coordinates.

Manual bounding box adjustment: It may be necessary to adjust the bounding box manually. To zero the automatic adjustment for Postscript or SVG output, put `linethick=0` at the end of the outermost scope. Then arbitrary margins can be added to the nominal box as shown below, where 2, 1, 1, and 0 points are added to the left, bottom, right, and top margins respectively:

```
.PS
Diagram:  [
  drawing commands
]
linethick = 0
move from Diagram.sw-(2,1)/72*scale to Diagram.ne+(1,0)/72*scale
.PE
```

5 Pic processor differences

Differences among processors, and between dpic and gpic particularly, are summarized below. Normally, the only changes required to process correct pic or gpic input with dpic are changes to `{...}` instead of `X...X` syntax as explained below, together with text formatting if the original code was written for groff. The remaining differences documented below are small syntactical differences or relate to the use of PSTricks or the other dpic output formats. Sometimes differences in default syntax (such as for arcs) must be considered.

Gpic is being actively maintained so some of the items below apply only to older versions.

5.1 Command-line options

They are completely different, of course. Type dpic -h to see a list of dpic options.

5.2 Output formats

Gpic `-t` output consists of a sequence of `\special` statements contained in the TeX box `\box\graph`. The `\special` statements are automatically copied into the `.dvi` file for interpretation by a printer driver such as dvips.

Dpic does not generate tpic specials. See the option list in Section 2 for output formats.

5.3 . lines and program-generated pic

Gpic passes lines beginning with . through to the output, thereby allowing arbitrary Troff macros to be interspersed with pic drawing commands. Some programs that generate pic output automatically insert the Troff line

```
  .ps 11
```

on the assumption that the text point size should be 11. Dpic ignores lines beginning with . within pictures. Some programs (e.g., pstoedit) add Troff comment lines beginning with `.\"` outside the `.PS`, `.PE` delimiters. These lines must be dealt with separately.

5.4 \ lines

Both gpic and dpic pass lines beginning with `\` to the output but dpic does not automatically append a `%` at the end as gpic does.

5.5 `for`-loop and `if` bodies

In gpic, a for loop has the form

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

where X is any character not occurring in body, but `{` *body* `}` is also allowed. In dpic only the latter is allowed. Similarly, the required form of an if statement for dpic is

`if` *expr* `then {` *if-true* `}` [`else {` *if-false* `}`]

5.6 End of line

The line end is significant in the pic grammar. The construction

`if` *condition* `then {` *if-true* `}`
`else {` *if-false* `}`

produces an error with all pic interpreters. To avoid this error, write

`if` *condition* `then {` *if-true* `} \`
`else {` *if-false* `}`

where `\` is the last character of the line or is followed by the `#` character beginning a comment which ends at the end of the line. However, dpic ignores line ends following `then`, `{`, `else`, or end of line. Both the CR (octal 015) and NL (octal 012) characters are treated as line ends.

5.7 Logic

Dpic and gpic give slightly different default precedences to the logical operators `!`, `&&`, `||`, `==`, `!=`, `>=`, `<=`, `<`, and `>`, so judicious use of parentheses may sometimes be in order to guarantee identical behavior. In addition, put string comparisons in parentheses, e.g.

`("`*text1*`" == "`*text2*`")`

The construct `x<A,B>` is intended to have the same meaning as `(x between A and B)` but in some obscure circumstances all pic interpreters have difficulty determining whether the `<` character is part of such an expression or is a logical comparison operator. Dpic treats `<` as a comparison in the expression following `if` so the form `(x between A and B)` should be used in such expressions, e.g.

```
if (0.5 between A and B).y < 2 then { ... }
```

5.8 `then`

Versions of gpic up to 1.19 ignore the `then` keyword, so that

```
line -> then up 0.5
```

draws one line segment and is the same as

```
  line -> up 0.5
```

whereas dpic does not ignore `then`, and draws two line segments. Newer versions of gpic also draw two segments.

5.9 `line`, `spline`, `arrow`, `move`

Dpic treats the defaults for linear objects consistently with planar objects with respect to the `at` modifier. Versions of gpic up to 1.19 treated them differently:

In dpic, `line at Here` means `line with .center at Here`.
In gpic, `line at Here` means `line with .start at Here`.

In dpic, the location corresponding to `last line` is `last line.c`.
In gpic, the location corresponding to `last line` is `last line.start`.

The compass corners of multisegmented linear objects are not precisely defined and they should be used with care.

5.10 Arc defaults

Gpic and dpic have different algorithms for picking a default radius. The best practice is to specify arcs completely. Note the ambiguity in the pic language:

```
  arc cw rad x from A to B
```

does not uniquely define a unique arc. There are two arcs, with centres on opposite sides of the line joining `A` and `B`, that satisfy this specification. Instead, use

```
  arc cw from A to B with .c at C
```

5.11 Strings

Strings are arbitrary character sequences between double quotes, with double quotes in strings preceded by the backslash character. Equivalently, a string is produced by the C-like sprintf function

  `sprintf("`*format*`"` [`, expression, ...`]`)`

The C sprintf function is used for implementing this; therefore, the precision of default formats such as `%g` may vary by machine and compiler. To produce transportable results, specify the precision completely, e.g. `%8.5f`. As in C, the pair `%%` in the format string prints the percent character. Only the `f`, `e`, `g` formatting parameters are valid, since expressions are stored as floating-point numbers, e.g.

```
  line sprintf("%g%g0", 2, 0 ) above
```

is equivalent to

```
  line "200" above
```

Similarly,

```
  command sprintf("\pscircle(%g,%g){%g}",0,0,0.5)
```

places the formatted string into the output. The numerical `sprintf` arguments can be arbitrary expressions rather than the constants shown.

Dpic allows strings to be concatenated by the `+` operator; thus,

```
  "abc" + sprintf(" def%g",2)
```

is equivalent to `"abc def2"`.

Both dpic and gpic treat `\` as an escape character prior to the quote character in a string, so `"\""` is a length-one string containing the double quote. Otherwise, the backslash is an ordinary string character. In a macro, a dollar sign followed by an integer in a string will expand to the corresponding macro argument if it is defined. Separate the dollar sign from the integer to avoid expansion, as in the TeX strings `"{\$}1"`, `"$\$ 1$"`, or `"${0}$"`, for example. Some previous versions of dpic allowed `$` to escape the dollar sign in strings but this created other difficulties.

Both dpic and gpic allow logical comparison of strings. Put the comparison in parentheses.

String height and width are unscaled on final output from dpic since these depend on later formatting by LaTeX.

5.12 `print` *arg*, ...

Dpic allows only one argument, which may be an expression, position, or string. To print several quantities at once, use

```
  print sprintf(...)
```

to generate a string and, if the string is complicated, remember that *string1* `+` *string2* `+` ... evaluates to one string.

Dpic sends the print output to a file using the command

  `print` *arg* `> "`*filename*`"`

which creates the named file, or

  `print` *arg* `>> "`*filename*`"`

which appends output to the named file if it exists. If the `-z` option has been invoked or dpic was compiled in safe mode, both of these give warning messages rather than writing to the file.

5.13 `command` *arg*, ...

Arbitrary commands are sent to the standard output stream. Dpic allows only one argument, which is a string or `sprintf(...)`.

5.14 Operating system commands

With dpic, the required form for a shell (operating system) command is
  `sh "`*text*`"`
or
  `sh sprintf("`*format*`",`*expression*`,...)`

5.15 `copy`

Dpic supports the command
  `copy "`*filename*`"`
but does not directly support the commands
  `copy` [*filename*] `thru X` *body* `X` [`until` *word*]
  `copy` [*filename*] `thru` *macro* [`until` *word*]
These functions (and more) are readily implementable with dpic in any unix-like environment. To customize an operation such as
  `copy` *filename* `thru` *macro*
modify the following example, as appropriate. This usage is not as simple as a built-in function but allows much more flexibility of data.

```
.PS
#                                Suppose that file.dat contains rows of data
#                                delimited by spaces.

#                                Macro to process a row of data, e.g.
#                                save the first 4 values:
  define store { n = n+1; x[n] = $1; y[n] = $2; z[n] = $3; w[n] = $4 }

#                                Use sed to convert the data to a sequence
#                                of calls to the store macro:
  sh "sed -e 's/^ */store(/' -e 's/ *$/)/' -e 's/  */,/g' file.dat >tempfile"

#                                Initialize the counter and process the data
  n = 0; copy {\tt tempfile}
```

```
#                               Delete the temporary file
  sh "rm tempfile"
.PE
```

5.16 `plot`

The `plot` command is deprecated in gpic and not allowed in dpic.

5.17 Line thickness

A negative line thickness value is meaningless in dpic. Big points are used (1/72 in) in MetaPost output to conform to PSTricks.

5.18 `fill`

In gpic, a fill value of 0 means white, 1 means black. Dpic uses 0 as black and 1 as white as do Postscript and the original ATT pic.

The pic language specifies fill only for box, ellipse, and circle, but fill is supported by dpic using the `shaded` directive. The concept of a path containing several arbitrary linear objects does not exist in the pic language but can be implemented using postprocessor commands inserted into `command` *string* statements.

5.19 Scaling

Dpic implements a `scaled` attribute, so that

```
box scaled 1.2
```

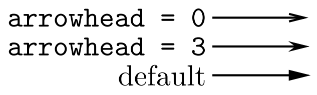
produces a box with dimensions scaled by 1.2, and

```
[box; line scaled 3; circle] scaled 0.5
```

scales all objects within the block by 0.5. The latter can be used in place of setting the scale environment variable when, for example, different parts of a diagram require different scaling. As always, line thicknesses are not scaled.

5.20 Arrowheads

Pic processors provide a limited variety of built-in arrowhead shapes. Dpic draws arrowheads when the the output format allows and the environment variable `arrowhead` is either 0 or 3 as shown below.



Any other value of `arrowhead` produces the filled head shown but also results in an a head shape native to the postprocessor in some cases. The default value of `arrowhead` is 2 in conformance with other pic processors. Postprocessor parameters can be changed using lines of the form

`command "`*postprocessor commands*`"`

Changing the line thickness either using the `linethick` environment variable or as an attribute does not affect arrowhead size parameters, which have to be changed explicitly. Whether this behaviour is more convenient than automatically changing these parameters to some default values is a matter of context; all pic processors are consistent. Arrowheads have to be resized explicitly by either of the following methods. The line thickness is specified in points but the arrowhead size parameters are in drawing units.

```
# Method 1:
  linethick = 2    # default 0.8 (bp)
  arrowht = 0.18   # default 0.1 (in)
  arrowwid = 0.09  # default 0.05 (in)
  arrow

# Method 2:
  arrow thick 2 ht 0.18 wid 0.09
```

There is a subtle language problem concerning arrowheads. Let us agree that the following examples should all produce an arrow of length 1 inch and arrowhead width 1 millimetre:

```
  .PS
    arrow right 1 width 1/25.4
  .PE
  .PS
    scale = 25.4
    arrow right 25.4 width 1
  .PE
  .PS 1
    arrow right 1/4 width 1/25.4
  .PE
```

The original (ATT) pic fails on the second example, insisting that arrowhead dimensions be given in inches. Gpic fails on the third by scaling the arrowhead on final output. Although it might be argued that this is a feature, it causes serious awkwardness when diagrams are to be scaled to exact final dimensions using the `.PS` x construction, since the effective scale factor is unknown until the `.PE` line is processed. Dpic generates the same arrow in all three cases, treating arrowhead parameters like line thickness (unscaled) parameters on final output.

5.21 Compass corners

Dpic consistently requires a dot before compass corners, so the gpic line

```
  x at center of last box
```

should be written for dpic as

```
  x at .center of last box
```

5.22 `continue`

In dpic, the `continue` command appends a linear drawn object to the previous drawn object as if `then` had been used in the original command, but calculations can be performed to determine size or placement of the appended part as in, for example,

```
  line up right
    calculations
  continue down
    more calculations
  continue up left
```

The keyword `continue` can also be used slightly differently. The line drawn by

```
  move to 0,0; line right 1 then to (Here,(2,1))
```

terminates at `(0,1)` since `Here` is the position `(0,0)`, whereas the following terminates at `(1,1)` since `Here` is `(1,0)`:

```
  move to 0,0; line right 1; continue to (Here,(2,1))
```

5.23 Subscripted variables and locations

Dpic allows subscripted variables and positions, as an aid in geometric calculations such as fitting splines to a set of points. Thus `Pos[`*expression*`]` is a valid name for a position. The rounded integer value of the expression is used. Similarly, `x[`*expression*`]` is a valid variable name. There are no array operations, but it is easy to write macros for them.

5.24 Splines

Gpic extends the ATT pic grammar to make `line 0.5` legal and mean "a line of length 0.5 in the current direction." All linear objects are treated similarly. Dpic does the same except for splines. In the statement

`spline` x `from A to B then to C ...`

the parameter x is a tension parameter, normally between 0 and 1, to control the spline curvature. If x is not present as in the normal pic grammar, the curve starts with a straight line halfway along the first segment and ends with a straight line along the second half of the last segment. However when x is present, dpic draws the spline from the start of the first segment to the end of the last segment.

5.25 Vector arithmetic

The dpic grammar permits the following:

```
X: Y + Z
```

where `Y` and `Z` are defined positions. Gpic requires

```
X: Y + (Z.x,Z.y)
```

Dpic also allows scalar multiplication:

`X: Y*2/3` (but not `X: 2/3*Y`)

5.26 Positions

If `X` is a position, then `(X)` is a valid position for dpic but not older versions of gpic, which give an error for

```
(a between A and B) + (x,y)
```

Dropping the parentheses to avoid the error gives

```
a between A and B + (x,y)
```

which is not the same resulting position. Use dpic or the latest gpic if you need this construction.

5.27 `int()`

Gpic `int()` up to version 1.19 computed the floor of its argument rather than the integer part as specified by ATT pic. Dpic provides both the `floor()` and `int()` functions but `int()` does not compute the same value as these versions of gpic `int()` for non-integer negative arguments.

5.28 `exec`

In dpic the contents of a string can be executed using

  `exec` *string*

or

  `exec sprintf(`*string*`, `*args*`)`

as if the string were the next line of input. This enables the programmed generation of names and labels, for example:

```
  for i=1 to 10 do  exec sprintf("A%g:  x%g,y%g",i,2*i,3*i)
```

This effect can also be accomplished with a simple macro.

5.29 Functions

A few additional mathematical functions are defined in dpic: `abs`, `acos`, `asin`, `expe`, `floor`, `loge`, `sign`, `tan`, and `pmod`.

5.30 PSTricks anomaly

In recent versions of the PSTricks package, a context dependency has been introduced for splines within the `\pscustom` environment. The normal spline syntax is

  `\psbezier(x1,y1)(x2,y2)(x3,y3)(x4,y4)` ...

Within a `\pscustom` environment, if the `\psbezier` command is not the beginning of a path, `(x1,y1)` must be omitted since, under these conditions, `\psbezier` takes its first coordinate pair to be the current position. This would not be a significant problem if it were always known at the time of generating the `\psbezier` coordinates whether these conditions hold. However, within the pic language in particular, the `\pscustom` command may be introduced independently of anything else, so dpic cannot know whether `\pscustom` has been invoked. Dpic always generates four (or more) coordinate-pair arguments as in the normal syntax, sometimes resulting in the addition of an extraneous line segment within `\pscustom`. A workaround for this problem is to insert the following PSTricks patch in your LaTeX code if you are enclosing splines within `\pscustom` commands:

```
\makeatletter%
\def\psbezier@ii{\addto@pscode{%
\ifshowpoints true \else false \fi\tx@OpenBezier%
\ifshowpoints\tx@BezierShowPoints\fi}\end@OpenObj}%
\makeatother%
```

References

[1] J. D. Aplevich. M4 macros for electric circuit diagrams in latex documents, 2009. Available with the CTAN Circuit_macros distribution: `http://www.ctan.org/tex-archive/graphics/circuit_macros/doc/CMman.pdf`.

[2] B. W. Kernighan and D. M. Richie. The M4 macro processor. Technical report, Bell Laboratories, 1977.

[3] B. W. Kernighan and D. M. Richie. PIC—A graphics language for typesetting, user manual. Technical Report 116, AT&T Bell Laboratories, 1991.

[4] E. S. Raymond. Making pictures with GNU PIC, 1995. In GNU groff source distribution.

[5] R. Seindal *et al.* GNU m4, 1994. `http://www.gnu.org/software/m4/manual/m4.html`.

6 Appendix: dpic grammar

The tokens recognized by the dpic parser are as shown. The tokens in `< >` pairs are generated internally. Equated tokens (`";" = "<NL>"`) have identical value.

```
"<" "cw" "ccw"
"(" ")" "*" "+" "-" "/" "%" ";" = "<NL>"
"^" "!" "&&" "||"
"," ":" "[" "]" "{" "}" "." "[]" "‘" "’"
"=" ":=" "+=" "-=" "*=" "/=" "%=" (* the order of these matters *)
"<float>" "<name>" "<Label>" "<LaTeX>"
’"’ = "<string>"
"#"
"$" = "<arg>"
                   (* keywords *)
"<START>" "<END>"
"ht" = "height" "wid" = "width"
"rad" = "radius" "diam" = "diameter"
"thick" = "thickness"
"scaled"
"from" "to" "at" "with" "by" "then" "continue"
"chop" "same"
"of" "the" "way" "between" "and" "Here"
"st" = "rd" = "nd" = "th" "last"
```

```
   "fill" = "filled"
   ".x" ".y"
   "print" "copy" "reset" "exec" "sh" "command"
   "define" "undef" = "undefine"
   "rand"
   "if" "else" "for" "do" (* repeat "repeat" "break" *)
   "sprintf"
"<corner>"            (* in the grammar <corner> is any of the following *)
   ".ne" ".se" ".nw" ".sw"
   ".t" = ".top" = "top" = ".north" = ".n"
   ".b" = ".bot" = ".bottom" = "bottom" = ".south" = ".s"
   ".right" = ".r" = ".east" = ".e"
   ".left" = ".l" = ".west" = ".w"
   ".start" = "start"
   ".end" = "end"
   ".center" = ".centre" = ".c"
"<compare>"
   "==" "!=" ">=" "<=" "<^>" ">"
"<param>"
   ".height" = ".ht"
   ".width" = ".wid"
   ".radius" = ".rad"
   ".diameter" = ".diam"
"<func1>"
   "abs" "acos" "asin" "cos" "exp" "expe" "int" "log" "loge"
   "sign" "sin" "sqrt" "tan" "floor"
"<func2>"
   "atan2" "max" "min" "pmod"
"<linetype>"
   "solid" "dotted" "dashed" "invis" = "invisible" "path"
"<colrspec>"
   "color" = "colour" = "colored" = "coloured"
   "outline" = "outlined"
   "shade" = "shaded"
"<textpos>"
   "centre" = "center" "ljust" "rjust" "above" "below"
"<arrowhd>"
   "<-" "->" "<->"
"<directon>"
   "up" "down" "right" "left"
```

```
"<primitiv>"
   "box" "circle" "ellipse" "arc" "line" "arrow" "move" "spline"
"<envvar>"
  "arcrad" "arrowht" "arrowwid" "boxht" "boxrad" "boxwid"
  "circlerad" "dashwid" "ellipseht" "ellipsewid" "lineht"
  "linewid" "moveht" "movewid" "textht" "textoffset" "textwid"
= "<lastsc>"          (* marker for last scaled env var *)
  "arrowhead" "fillval" "linethick" "maxpsht" "maxpswid" "scale"
= "<lastenv>"         (* marker for last env var *)
```

The expanded dpic grammar follows:

```
METAGOAL = input "<EOF>"

input = "<EMPTY>"
      | input picture NL

picture = start NL elementlist "<END>"
        | start NL elementlist NL "<END>"

NL = "<NL>"
   | "<ERROR>"

start = "<START>"
      | "<START>" term
      | "<START>" term term

elementlist = "<EMPTY>"
            | element
            | elementlist NL element

term = factor
     | term "*" factor
     | term "/" factor
     | term "%" factor

element = namedbox
        | "<Label>" suffix ":" position
        | assignlist
        | "<directon>"
        | "<LaTeX>"
        | command
        | lbrace "{" elementlist optnl "}"
        | ifpart
        | elsehead "{" elementlist optnl "}"
        | for "}"
        | "command" stringexpr
        | "exec" stringexpr

lbrace = "<EMPTY>"

namedbox = object
         | "<Label>" suffix ":" object

suffix = "<EMPTY>"
       | "[" expression "]"

position = pair
         | expression "between" position "and" position
         | expression "of" "the" "way" "between" position "and" position
         | expression "<" position "," position "<compare>" shift

assignlist = assignment
           | assignlist "," assignment

command = "print" expression redirect
        | "print" position redirect
        | "print" stringexpr redirect
        | "reset"
        | "reset" resetlist
        | "sh" stringexpr
        | "copy" stringexpr
        | defhead optnl "{" "}"
        | "undefine" "<name>"
        | "undefine" "<Label>"

optnl = "<EMPTY>"
      | NL

ifpart = ifhead "{" elementlist optnl "}"
```

```
elsehead = ifpart "else"

for = forhead "{" elementlist optnl
    | forincr elementlist optnl

stringexpr = string
           | stringexpr "+" string

string = "<string>"
       | sprintf ")"

assignment = "<name>" suffix "=" expression
           | "<name>" suffix "=" assignment
           | "<envvar>" "=" expression
           | "<envvar>" "=" assignment

expression = term
           | "+" term
           | "-" term
           | expression "+" term
           | expression "-" term

ifhead = setlogic "if" logexpr "then"

setlogic = "<EMPTY>"

logexpr = logprod
        | logexpr "||" logprod

forhead = "for" assignlist "to" expression do

forincr = for "~"

do = "do"
   | by expression "do"

by = "by"
   | "by" "*"
```

```
redirect = "<EMPTY>"
         | "<compare>" stringexpr
         | "<compare>" "<compare>" stringexpr

resetlist = "<envvar>"
          | resetlist "," "<envvar>"

defhead = "define" "<name>"
        | "define" "<Label>"

sprintf = "sprintf" "(" stringexpr
        | "sprintf" "(" stringexpr "," exprlist

exprlist = expression
         | expression "," exprlist

object = block
       | object "height" expression
       | object "width" expression
       | object "radius" expression
       | object "diameter" expression
       | object "thickness" expression
       | object "scaled" expression
       | object "<directon>" optexp
       | object "by" pair
       | object "then"
       | object "<linetype>" optexp
       | object "chop" optexp
       | object "filled" optexp
       | object "<arrowhd>"
       | object "cw"
       | object "ccw"
       | object "same"
       | object stringexpr
       | object "from" position
       | object "to" position
       | object "at" position
       | object "<textpos>"
       | object "<colrspec>" stringexpr
       | objectwith "<corner>" "at" position
       | objectwith pair "at" position
       | objectwith "at" position
       | "continue"

openblock = "<EMPTY>"

block = "<primitiv>" optexp
      | stringexpr
      | openblock "[" closeblock "]"
      | openblock "[]"

optexp = "<EMPTY>"
       | expression

closeblock = elementlist optnl

pair = expression "," expression
     | location shift

objectwith = object "with"
           | objectwith "." "<Label>" suffix
           | objectwith "." nth primobj

nth = ncount "th"
    | ncount "th" "last"
    | "last"

primobj = "<primitiv>"
        | "[]"
        | "<string>"
        | "[" "]"

shift = "<EMPTY>"
      | shift "+" location
      | shift "-" location

location = "(" position ")"
         | "(" position "," position ")"
         | place
         | location "*" factor
         | location "/" factor

place = placename
      | placename "<corner>"
      | "<corner>" placename
      | "<corner>" "of" placename
      | "Here"

factor = primary
       | "!" primary
       | primary "^" factor

placename = "<Label>" suffix
          | nth primobj
          | placename "." "<Label>" suffix
          | placename "." nth primobj

ncount = "<float>"
       | "‘" expression "’"
       | "{" expression "}"

logprod = logval
        | logprod "&&" logval

logval = lcompare
       | stringexpr "<" stringexpr
       | expression "<" expression

lcompare = expression
         | stringexpr
         | lcompare "<compare>" expression
         | lcompare "<compare>" stringexpr

primary = "<envvar>"
        | "<name>" suffix
        | "<float>"
        | "(" logexpr ")"
        | location ".x"
        | location ".y"
        | placename "<param>"
        | "rand" "(" ")"
        | "rand" "(" expression ")"
        | "<func1>" "(" expression ")"
        | "<func2>" "(" expression "," expression ")"
        | "(" assignlist ")"
```