

# TransFig: Portable Figures for L<sup>A</sup>T<sub>E</sub>X

## Version 2.1.

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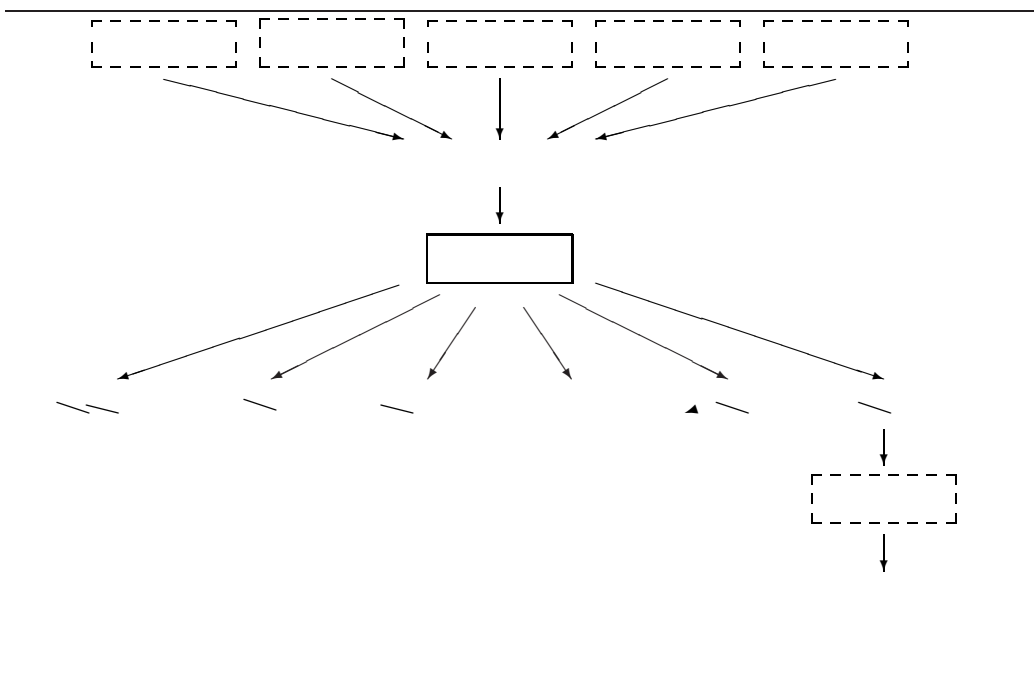
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TransFig is a mechanism for integrating  $\text{\LaTeX}$  documents. Several graphics languages exist which achieve a goal that is widely enough used to be called a standard. TransFig's goal is the portability of  $\text{\LaTeX}$  documents across printers and operating environments. The mechanism in TransFig is Fig code, the graphics description of the Fig interactive graphics editor. TransFig provides a uniform way to translate Fig code into various graphics languages and to integrate that with a  $\text{\LaTeX}$  document.

## 1 TransFig

The TransFig package consists of the program, which translates between Fig code and other graphics languages, and the command which can be used to invoke it. The available translation is illustrated in Figure 1 which was included using TransFig. TransFig can be used directly to translate from Fig code to the various graphics languages. Each graphics language requires the user to load a particular set of  $\text{\LaTeX}$  particular commands to include the figure. TransFig allows these to be defined.

When the graphics language is specified with the command, it creates a macro `\load` and a make file. The macro `\load` loads the  $\text{\LaTeX}$  macros, and the make file specifies the appropriate commands to  $\text{\LaTeX}$  to load the figures. The user simply the macro `\load` and the names of the files for loading the figures. To switch graphics languages, only to rerun `transfig`, and then `make`. Make can also be used to keep the translated code up to date when figures change.



/

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```

\documentstyle{article}
\input{transfig}          TransFig macro le
\begin{document}
:
\begin{figure}
  \begin{center}
    \input{figurei}        i'th TransFig gure
    \end{center}
  \end{figure}
:

```

---

Figure 2: Layout of a TransFig Document

## 1.1 File Name Conventions

Suppose that a document is to include a set of figures which are stored in TeX code form. These should be in files with the name, for instance figure1.fig, figure2.fig, ... figuren.fig. TransFig will create files figure1.tex, figure2.tex, ... figuren.tex for input to the TeX document, and in some cases will create files with additional names. Additionally, TransFig creates a file transfig.tex which must be input at the start of the document.

## 1.2 Trans Fig TeX Documents

In order to use TransFig, a TeX document must follow the format shown in Figure 2. The file transfig.tex must be input before any TransFig figure is encountered. At the point where figurei is to be inserted, the file figurei.tex is input.

### 1.3 Using TransFig

The `transfig` command has the form

```
transfig option... control..lename..
```

Where options are one of the following:

- L language to translate into the language default `pic`tex.
- M make to name the output makefile default `Makefile`.
- T tex to name the output TeX macro file default `transfig.tex`.

The language specifies `eps`, `epsic`, `eepic`, `eepicemu`, `ibmgl`, `latex`, `pic`tex, `ps`, `psfig`, `pstex`, `textyl` and `tpic`, indicate translation into the corresponding picture environment, `XF` macros, PostScript, or Specials for specials. See section 2 for further details about these special languages. `speci box` causes the figures to be replaced by empty boxes of the appropriate size.

A control specifier sets a parameter which governs the translation of a to its left in the argument list, until it is overridden. It must be one of the following:

- mmagnification to scale figures magnification default 1.0.
- ffont to set the default font family default
- ssize to set the default font size default 12

Each `lename` specifies a Fig file, either with or without the `transfig` creates a `Makefile` to apply `fig2dev` with the appropriate arguments to the named files, and creates an appropriate file. Thus, to create `Makefile` which will translate all figures in a TeX directory to L picture environment, with Computer Modern Bold as the default, the command would be

```
transfig -L latex -f cmb *.fig
```

After running `transfig`, simply `make` to create the appropriate L files. `Make` should be rerun whenever a Fig file is changed to recreate the corresponding L file. To change between graphics languages, simply run `clean` to remove the files created by `transfig`, and then rerun `transfig`.

The `transfig` command can also be used to include figures described in Brian Kernighan's graphics language or in PostScript. These graphics formats are distinguished by the file names `canfig` and `xps` respectively. Translation from PICS is accomplished by invoking the `transfig` program see section 2.3.

## 1. Text in Figures and Portability

In order to be translatable into different graphics languages, TransFig documents should use only those features which are supported. In particular, some graphics languages support text objects consisting of text which is part of the figure than others. For example, `TeX` allows full use of `TeX` commands in text strings, while PostScript does not.

The standard way to use text in TransFig figures is to input text with no `TeX` commands. However, if a text object is tagged as special, it is understood to include formatting commands which are in the graphics language. A document with special text will not be output in languages.

The standard font specifiers are a small set of names. However, if a text object is tagged as `PSFont`, then its font is specified as PostScript font. When translating such text into PostScript, the name is used. However, translations into other graphics languages will use some of the PS font. This approximation may be quite different from the name.

## 2 Fig Code and Graphics Languages

TransFig's goal is to provide a framework for ~~files which contain~~ ~~the portability of documents across printers and operating environments.~~ The central mechanism in TransFig is Fig code, ~~an application-independent~~ which is produced by the Fig interactive graphics editor ~~is widely~~ used as an intermediate form for ~~figures, the building blocks of the~~ may be attracted to produce compatible output. ~~The reference appendix A~~ describes Fig code in more detail.

### 2.1 Translations From Fig

TransFig currently translates Fig code into ~~three graphics~~ ~~TeX picture environment, XPostScript, and Xtyl specials.~~ The program which accomplishes these translations is ~~fig2dev, which replaces the~~ now-obsolete programs ~~fig2tex, fig2ps, fig2latex, and~~ fig2epic. The transfig command supports the translation of Fig code into ~~tpic specials see below using, which is not part of the TransFig pack-~~ age. Each language may be appropriate in different ~~environments or for~~ different applications. A short description is given below.

PiTeX is a set of ~~TeX~~ macros which implement simple graphics objects directly. ~~PiTeX~~ makes no use of pre- or post-processors ~~the~~ les it generates are completely standard, and can be printed or previewed in any environment where T is used. This result is achieved by using ~~high speed~~ arithmetic to do all plotting calculations, and by drawing the figure using the period character as a brush. As a result, PiT is slow and requires a large ~~in memory~~.

PostScript is a powerful graphics language which is gaining acceptance as a standard. In an environment where is translated ~~before~~ being printed, it is usually possible to insert a separately generated PostScript file into a document using the ~~TeX~~ special command. However, the resulting file can only be previewed using a viewer, and must be printed on a printer, such as the Apple LaserWriter. Various options are available for ~~integration~~ of Theps gmacro automatically scans ~~the~~ for bounding

box information and generates appropriate TeX-spacing and inclusion commands. One limitation of the output is the lack of ETeX formatting for special objects. The language specifier to the transfig command uses special dev output drivers which separate the figure in text and non-text portions, rendering the former and the latter in TeX. The pstex option uses gto to generate the inclusion commands.

LaTeX picture environment is a restricted graphics facility implemented within LaTeX. It is a standard part of every TeX version of LaTeX. It is processed quickly, and does not require a large internal TeX memory. However, not every graphics object which can be described with Fig code can be drawn using the LaTeX picture environment. Restrictions include a limited set of slopes at which lines can be drawn, and no ability to draw splines.

EPIC is an enhanced version of the LaTeX picture environment which removes many restrictions. It uses no facilities outside of those needed for the LaTeX picture environment.

EEPIC is a further enhancement which uses TeX specials to implement general graphics objects. It is subject to the same software requirements as TeX specials.

TeX specials are a set of special commands which produce graphics instructions in the format produced by TeX. The resulting file must be postprocessed using the xtyl program, which transforms it into a standard file which uses its own line drawing fonts.

tpic specials are a set of special commands which produce graphics instructions in the format produced by TeX. However, the graphics in the resulting file can only be previewed or printed using software which understands these commands.

IBM-GL IBM-GL International Business Machines Graphics Language and HP-GL Hewlett-Packard Graphics Language are compatible languages which drive a variety of IBM and HP pen plotters.

When LaTeX processes the transfig.tex, it will print the message TransFig: figures in language indicating which graphics language is in use.

## 2.2 The Fig Graphics Editor

The interpretation of Fig code was originally done graphically by the editor and the program `fig`, which translates Fig code into graphics language. The most recent version is V2.1 it is implemented by `fig` and the Fig graphics editor, which runs under SunView, and by `fig` version 2.

Previous versions of Fig code which have been widely used are V2.0. The V2.1 format is in effect a unification of these features compatible formats, and supersedes both of them. `TransFig` supports Fig code formats V1.3, V1., V these formats. as well as the old format S.a

## 2.3 Other Fig Compatible Programs

The following programs use Fig code as a graphics format, and thus are compatible with `TransFig`:

The numerical plotting program `gnuplot` can optionally produce output in Fig code format.

The `pic`-to-`Fig` translator `pic2fig` translates the language of Brian Kernighan's graphics preprocessor for `Troff`, `pic`, into Fig code users to create figures without employing a graphics editor.

The Fig code produced by these programs can be viewed using the Fig graphics editor.



### 3 Related Software

Software availability is subject to change, and this list may be out of date.

EPIC is an enhancement of the TeX picture environment which removes many restrictions. It uses only the facilities which TeX implements in the picture environment. EPIC was developed by Sunil Podar at the State University of New York at Stony Brook, and is available via anonymous FTP from SUN.SOE.CLARKSON.EDU.

EEPIC is a further enhancement which uses TeX specials to implement general graphics objects. It is a subject to the same requirements as TeX, although there is an emulation package which will implement most of them using the same facilities as TeX. It was developed by Conrad Kwok at the University of California, and is available via anonymous FTP from SUN.SOE.CLARKSON.EDU.

Fig is an interactive graphics editor in the style of MacDraw, which uses the Suntools/SunView windowing system. It produces output in the form of Postscript, and X-PiCT.

Fig was developed by Supoj Sutanthavibul at the University of Texas at Austin, supoj@sally.utexas.edu, and is available via anonymous FTP from SALLY.

Fig2.1 is a version of Fig which implements various enhancements to the interface, and uses Fig code V2.1. Fig2.1 was developed by contributors. It is available via anonymous FTP from FTP.CS.CORNELL.EDU.

Fig2dev translates from Fig code, X-PiCTs, Postscript, TeX picture environment commands, EPIC macros, Etyl, and the graphics language. It is part of the TransFig package, and supports Fig code.

Fig2tex, Fig2ps, Fig2latex, Fig2epic, Fig2pde translation programs which were distributed as part of earlier versions of the TransFig package. They have been replaced by g2dev see above.

F2p, F2ps are the original Fig code translation programs. These programs are out of date and have been subsumed by g2dev see above.

GnuPlot is a numerical plotting program which can optionally produce Fig code format. GnuPlot was developed by a group of people, including Thomas Williams and Colin Kelly of Pixar Corp. INFO-GNUPLOT@SUN.COM, and David F. Kotz of Duke University. DUKE.CS.DUKE.EDU. GnuPlot is available via anonymous FTP from DUKE.

TEX is a standard macro package used for describing documents in of this package is the TeX structure environment, a restricted graphics facility. The capabilities of this facility are described in section Document Preparation Styles by Leslie Lamport.

Pic2 g is a version of Brian Kernighan's graphics preprocessor for Troff. Pic2 g, which is a modified form of Pic2 g, has been altered to produce Fig code.

PiCTEX is a set of macros for describing documents. PiCTEX is implemented entirely within TeX, and requires no pre- or post processing programs or special fonts. The main problem in its use is its slow operation all calculations are done using arithmetic and large memory requirements. Many users have turned to C implementations of PiCTEX in order to obtain memory sizes larger than are possible using the standard WebPascal version.

PiCTEX was developed by Michael Wichura at the University of Chicago. wichura@GALTON.UCHICAGO.EDU, and is available via anonymous FTP from A.CS.UIUC.EDU. It is also included as contributed software with the Unix Distribution.

Plot2 g translates figures from the Unix plot file format to Fig code. P developed by Richard Murphy of Rice University. RICE.EDU, and is available via anonymous FTP from QED.RICE.EDU.

TeX is a dvips file postprocessor which translates commands into its own set of drawing fonts. The result of this is a standard dvips file which can be printed using any driver, as long as its drawing fonts are available. TeX is available via anonymous FTP from VENUS.YCC.YALE.EDU.

tpic is a version of Brian Kernighan's graphics preprocessor for Troff. tpic has been altered to produce special commands which are understood by some print drivers and previewers. For information

about distribution, contact Tim Morgan of the University of California at Irvine at [tmorgan@ICS.UCI.EDU](mailto:tmorgan@ICS.UCI.EDU).

TransFig was developed by Micah Beck with major contributors, Frank Schryer, now of IBM, and Conrad Kwok of UC Davis. It is available via anonymous FTP from [FTP.CS.CORNELL.EDU](ftp://FTP.CS.CORNELL.EDU).

Xfig is a version of the Fig graphics editor which can be compiled for Suntools or X Windows Version 11 windowing systems. It is part of the contributed software distributed with the X Windowing System obtained by anonymous FTP from [LCS.MIT.EDU](ftp://LCS.MIT.EDU).

Xpic is a graphical editor similar to Fig which runs under X Windows 11. Xpic was developed by Mark Moraes at the University of Toronto at [moraes@csri.toronto.edu](mailto:moraes@csri.toronto.edu) and is available via anonymous FTP from [ai.toronto.edu](ftp://ai.toronto.edu).

## A Fig Code V2.1 Reference Guide

PLEASE NOTE: This guide has not been updated to the current 3.0 col. Please refer to the x g document FORMAT3.0 for a complete des

A Fig code version V2.1 le has the following structure:

```
#FIG 2.1
global parameters
object description
object description
:
```

### A.1 Comment Lines

The very rst line is a comment line containing the Fig format. Programs which interpret Fig code verify compackind by st line for this comment. All other lines which contain a # in the first column are treated as comments and are ignored.

### A.2 Global Parameters

The rst non-comment line consists of two global parameters

```
fig_resolution coordinate_system
```

Fields in a line of a Fig le are separated by blanks or tabs. The object descriptions. The elds of lines in Fig files are organized in this guide by tables like the one below. The elds must appear in the table.

Type	Field	Units values
int	fig_resolution	pixels/inch Fig value: 0
int	coordinate_system	1: origin at lower left corner 2: origin at upper left corner Fig value: 2

The Type column speci es the type of the eld, and is either, integer or string. The notation following the type indicates that 1 are

interpreted as values in this field. The rightmost column of this table either defines the units in which the field is expressed, or lists values which the field can take. The **DEFAULT** in this column indicates that no value other than the default values are allowed. It is intended that of Fig will define other values for these fields, but that these will remain legal, thus providing backward compatibility.

The basic unit of position in Fig files is the pixel. While legal are described at this resolution, the figure can be drawn at a higher resolution. Pixels are square, and so resolution represents position resolution in both the x and y dimensions.

Some values are expressed as symbols and their numerical values are listed. These symbols are defined in the `object.h` file.

### A.3 Object Descriptions

The rest of the file contains objects described in six types:

1. Ellipse.
2. Polyline, including Polygons and Boxes.
3. Spline, including Closed Open Control Interpolated Splines.
- . Text.
- . Circular Arc.
- . Compound object which is composed of one or more objects.

The following group of common fields appear in several objects, and so they are described here, and later are simply referred to as common fields.

Type	Field	Units values
int	line_style	SOLID_LINE 0
		DASH_LINE 1
		DOTTED_LINE 2
int	line_thickness	pixels
int	color	DEFAULT
		BLACK_COLOR 0
		BLUE_COLOR 1
		GREEN_COLOR 2
		CYAN_COLOR 3
		RED_COLOR
		MAGENTA_COLOR
		YELLOW_COLOR
		WHITE_COLOR
int	depth	no units
int	pen	DEFAULT
int	fill_style	DEFAULT
		WHITE_FILL 1
		BLACK_FILL 21
oat	style_val	pixels

For the dashed line style, the value specifies the length of a dash. For dotted lines it indicates the gap between consecutive dots.

Depth determines which filled objects will obscure other objects of greater depth being obscured. If two objects that they overlap, the object which occurs first in the Edg file is obscured.

The values between WHITE\_FILL and BLACK\_FILL define a gray scale. Many graphics languages cannot fully implement area fill.

The color field will be extended in the future to two or three byte RGB specifiers: one for line color and one for fill color.

Arrow lines are used to describe optional arrowheads, Polyline, and Spline objects. If an object has a forward arrow, then describing it follows the object description. If an object has a backward arrow

line describing it follows the object description, if there is one.

An arrow line consists of the following fields

Type	Field	Units values
int	arrow_type	DEFAULT
int	arrow_style	DEFAULT
oat	arrow_thickness	DEFAULT
oat	arrow_width	pixels
oat	arrow_height	pixels

The pen field can only take the value DEFAULT. It is intended that extensions to Fig code will define other values for this field. It is to define the shape of the pen used in drawing objects. It includes the stipple pattern for line filling. The default pen is dark blue.

### A.3.1 Ellipse Objects

Type	Field	Units values
int	object_code	O_ELLIPSE 1
int	sub_type	T_ELLIPSE_BY_RAD 1 T_ELLIPSE_BY_DIA 2 T_CIRCLE_BY_RAD 3 T_CIRCLE_BY_DIA

common fields

int	direction	1
oat	angle	radians
int	center_x,center_y	pixels
int	radius_x,radius_y	pixels
int	start_x,start_y	pixels
int	end_x,end_y	pixels

The Ellipse object describes an ellipse or circle. It is defined by center\_x, center\_y with radius\_x and radius\_y, and whose x-axis is rotated by angle from the horizontal. If the object describes a circle, then radius\_x and radius\_y must be equal.

The fields start\_x, start\_y, end\_x and end\_y are used only by Fig, and are not used in drawing the object. If the ellipse is specified

startx starty is centerx centery , and endx endy is a corner of a box which bounds the ellipse. If the ellipse is specified by startx starty and endx endy are the two corners of the box which bound the ellipse.

### A.3.2 Polyline Objects

Type	Field	Units values
int	object_code	O_POLYLINE 2
int	sub_type	T_POLYLINE 1 T_BOX 2 T_POLYGON 3 T_ARC_BOX T_EPS_BOX

common elds

int	radius	no units
int	forward_arrow,	0: no arrow
	backward_arrow	1: arrow

The Polyline object description has points following any arrow lines. The line consists of a sequence of coordinate pairs which marks the end of the line.

$x_1 y_1 x_2 y_2 : : x_n y_n$

Type	Field	Units values
int	$x_i y_i$	pixels

The Polyline object describes a piecewise line at the point  $x_1 y_1$  and passing through each point for  $2 : : n$ . If sub.type is T\_BOX or T\_POLYGON then  $x_1 y_1$  and  $x_n y_n$  must be identical. If sub.type is T\_BOX, then the line segments must all be a vertically oriented rectangle. If sub.type is T\_ARC\_BOX, then the corners of the box are drawn with circular arcs, the size of which are determined by the radius. Many output modes draw T\_ARC\_BOX object as simple boxes.

The T\_EPS\_BOX object is a simple box filled with a figure described by an imported Encapsulated PostScript EPS file. Following any which are ignored is an EPS specification, consisting of a tag indicating the vertical orientation of the figure, and the name of the EPS file. Following that is a points line describing the two opposite corners of the



Type	Field	Units values
int	ipped	0: normal orientation 1: ipped
string	lename	

### A.3.3 Spline Objects

Type	Field	Units values
int	object_code	O_SPLINE 3
int	sub_type	T_OPEN_NORMAL 0 T_CLOSED_NORMAL 1 T_OPEN_INTERPOLATED 2 T_CLOSED_INTERPOLATED 3
common elds		
int	forward_arrow, backward_arrow	0: no arrow 1: arrow

The Spline object descriptor has the following format. If the sub\_type of the spline is T\_OPEN\_INTERPOLATED or T\_CLOSED\_INTERPOLATED, then an additional control points line follows the points line. The line consists of a sequence of x, y coordinate pairs for each point in the points line. Note that when some integers, the control line consists of floating point number

$lx_1 ly_1 rx_1 ry_1 lx_2 ly_2 rx_2 ry_2 :: lx_n ly_n rx_n ry_n$

Type	Field	Units values
float	$lx_i ly_i rx_i ry_i$	pixels

The interpretation of Spline objects is more complex than descriptions, and is discussed in section A..

### A.3. Text Objects

Type	Field	Units values
int	object_type	O_TEXT
int	sub_type	T_LEFT_JUSTIFIED 0 T_CENTER_JUSTIFIED 1 T_RIGHT_JUSTIFIED 2
int	font	DEFAULT ROMAN 1 BOLD 2 ITALICS 3 SANSSERIF TYPEWRITER
oat	font_size	points
int	pen	DEFAULT
int	color	DEFAULT
int	depth	no units
oat	angle	radians
int	text_flags	no units
oat	height, length	pixels
int	x, y	pixels
string	string	

The positioning of the string is specified by the value of `sub_type`. The values `T_LEFT_JUSTIFIED`, `T_CENTER_JUSTIFIED`, and `T_RIGHT_JUSTIFIED` specify that it is the left end, center and right end of the baseline, respectively. The `height` and `length` fields specify the box that the text fits into. These are specific to the fonts used by Fig.

The `string` field is an ASCII string terminated by the character `\0`. This terminating character is not a part of the string. It may contain the new-line character. Some output modes will interpret ISO encoded European accents not found in the ASCII character set.

The `text_flags` field is a bit vector which specifies various settable properties of the text object. Each flag corresponds to a bit in the default value of each flag.

Flag	Bit mask in binary	Description
RIGID_TEXT	0001	Font size doesn't scale inside compound
SPECIAL_TEXT	0010	Text includes formatting commands
PSFONT_TEXT	0100	Font eld speci es PS font
HIDDEN_TEXT	1000	Fig editor should not display text

The RIGID\_TEXT flag is used to preserve the absolute size of text objects when inside compound and that compound is scaled. The SPECIAL\_TEXT flag is used to inhibit the escaping of formatting commands in text to TeX or Troff, in order to allow the user to inject such commands directly into the figure. The PSFONT\_TEXT flag changes the interpretation of the font eld. Rather than selecting from the limited ones shown in the table above, the eld is interpreted as selecting from the fonts of PostScript fonts. A text object with PSFONT\_TEXT flag set may not be fully translatable into output forms other than PostScript. The HIDDEN\_TEXT flag is meaningful only to graphics editors, and specifies that the object is displayed on the screen. This is most useful for special text objects such as very long formatting command strings.

PS Font	Value
Times-Roman	1
Times-Italic	2
Times-Bold	3
Times-BoldItalic	4
AvantGarde	5
AvantGarde-BookOblique	6
AvantGarde-Demi	7
AvantGarde-DemiOblique	8
Bookman-Light	9
Bookman-LightItalic	10
Bookman-Demi	11
Bookman-DemiItalic	12
Courier	13
Courier-Oblique	14
Courier-Bold	15
Courier-BoldItalic	16
Helvetica	17
Helvetica-Oblique	18
Helvetica-Bold	19
Helvetica-BoldOblique	20
Helvetica-Narrow	21
Helvetica-Narrow-Oblique	22
Helvetica-Narrow-Bold	23
Helvetica-Narrow-BoldOblique	24
NewCenturySchlbk-Roman	25
NewCenturySchlbk-Italic	26
NewCenturySchlbk-Bold	27
NewCenturySchlbk-BoldItalic	28
Palatino-Roman	29
Palatino-Italic	30
Palatino-Bold	31
Palatino-BoldItalic	32
Symbol	33
ZapfChancery-MediumItalic	34
ZapfDingbats	35

### A.3. Arc Objects

Type	Field	Units values
int	object_code	O_ARC
int	sub_type	T_3_POINT_ARC 1
common elds		
int	direction	0: clockwise 1: counter
int	forward_arrow, backward_arrow	0: no arrow 1: arrow
oat	center_x,center_y	pixels
int	x <sub>1</sub> y <sub>1</sub> x <sub>2</sub> y <sub>2</sub> x <sub>3</sub> y <sub>3</sub>	pixels

The Arc object describes a circular arc centered at the point center\_x center\_y , starting at x<sub>1</sub> y<sub>1</sub> , passing through x<sub>2</sub> y<sub>2</sub> , and ending at x<sub>3</sub> y<sub>3</sub> . It is drawn either clockwise or counter-clockwise as specified by direction. Note that this description is quite over-determined, as the center and direction of the arc can be deduced from the three points which are specified.

### A.3. Compound Objects

Type	Field	Units values
int	object_type	O_COMPOUND
int	upperright_corner_x	pixels
int	upperright_corner_y	
int	lowerleft_corner_x	
int	lowerleft_corner_y	

The Compound object description describes a compound object by the rectangle determined by the points

upperright\_corner\_x upperright\_corner\_y  
lowerleft\_corner\_x lowerleft\_corner\_y

It consists of all the objects following it until an object which is O\_END\_COMPOUND - is encountered. Compound objects may be nested.

## A. Splines

Specifying the interpretation of a Spline object is more problematic than other graphics objects. A graphics object is viewed as having two parts: an abstract description of the object and a set of appearance parameters which specify how the object is to be represented. For example, a circular arc is a very understood abstract definition, independent of how it is drawn. Unfortunately, the abstract specifications of splines. The following descriptions come at second hand the author is not involved in spline algorithms, and so may have garbled the meaning of the knowledgeable reader some idea of the intended meaning of Sp

Fig splines come in two major varieties: B-splines and Inter. Each of these is available in open or closed subtypes. If the value is OPEN.NORMAL or T.CLOSED.NORMAL then it describes a B-spline. In these cases, the points line which follows contains the control points for the spline. The spline does not actually pass through them, but they determine where it will pass, which is generally the control points. B-splines are quite smooth.

If the subtype field has the values OPEN.INTERPOLATED or T.CLOSED.INTERPOLATED then it describes an interpolated spline. In these cases, the points line which follows contains the control points through which the spline will pass. In addition, there follows the points line, which specifies two control points  $rx_i$   $ry_i$  for each interpolation point. The section of the interpolated spline is drawn using the Bezier with the four points  $x_i$   $y_i$ ,  $rx_i$   $ry_i$ ,  $lx_{i+1}$   $ly_{i+1}$ , and  $x_{i+1}$   $y_{i+1}$ . Interpolated splines are not as smooth as B-splines.

For either type of closed splines, the first and last points on  $x_1$   $y_1$  and  $x_n$   $y_n$  are identical. For closed interpolated splines, the last pair of control points on the control points line,  $rx_n$   $ry_n$  are the same as  $lx_1$   $ly_1$  and  $rx_1$   $ry_1$  respectively.