Package curve2e user manual

Claudio Beccari[*]

Version 2.2.3 – Last revised 2020-02-28

Contents

Abstract

This file contains the user manual of the curve2e extension package to the pict2e bundle; the latter was described by Lamport himself in the 1994 second edition of his LaTeX handbook.

Please take notice that on April 2011 a package pict2e upgraded version has been released that incorporates some of the commands defined in early versions of this package; apparently there are no conflicts, because curve2e contains only the advanced features that extend the above package.

Since this extension redefines some commands and introduces some more drawing facilities (that allow to draw circular arcs and arbitrary curves with the minimum of user intervention) the user needs a user manual that contains several actual examples. The software available to show the code and its result after compilation is incompatible with the usual LaTeX `ltxdoc` class for code documentation, therefore a separate user manual has been made available. If the user wants to explore the curve2e code and its documentation s/he has available the documented file `curve2e.pdf`.

1 Installation

If you installed your TeX system with a TeX Live or a MikTeX complete and updated distribution you already have this package installed; in order to verify open a terminal or command prompt window and use it to enter the `texdoc curve2e-manual`; as soon as the command is executed a screen window should open displaying this manual. If this does not happen, either you misspelt the command (it happens more often than not), or your installation is not complete and updated.

I suggest you to youse your computer installation facilities to install this bundle. Otherwise, download this curve2e.zip package from one of the CTAN (Comprehensive TeX Archive Network) archives, to your downloads folder. Before doing anything else verify if you have a personal `temf` tree; if not, create

[*]E-mail: `claudio dot beccari at gmail dot com`

one reading you distribution instruction; let us assume that your personal `texmf` archive is in `HOME/texmf` (on Windows change the slash with a backslash) and `HOME` is a path starting from the root of you hard disk and going though several other folders. On Windows 10 it might be `C:\Users\YouName`; on Linux it might be simply `~`; On Mac it would be `~\Library`, but sometimes the `HOME` might be different, especially o Windows platforms. Create the following subfolders:

1. `HOME/texmf/source/latex/curve2e/`
2. `HOME/texmf/doc/latex/curve2e/`
3. `HOME/texmf/tex/latex/curve2e/`

Now move file `curve2e.zip` to the `.../source/latex/curve2e/` folder; the decompress the `.zip` file with the software you have on board of your platform. Run with `pdflatex` on `.dtx` file; then do the same with the `curve2e-manual.tex`. You might need to repeat these compilations two or three times in order to have the table of contents and all the references correctly connected.

This done move the `.pdf` files to the `.../doc/latex/curve2e/` folder. and move the `.sty` files to the `.../tex/latex/curve2e/` folder.

Clear the `.../source/latex/curve2e/` folder from the auxiliary files, all those remaining in the folder except those that have the extensions `.zip`, `.dtx`, `.tex`, and `.txt`. Read the `README.txt` file.

If your TEX system is correctly set up, your files in your persanl tree should be immediately usable; probably you have to create the file name database with MikTEX; in this case read the documentation of your MikTEX installation to discover how to do it.

Remember to delete all these subfolders if you decide to install a complete updated version of your favourite distribution, and if you keep it updated approximately once every 7-10 days. This is much simpler than to struggle with these manual operations.

2 Package pict2e and this extension curve2e

Package pict2e was announced in issue 15 of `latexnews` around December 2003; it was declared that the new package would replace the dummy one that has been accompanying every release of LATEX 2$_\varepsilon$ since its beginnings in 1994. The dummy package was just issuing an info message that simply announced the temporary unavailability of the real package.

Eventually Gäßlein and Niepraschk implemented what Lamport himself had already documented in the second edition of his LATEX handbook, that is a LATEX package that contained the macros capable of removing all the limitations contained in the standard commands of the original `picture` environment; specifically what follows.

1. The line and vector slopes were limited to the ratios of relative prime one-digit integers of magnitude not exceeding 6 for lines and 4 for vectors.
2. Filled and unfilled full circles were limited by the necessarily limited number of specific glyphs contained in the special LATEX `picture` fonts.
3. Quarter circles were also limited in their radii for the same reason.
4. Ovals (rectangles with rounded corners) could not be too small because of the unavailability of small radius quarter circles, nor could be too large,

in the sense that after a certain radius the rounded corners remained the same and would not increase proportionally to the oval size.
5. Vector arrows had only one possible shape and matched the limited number of vector slopes.
6. For circles and inclined lines and vectors just two possible thicknesses were available.

Package `pict2e` removes most if not all the above limitations.

1. Line and vector slopes are virtually unlimited; the only remaining limitation is that the direction coefficients must be three-digit integer numbers; they need not be relatively prime; with the 2009 upgrade even this limitation was removed and now slope coefficients can be any fractional number whose magnitude does not exceed 16 384, the maximum dimension in points that TEX can handle.
2. Filled and unfilled circles can be of any size.
3. Ovals can be designed with any specified corner curvature and there is virtually no limitation to such curvatures; of course corner radii should not exceed half the lower value between the base and the height of the oval.
4. There are two shapes for the arrow tips; the triangular one traditional with LATEX vectors, or the arrow tip with PostScript style.
5. The `\linethickness` command changes the thickness of all lines, straight, curved, vertical, horizontal, arrow tipped, et cetera.

This specific extension package `curve2e` adds the following features.

1. Point coordinates my be specified in both cartesian and polar form: internally they are handled as cartesian coordinates, but the user can specify his/her points also in polar form. In order to avoid confusion with other graphic packages, `curve2e` uses the usual comma separated couple $\langle x, y\rangle$ of integer or fractional numbers for cartesian coordinates, and the couple $\langle\theta\rangle$:$\langle\rho\rangle$ for polar coordinates (the angle preceding the radius). All graphic object commands accept polar or cartesian coordinates at the choice of the user who may use for each object the formalism s/he prefers. Also the `\put` and `\multiput` commands have been redefined so as to accept cartesian or polar coordinates.
   Of course the user should pay attention to the meaning of cartesian vs. polar coordinates. Both imply a displacement with respect to the actual origin of the axes. So when a circle is placed at coordinates a, b with a normal `\put` command, the circle is placed exactly in that point; with a normal `\put` command the same happens if coordinates $\alpha{:}\rho$ are specified. But if the `\put` command is nested into another `\put` command, the current origin of the axes is displaced — this is obvious and the purpose of nesting `\put` commands is exactly that. But if a segment is specified so that its ending point is at a specific distance and in specific direction form its starting point, polar coordinates appear to be the most convenient to use; in this case, though, the origin of the axes becomes the stating point of the segment, therefore the segment might be drawn in a strange way. Attention has been paid to avoid such misinterpretation, but maybe some unusual situation may not have come to my mind; feedback is very welcome. Meanwhile pay attention when you use polar coordinates.

2. Most if not all cartesian coordinate pairs and slope pairs are treated as *ordered pairs*, that is *complex numbers*; in practice the user does not notice any difference from what s/he was used to, but all the mathematical treatment to be applied to these entities is coded as complex number operations, since complex numbers may be viewed non only as ordered pairs, but also as vectors or as roto-amplification operators.
3. Commands for setting the line terminations were introduced; the user can chose between square or rounded caps; the default is set to rounded caps; now this feature is directly available with `pict2e`.
4. Commands for specifying the way two lines or curves join to one another.
5. Originally the `\line` macro was redefined so as to allow large (up to three digits) integer direction coefficients, but maintaining the same syntax as in the original `picture` environment; now `pict2e` removes the integer number limitations and allows fractional values, initially implemented by `curve2e`.
6. A new macro `\Line` was originally defined by `curve2e` so as to avoid the need to specify the horizontal projection of inclined lines; now this functionality is available directly with `pict2e`; but this `curve2e` macro name now conflicts with `pict2e` 2009 version; therefore its name is changed to `\LIne` and supposedly it will not be used very often, if ever, by the end user (but it is used within this package macros).
7. A new macro `\LINE` was defined in order to join two points specified with their coordinates; this is now the normal behaviour of the `\Line` macro of `pict2e` so that in this package `\LINE` is now renamed `\segment`; there is no need to use the `\put` command with this segment specification.
8. A new macro `\DashLine` (alias: `\Dline`) is defined in order to draw dashed lines joining any two given points; the dash length and gap (equal to one another) get specified through one of the macro arguments.The starting point may be specified in cartesiano or polar form; the end point in cartesian format specifies the desired end point; while if the second point is in polar form it is meant *relative to the starting point*, not as an absolute end point. See the examples further on.
9. A similar new macro `\Dotline` is defined in order to draw dotted straight lines as a sequence of equally spaced dots, where the gap can be specified by the user; such straight line may have any inclination, as well as the above dashed lines.Polar coordinates for the second point have the same relative meaning as specified for the `\Dashline` macro. The dot diameter may be specified with an optional argument; by default this diameter equals the `1pt` width.
10. Similar macros are redefined for vectors; `\vector` redefines the original macro but with the vector slope limitations removed; `\Vector` gets specified with its two horizontal and vertical components in analogy with `\LIne`; `\VECTOR` joins two specified points (without using the `\put` command) with the arrow pointing to the second point.
11. A new macro `\polyline` for drawing polygonal lines is defined that accepts from two vertices up to an arbitrary (reasonably limited) number of them (available now also in `pict2e`); here it is redefined so as to allow an optional specification of the way segments for the polyline are joined to one another. Vertices may be specified with polar coordinates and are always relative to the preceding point.
12. The `pict2e` `polygon` macro to draw closed polylines (in practice general

polygons) has been redefined in such a way that it can accept the various vertices specified with (relative) polar coordinates. The `polygon*` macro produces a color filled polygon; the default color is black, but a different color may be specified with the usual `\color` command given within the same group where `\polygon*` is enclosed.

13. A new macro `\Arc` is defined in order to draw an arc with arbitrary radius and arbitrary aperture (angle amplitude); this amplitude is specified in sexagesimal degrees, not in radians; a similar functionality is now achieved with the `\arc` macro of pict2e, which provides also the starred version `\arc*` that fills up the interior of the generated circular arc with the current color. It must be noticed that the syntax is slightly different, so that it's reasonable that these commands, in spite of producing identical arcs, might be more comfortable with this or that syntax.
14. Two new macros `\VectorArc` and `\VectorARC` are defined in order to draw circular arcs with an arrow at one or both ends.
15. A new macro `\Curve` is defined so as to draw arbitrary curved lines by means of cubic Bézier splines; the `\Curve` macro requires only the curve nodes and the directions of the tangents at each node. The starred version fills up the interior of the curve with the current color.
16. the above `\Curve` macro is a recursive macro that can draw an unlimited (reasonably limited) number of connected Bézier spline arcs withspecification of the tangent direction at the interpolation nodes. It is possible to use a lower level macro `\CbezierTo` that does the same but lets the user specify the control points of each arc; it is more difficult to use but it is more performant.
17. The basic macros used within the cumulative `\Curve` macro can be used individually in order to draw any curve, one cubic arc at the time; but they are intended for internal use, even if it is not prohibited to use them; by themselves such arcs are not different form those used by `Curve`, but the final command, `\FillCurve`, should be used in place of `\CurveFinish`, so as to fill up the closed path with the locally specified color; see figure 10. It is much more convenient to use the starred version of the `\Curve` macro.

The pict2e package already defines macros such as `\moveto`, `\lineto`, `\curveto`, `\closepath`, `\fillpath`, and `\strokepath`; of course these macros can be used by the end user, and sometimes they perform better than the macros defined in this package, because the user has a better control on the position of the Bézier splines control points, while here the control points are sort of rigid. It would be very useful to resort to the hobby package, but its macros are compatible with those of the tikz and pgf packages, not withcurve2e; an interface should be created in order to deal with the hobby package, but this has not been done yet. In any case they are redefined so as to accept symbolic names for the point coordinates in both the cartesian and polar form.

In order to make the necessary calculations many macros have been defined so as to use complex number arithmetics to manipulate point coordinates, directions (unit vectors, also known as 'versors'), rotations and the like. In the first versions of this package the trigonometric functions were also defined in a way that the author believed to be more efficient than those defined by the `trig` package; in any case the macro names were sufficiently different to accommodate both definition sets in the same LaTeX run. With the progress of the LaTeX 3 language, package xfp has recently become available, by which any sort of calculations can be done with floating point decimal numbers; therefore the most common algebraic, irrational and transcendental functions can be computed in the background with the stable internal floating point facilities. We maintain some computation with complex number algebra, but use the `xfp` functionalities for other computations.

Many aspects of this extension could be fine tuned for better performance; many new commands could be defined in order to further extend this extension. If the new service macros are accepted by other TeX and LaTeX programmers, this version could become the start for a real extension of the pict2e package or even become a part of it. Actually some macros have already been included in the pict2e package. The `\Curve` algorithm, as said before, might be redefined so as to use the macros introduced by the hobby package, that implements for the tikz and pgf packages the same functionalities that John Hobby implemented for the METAFONT and METAPOST programs.

For these reasons I suppose that every enhancement should be submitted to Gäßlein, Niepraschk, and Tkadlec who are the prime maintainers of pict2e; they are the only ones who can decide whether or not to incorporate new macros in their package.

3 Summary and examples of new commands

This package curve2e extends the power of pict2e with the following modifications and the following new commands.

1. This package curve2e calls directly the LaTeX packages `color` and pict2e; it passes to the latter one any possible option that it can receive; actually the only options that make sense for pict2e are those concerning the arrow tips, either LaTeX or PostScript styled, because it is assumed that if this package is used, the original LaTeX commands are of no interest: see the pict2e documentation in order to see the correct options pict2e can receive. If the user wants to use the xcolor package, it has to load this one *before* curve2e.
2. The user is offered new commands in order to control the line terminators and the line joins; specifically:
   - `\roundcap`: the line is terminated with a semicircle;
   - `\squarecap`: the line is terminated with a half square;
   - `\roundjoin`: two lines are joined with a rounded join;
   - `\beveljoin`: two lines are joined with a bevel join;
   - `\miterjoin`: two lines are joined with a miter join.

   All the above commands should respect the intended range; but since they act at the PostScript or PDF level, not at TeX level, it might be necessary to issue the necessary commands in order to restore the previous terminator or join; in other words, groups and environments do not have any influence on these commands.
3. The commands `\linethickness`, `\thicklines`, `\thinlines` together with `\defaultlinethickness` always redefine the internal `\@wholewidth` and `\@halfwidth` so that the latter ones always refer to a full width and to a

```
\unitlength=0.01\linewidth
\begin{picture}(80,20)
\AutoGrid
\put(0,0){\vector(1.5,2.3){10}}
\put(20,0){\Vector(10,15.33333)}
\VECTOR(40,0)(50,15.33333)
\ifdefined\VVECTOR \VVECTOR(60,0)(80,10)\fi
\end{picture}
```

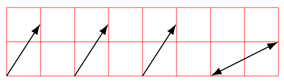


Figure 1: Three (displaced) identical vectors obtained with the three vector macros; a double tipped vector is also shown.

half of it in this way: if you issue the command `\defaultlinethickness{2pt}` all thin lines will be drawn with a thickness of 1 pt while, if a drawing command directly refers to the internal value `\@wholewidth`, its line will be drawn with a thickness of 2 pt. If one issues the declaration `\thinlines` all lines will be drawn with a 1 pt width, but if a command refers to the internal value `\@halfwidth` the line will be drawn with a thickness of 0.5 pt. The command `\linethickness` redefines the above internals but does not change the default width value; all these width specifications apply to all lines, straight ones, curved ones, circles, ovals, vectors, dashed lines, and so on. It's better to recall that `\thinlines` and `\thicklines` are declarations that do not take arguments; on the opposite the other commands follow the standard syntax:

`\linethickness`{⟨*dimensioned value*⟩}
`\defaultlinethicknes`{⟨*dimensioned value*⟩}

where ⟨*dimensioned value*⟩ means either a length specification complete of its units, or a dimensional expression.

4. Straight lines and vectors are redefined in such a way that fractional slope coefficients may be specified; the zero length line does not produce errors and is ignored; the zero length vectors draw only the arrow tips.
5. New line and vector macros are defined that avoid the necessity of specifying the horizontal component; `\put(3,4){\LIne(25,15)}` specifies a segment that starts at point $(3,4)$ and goes to point $(3+25,4+15)$; the command `\segment(3,4)(28,19)` achieves the same result without the need of using the `\put` command. Therefore `\LIne` is just for internal usage, rather than a user command. Now `curve2e` has available also the "arc vectors" with the arrow tip at one or at both ends.
   The same applies to the vector commands `\Vector` and `\VECTOR` and `\VVECTOR`; the latter command behaves as `\VECTOR` but draws a vector with arrow tips at both ends; furthermore this command is available only with main versions 2 or higher of `curve2e`.
   Experience has shown that the commands intended to join two specified points are particularly useful.
6. The `\polyline` command has already been introduced in `pict2e`: in `curve2e` it is redefined so as to accept also polar coordinates this new version of `\polyline` accepts also an optional argument to specify how two consecutive segments join together;; it accepts an unlimited list of point coordi-

nates, possibly stored in macros, enclosed within round parentheses; the command draws a sequence of connected segments that join in order the specified points; the syntax is:

`\polyline[`⟨*optional join style*⟩`](`⟨P_1⟩`)(`⟨P_2⟩`)...(`⟨P_n⟩`)`

See figure 2 where a regular pentagon is drawn; usage of polar coordinates is also shown; please notice how polar coordinates act in this figure.

```
\unitlength=.5mm
\begin{picture}(40,32)(-20,-17)
\polyline(90:20)(162:20)(234:20)(306:20)(378:20)(90:20)
\end{picture}
```

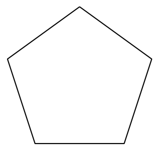


Figure 2: Polygonal line obtained by means of the `\polyline` command; vertex coordinates are in polar form.

Examples of using polar and cartesian coordinates are shown in figure 3.

```
\unitlength =0.02\textwidth
\begin{picture}(40,30)
\AutoGrid(40,30)
\Zbox(40,0)[l]{40,0}[1]
\Zbox(90:30)[bc]{90{:}30}[1]
\Zbox(60:30)[bc]{60{:}30}[1]
\Zbox(30,30)[bc]{30,30}[1]
\multiput(0,0)(30:10){5}%
   {\makebox(0,0){\rule{1.5mm}{1.5mm}}}
\end{picture}
```

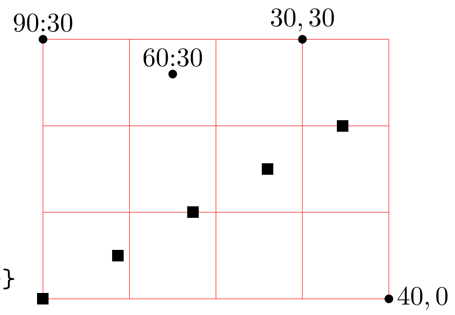


Figure 3: Use of cartesian and absolute polar coordinates. The `\Zbox` macro is just a shortcut to set a small dot with a (math) legend close to it.

A similar example may be obtained with the `\polygon` macro that does not require to terminate the polyline at the starting point. Figure 4 shows how to get a coloured filled pentagon.

```
\unitlength =.5mm
\begin{picture}(40,32)(-20,-20)
\color{magenta}
\polygon*(90:20)(162:20)(234:20)(306:20)(378:20)
\end{picture}
```

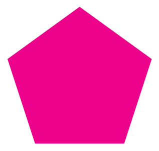


Figure 4: A pentagon obtained by means of the `\polygon*` command; vertex coordinates are in relative polar form.

7. The new command `\Dashline` (alias: `\Dline` for backwards compatibility):

   `\Dashline(`⟨*first point*⟩`)(`⟨*second point*⟩`){`⟨*dash length*⟩`}`

draws a dashed line containing as many dashes as possible, just as long as specified, and separated by a gap exactly the same size; actually, in order to make an even gap-dash sequence, the desired dash length is used to do some computations in order to find a suitable length, close to the one specified, such that the distance of the end points is evenly divided in equally sized dashes and gaps. The end points may be anywhere in the drawing area, without any constraint on the slope of the joining segment. The desired dash length is specified as a fractional multiple of `\unitlength`; see figure 5.

```
\unitlength =1mm
\begin{picture}(40,40)
\AutoGrid(40,40)
\Dashline(0,0)(40,10){4}
\put(0,0){\circle*{2}}
\Dashline(40,10)(0,25){4}
\put(40,10){\circle*{2}}
\Dashline(0,25)(20,40){4}
\put(0,25){\circle*{2}}
\put(20,40){\circle*{2}}
\Dotline(0,0)(40,40){2}[0.75mm]
\put(40,40){\circle*{2}}
\end{picture}
```

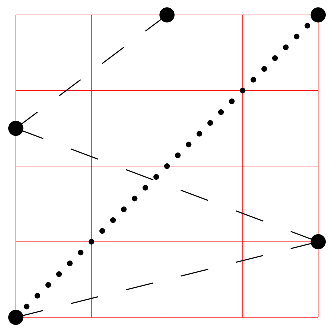


Figure 5: Dashed lines and graph grid

Another example of usage of cartesian and polar coordinates usage is shown in figure 3 together with its code.

8. Analogous to `\Dashline`, a new command `\Dotline` draws a dotted line with the syntax:

   `\Dotline(`⟨*first point*⟩`)(`⟨*end point*⟩`){`⟨*dot gap*⟩`}`

   See figures 5 and 7 for examples.

9. `\GraphGrid` and `\AutoGrid` are commands that draw a red grid under the drawing with lines separated `10\unitlength`s apart; it is described only with a comma separated couple of numbers, representing the base and the height of the grid, see figure 5; it's better to specify multiples of ten and the grid can be placed anywhere in the drawing canvas by means of `\put`, whose cartesian coordinates are multiples of 10; nevertheless the grid line distance is rounded to the nearest multiple of 10, while the point coordinates specified to `\put` are not rounded at all; therefore some care should be used to place the working grid on the drawing canvas. This grid is intended as an aid while drawing; even if you sketch your drawing on millimetre paper, the drawing grid turns out to be very useful; one must only delete or comment out the command when the drawing is finished. Several examples of usage of such grid are shown in several figures. `\Autogrid` does not require arguments; if the latter are specified they are simply ignored.

10. New trigonometric function macros have been computed by means of the functionalities of the `xfp` package. The difference with the other exist-

```
\unitlength =0.025\textwidth
\begin{picture}(40,30)
\AutoGrid(40,30)
\Dashline(0,0)(40,10){2}
\Dashline(0,0)(40,20){2}
\Dashline(0,0)(40,30){2}
\Dashline(0,0)(30,30){2}
\Dashline(0,0)(20,30){2}
\Dashline(0,0)(10,30){2}
{\color{blue}%
\Dashline(40,0)(108:30){2}
\Dashline(40,0)(126:30){2}
\Dashline(40,0)(144:30){2}
\Dashline(40,0)(162:30){2}}
\end{picture}
```

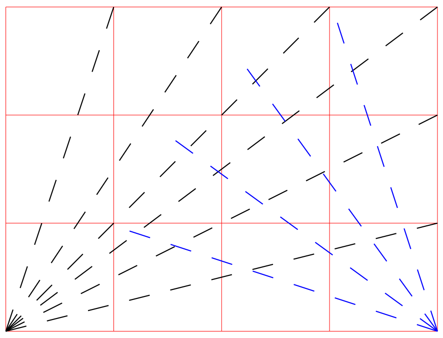


Figure 6: Different length dashed lines with the same nominal dash length; notice the relative polar coordinates used for the dashed lines starting at the grid lower right vertex.

ing macros is that angles are specified in sexagesimal degrees, so that the users need not transform to radians. The computations are done taking into account that “abnormal” values can occasionally be avoided, for example $\tan 90°$ must be avoided and replaced with a suitably large number, because the TeX system does not handle “infinity”.
These trigonometric functions are used within the complex number macros; but if the user wants to use them the syntax is the following:

`\SinOf`⟨*angle*⟩`to`⟨*control sequence*⟩
`\CosOf`⟨*angle*⟩`to`⟨*control sequence*⟩
`\TanOf`⟨*angle*⟩`to`⟨*control sequence*⟩

The ⟨*control sequence*⟩ may then be used, for example, as a multiplying factor of a length.

11. Arcs can be drawn as simple circular arcs, or with one or two arrows at their ends (curved vectors); the syntax is:

    `\Arc(`⟨*center*⟩`)(`⟨*starting point*⟩`){`⟨*angle*⟩`}`
    `\VectorArc(`⟨*center*⟩`)(`⟨*starting point*⟩`){`⟨*angle*⟩`}`
    `\VectorARC(`⟨*center*⟩`)(`⟨*starting point*⟩`){`⟨*angle*⟩`}`

    If the angle is specified numerically it must be enclosed in braces, while if it is specified with a control sequence the braces (curly brackets) are not necessary. The above macro `\Arc` draws a simple circular arc without arrows; `\VectorArc` draws an arc with an arrow tip at the ending point; `\VectorARC` draws an arc with arrow tips at both ends; see figure 8.

12. A multitude of commands have been defined in order to manage complex numbers; actually complex numbers are represented as a comma separated pair of fractional numbers (here we use only cartesian coordinates). They are used to address specific points in the drawing plane, but also as operators so as to scale and rotate other objects. In the following ⟨*vector*⟩ means a comma separated pair of fractional numbers, ⟨*vector macro*⟩

```
\unitlength =0.025\textwidth
\begin{picture}(40,30)
\AutoGrid(40,30)
\Dotline(0,0)(40,10){1.5}[2pt]
\Dotline(0,0)(40,20){1.5}[2pt]
\Dotline(0,0)(40,30){1.5}[2pt]
\Dotline(0,0)(30,30){1.5}[2pt]
\Dotline(0,0)(20,30){1.5}[2pt]
\Dotline(0,0)(10,30){1.5}[2pt]
{\color{red}\relax
\Dotline(40,0)(108:30){1.5}
\Dotline(40,0)(126:30){1.5}[2pt]
\Dotline(40,0)(144:30){1.5}[2pt]
\Dotline(40,0)(162:30){1.5}[2pt]}%
\end{picture}
```

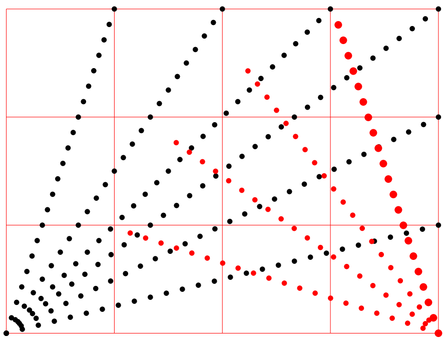


Figure 7: Different length dotted lines with the same nominal dot gap; again notice the relative polar coordinates for the dotted lines starting at the grid lower right vertex.

```
\unitlength =0.5mm
\begin{picture}(60,40)
\GraphGrid(60,40)
\Arc(0,20)(30,0){60}
\VECTOR(0,20)(30,0)\VECTOR(0,20)(32.5,36)
\VectorArc(0,20)(15,10){60}
\put(20,20){\makebox(0,0)[l]{$60^\circ$}}
\VectorARC(60,20)(60,0){-180}
\end{picture}
```

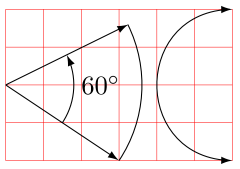


Figure 8: Arcs and curved vectors

means a macro that contains a comma separated pair of fractional numbers; ⟨*angle macro*⟩ means a macro that contains the angle of a vector in sexagesimal degrees; ⟨*argument*⟩ means a brace delimited numeric value, even a macro; ⟨*numeric macro*⟩ means a macro that contains a fractional number; *macro* is a valid macro name, i.e. a backslash followed by letters, or anything else that can receive a definition. A *direction* of a vector is its versor; the angle of a vector is the angle between the vector and the positive x axis in counterclockwise direction, as it is used in the Euler formula $\vec{v} = Me^{j\varphi}$.

- `\MakeVectorFrom`⟨*numeric macro*⟩⟨*numeric macro*⟩`to`⟨*vector macro*⟩
- `\CopyVect`⟨*first vector*⟩`to`⟨*second vector macro*⟩
- `\ModOfVect`⟨*vector*⟩`to`⟨*modulus macro*⟩
- `\DirOfvect`⟨*vector*⟩`to`⟨*versor macro*⟩
- `\ModAndDirOfVect`⟨*vector*⟩`to`⟨*modulus macro*⟩`and`⟨*versor macro*⟩
- `\ModAndAngleOfVect`⟨*vector*⟩`to`⟨*modulus macro*⟩`and`⟨*angle macro*⟩

- `\DistanceAndDirOfVect`⟨*1st vector*⟩ `minus`⟨*2nd vector*⟩ `to`⟨*distance macro*⟩ `and`⟨*versor macro*⟩
- `\XpartOfVect`⟨*vector*⟩`to`⟨*macro*⟩
- `\YpartOfVect`⟨*vector*⟩`to`⟨*macro*⟩
- `\DirFromAngle`⟨*angle*⟩`to`⟨*versor macro*⟩
- `\ArgOfVect`⟨*vector*⟩`to`⟨*angle macro*⟩
- `\ScaleVect`⟨*vector*⟩`by`⟨*scaling factor*⟩`to`⟨*vector macro*⟩
- `\ConjVect`⟨*vector*⟩`to`⟨*conjugate vector macro*⟩
- `\SubVect`⟨*subtrahend vector*⟩`from`⟨*minuend vector*⟩`to`⟨*vector macro*⟩
- `\AddVect`⟨*first vector*⟩`and`⟨*second vector*⟩`to`⟨*vector macro*⟩
- `\Multvect`{⟨*first vector*⟩}*{⟨*second vector*⟩}*{⟨*vector macro*⟩} (the asterisks are optional; either one changes the second vector into its complex conjugate)
- `\MultVect`⟨*first vector*⟩`by`⟨*second vector*⟩`to`⟨*vector macro*⟩ (discouraged; maintained for backwards compatibility)
- `\MultVect`⟨*first vector*⟩`by*`⟨*second vector*⟩`to`⟨*vector macro*⟩ (discouraged; maintained for backwards compatibility)
- `\Divvect`{⟨*dividend vector*⟩}{⟨*divisor vector*⟩}{⟨ *vector macro*⟩}
- `\DivVect`⟨*dividend vector*⟩`by`⟨*divisor vector*⟩`to`⟨*vector macro*⟩ (maintained for backwards compatibility)

13. General curves can be drawn with the pict2e macro `\curve` but it requires the specification of the third-order Bézier-spline control points; sometimes it's better to be very specific with the control points and there is no other means to do a decent graph; sometimes the curves to be drawn are not so tricky and a general set of macros can be defined so as to compute the control points, while letting the user specify only the nodes through which the curve must pass, and the tangent direction of the curve in such nodes. Such commands are the following:

    - `\Curve` draws a sequence of arcs as explained above, using third order (cubic) Bézier splines. The starred version of this command fills the internal part of the curve with the current color; if the last arc finishes where the fist arc starts, it is clear what is the interior; if it does not, the driver (not the code of this package, but the driver between this code and the physical representation on paper or screen) assumes a straight line closure of the whole path.
    - `\Qurve` is similar to `\Curve`, but with second order (quadratic) Bézier splines. The starred version fills the interior with the current color.
    - `\CurveBetween` draws a single cubic Bézier spline between two given nodes and with two given directions vectors.
    - `\CBezierBetween` draws a single cubic Bézier spline between two given nodes, with two given direction versors along which the control node distances are specified. This is the most general macro (rather difficult to use) with which not only the arc end points are specified but also the control nodes coordinates are given.

The main macro is `\Curve` and must be followed by an "unlimited" sequence of node-direction coordinates as a quadruple defined as

$$\texttt{(}\langle\textit{node coordinates}\rangle\texttt{)<}\langle\textit{direction vector}\rangle\texttt{>}$$

Possibly if a sudden change of direction has to be performed (cusp) another item can be inserted after one of those quadruples in the form

$$\ldots\texttt{(}\langle\ldots\rangle\texttt{)<}\langle\ldots\rangle\texttt{>[}\langle\textit{new direction vector}\rangle\texttt{](}\langle\ldots\rangle\texttt{)<}\langle\ldots\rangle\texttt{>}\ldots$$

Possibly it is necessary to specify the "tension" or the "looseness" of a specific Bézier arc; such tension parameters range from 0 (zero) to 4; the zero value implies a very stiff arc, as if it was a string subject to a high tension (i.e. with zero looseness); a value of 4 implies a very low tension (very high looseness), almost as if the string was not subject to any tension. In METAFONT or METAPOST language such a concept is used very often; in this package, where the Hobby algorithms are not used, the parameter value appears to mean the opposite of tension. A couple of comma separated tension values may be optionally used, they are separated with a semicolon form the direction vector, and they apply to the arc terminating with the last node; their specification must precede any possible change of tangent according to this syntax[1]:

$$\ldots\texttt{(}\langle\ldots\rangle\texttt{)<}\langle\textit{direction vector}\texttt{;}\textit{start tension}\texttt{,}\textit{end tension}\rangle\texttt{>(}\langle\ldots\rangle\texttt{)<}\langle\ldots\rangle\texttt{>}\ldots$$

The `\Curve` macro does not (still) have facilities for cycling the path, that is to close the path from the last specified node-direction to the first specified node-direction; but, as already mentioned, if the ending node of the last arc does not coincide with the starting node of the first arc, a straight line is assumed to join such nodes; this line does not get drawn, but with starred commands no lines are drawn because only the interior is coloured. The tangent direction need not be specified with a unit vector, although only its direction is relevant; the scaling of the specified direction vector to a unit vector is performed by the macro itself. Therefore one cannot specify the fine tuning of the curve convexity as it can be done with other programs or commands, as, for example, with METAFONT or the `pgf/tikz` package and environment. See figure 9 for an example.
With the starred version of `\Curve`, instead of stroking the contour, the macro fills up the contour with the selected current color, figure 10.
Figure 11 shows a geometric construction that contains the geometric elements and symbols used to determine the parameters of a cubic spline required to draw a quarter circle. This construction contains many of the commands described so far.
To show what you can do with `\CurveBetween` see the code and result shown in figure 12. Notice the effect of changing the directions at both or a the end nodes of a single cubic spline. The directions are conveniently expressed with unit vectors described by polar coordinates.
A little more complicated is the use of the `\CBezierBetween` macro, figure 13. The directions are specified with unit vectors in polar form; the

[1]The tension may be specified only for cubic splines, because the quadratic ones do not use enough parameters to control the tension; not all commands for drawing cubic splines accept this optional tension specification.

```
\unitlength =8mm\relax
\begin{picture}(5,5)
\put(0,0){\framebox(5,5){}}\thicklines\roundcap
\Curve(2.5,0)<0.1,1>(5,3.5)<0,1>%
  (4,5)<-1,0>(2.5,3.5)<-0.1,-1.2>[-0.1,1.2]%
  (1,5)<-1,0>(0,3.5)<0,-1>(2.5,0)<0.1,-1>
\end{picture}
```

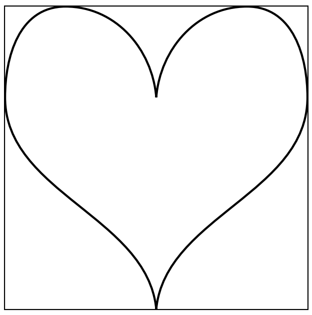


Figure 9: A heart shaped curve with cusps drawn with `\Curve`

```
\unitlength =8mm\relax
\begin{picture}(5,5)
\put(0,0){\framebox(5,5){}}\thicklines\roundcap
   \color{green}\relax
\Curve*(2.5,0)<0.1,1>(5,3.5)<0,1>%
  (4,5)<-1,0>(2.5,3.5)<-0.1,-1.2>[-0.1,1.2]%
  (1,5)<-1,0>(0,3.5)<0,-1>(2.5,0)<0.1,-1>
\end{picture}
```

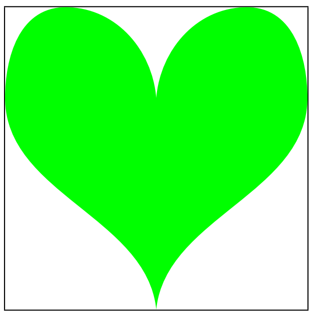


Figure 10: Coloring the inside of a closed path drawn with `\Curve*`

```
\unitlength=0.007\textwidth
\begin{picture}(100,90)(-50,-50)
\put(-50,0){\vector(1,0){100}}\put(50,1){\makebox(0,0)[br]{$x$}}%
\put(20,-1){\makebox(0,0)[t]{$s$}}%
\put(0,0){\circle*{2}}\put(-1,-1){\makebox(0,0)[tr]{$M$}}%
\legenda(12,-45){s=\overline{MP_2}=R\sin\theta}%
\put(0,-50){\vector(0,1){90}}%
\put(1,40){\makebox(0,0)[tl]{$y$}}%
\put(0,-40){\circle*{2}}\put(1,-41){\makebox(0,0)[lt]{$C$}}%
\segment(0,-40)(-40,0)\segment(0,-40)(40,0)%
\put(-41,1){\makebox(0,0)[br]{$P_1$}}\put(-40,0){\circle*{2}}%
\put(41,1){\makebox(0,0)[bl]{$P_2$}}\put(40,0){\circle*{2}}%
\put(0,0){\linethickness{1pt}\Arc(0,-40)(40,0){90}}%
\segment(-40,0)(-20,20)\put(-20,20){\circle*{2}}%
\put(-20,21.5){\makebox(0,0)[b]{$C_1$}}%
\segment(40,0)(20,20)\put(20,20){\circle*{2}}%
\put(20,21.5){\makebox(0,0)[b]{$C_2$}}%
\put(0,-40){\put(0,56.5685){\circle*{2}}%
\put(1,58){\makebox(0,0)[bl]{$P$}}}%
\VectorARC(0,-40)(15,-25){45}\put(10,-18){\makebox(0,0)[c]{$\theta$}}%
\VectorARC(40,0)(20,0){-45}\put(19,5){\makebox(0,0)[r]{$\theta$}}%
\VectorARC(-40,0)(-20,0){45}\put(-19,5){\makebox(0,0)[l]{$\theta$}}%
\put(-20,-18){\makebox(0,0)[bl]{$R$}}%
\put(-32,13){\makebox(0,0)[bl]{$K$}}%
\put(32,13){\makebox(0,0)[br]{$K$}}%
\end{picture}
```

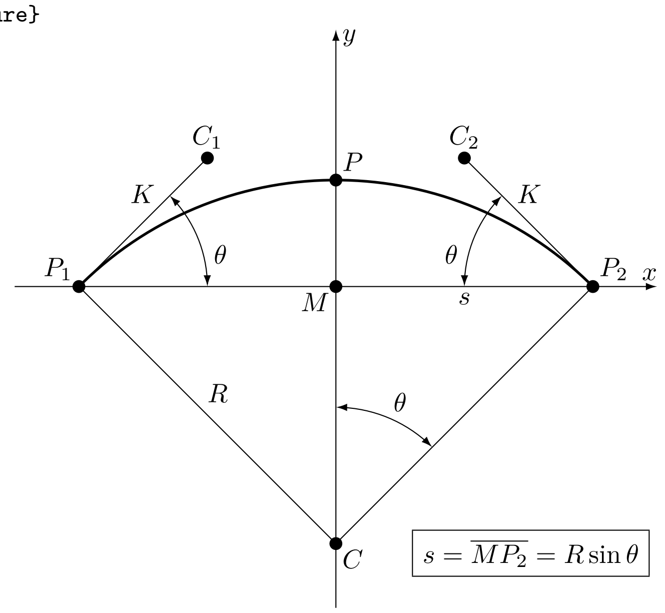


Figure 11: The code to display the nodes and control points for an arc to be approximated with a cubic Bézier spline

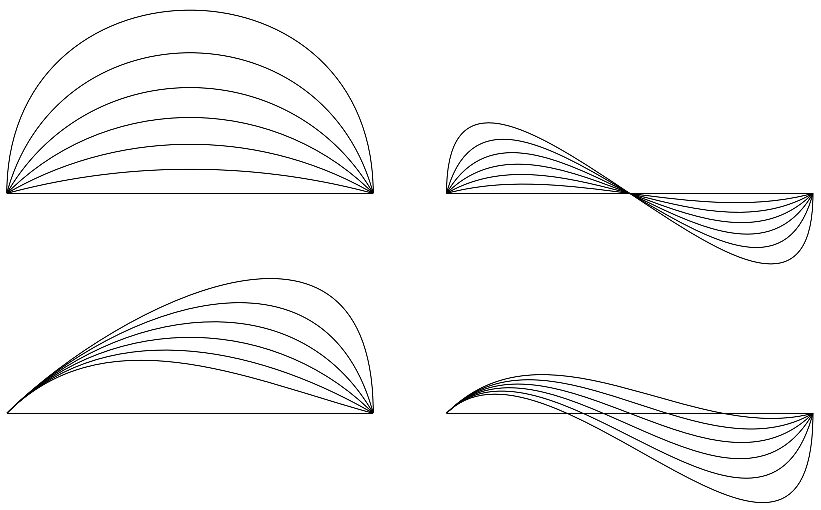


Figure 12: Curves between two points with different start and end slopes

```
\unitlength=0.1\textwidth
\begin{picture}(10,3)
\CurveBetween0,0and10,0WithDirs1,1and{1,-1}
\color{red}%
\CbezierBetween0,0And10,0 WithDirs45:1And-45:1UsingDists4And{1}
\CbezierBetween0,0And10,0 WithDirs45:1And-45:1UsingDists6And{1}
\CbezierBetween0,0And10,0 WithDirs45:1And-45:1UsingDists8And{1}
\CbezierBetween0,0And10,0 WithDirs45:1And-45:1UsingDists10And{1}
\CbezierBetween0,0And10,0 WithDirs45:1And-45:1UsingDists12And{1}
\end{picture}
```

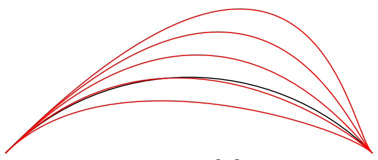


Figure 13: Comparison between similar arcs drawn with `\CurveBetween` (black) and `\CbezierTo` (red)

control points are specified by adding their distances from their neighbouring nodes; actually the right distance is maintained to the value 1, while the left one increases from 4 to 10. The black line corresponds to the standard `\CurveBetween` where the default distance is computed to trace an arc of a circle and is approximately 3.5.
In figure 14 the effect of tension specification is shown. The red line corresponds to the default tension, since the tension values are not specified. The black lines correspond to the various values used in the various commands to the `\Curve` macro. With a tension of zero, the spline is almost coincident with the horizontal base line of the frame. Increasing the parameter value to 4.5, the curved becomes taller and taller, until it wraps itself displaying an evident loop. We would say that the value of 2 is a reasonable maximum and increasing that value is just to obtain special effects.
Figure 15 displays two approximations of a sine wave; Bézier splines can approximate transcendental curves, but the approximation may be a poor one, depending on the approximated curve, when few arcs are used to draw it. With arcs specified with more complicated macros the approx-

```
\unitlength =0.01\textwidth
\begin{picture}(70,70)
\put(0,0){\color{blue}\framebox(70,70){}}
\put(0,0){\color{red}%
  \Curve(0,0)<1,1>(70,0)<1,-1>}
\Curve(0,0)<1,1>(70,0)<1,-1;0,0>
\Curve(0,0)<1,1>(70,0)<1,-1;0.2,0.2>
\Curve(0,0)<1,1>(70,0)<1,-1;2,2>
\Curve(0,0)<1,1>(70,0)<1,-1;4.5,4.5>
\Curve(0,0)<1,1>(70,0)<1,-1;0,3>
\Curve(0,0)<1,1>(70,0)<1,-1;3,0>
\end{picture}
```

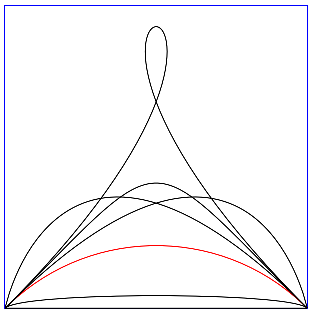


Figure 14: The effects of tension factors

imation is better even with a lower number of arcs. With many arcs it is possible to approximate almost anything. On the left side a modest approximation is obtained with just three standard arcs obtained with `\Curve` and four node specifications; on the right we have just two arcs created with `CBezierBetween` with tension specification and control point distances; this drawing is almost undistinguishable from a real sinusoid.
In figure 16 some lines drawn are shown; they are drawn with quadratic splines by means of the `\Qurve` macro. In the left there are some open and closed curves inscribed within a square. On the right a "real" circle is compared to a quadratic spline circle; the word "real" is emphasised because it actually is an approximation with four quarter-circle cubic splines that, in spite of being drawn with third degree parametric polynomials, approximate very well a real circle; on the opposite the quadratic spline circle is clearly a poor approximation even if the maximum radial error amounts just to about 6% of the radius.
Notice that the previous version of `curve2e` contained an error and would color the outside of the green four-pointed star. The `curve2e-v161`, attached to this bundle, has been corrected; therefore it is not actually identical to the previous version, although the latter one performed correctly for everything else except for color-filled quadratic paths.

14. The new version of `\multiput` is backwards compatibile with the original version contained in the LaTeX kernel. The new macro adds the handling of the coordinate increments from one position to the next for the ⟨*object*⟩ to include in the drawing.
On page **??** we show the code for the figure shown there. The red grid is nothing new, except that it displays the traditional `\multiput` used in this code, shown in a previous example, produces exactly the same result. But the for "graphs" on the grid, it display an alignment of black dots along the diagonal of the grid (again traditional `\multiput` rendered with the new version); a number of blue dots along a parabola; another number of magenta dots alined along a half sine wave; a number of little green squares aligned along a $-15\circ$ line starting from the center of the grid; notice the polar values that are used as polar relative coordinate increments.

A new command `\xmultiput` (not available with the previous versions of

```
\unitlength=0.01\textwidth
\begin{picture}(100,50)(0,-25)
\put(0,0){%
\VECTOR(0,0)(45,0)\VECTOR(0,-25)(0,25)
\Pbox(45,0)[b]{x}[0]\Pbox(0,26)[tl]{y[0]}
\Curve(0,0)<77:1>(10,20)<1,0;2,0.4>(30,-20)<1,0;0.4,0.4>(40,0)<77:1;0.4,2>
}
\put(55,0){%
\VECTOR(0,0)(45,0)\VECTOR(0,-25)(0,25)
\Pbox(45,0)[b]{x}[0]\Pbox(0,26)[tl]{y}[0]
\CbezierBetween0,0And20,0WithDirs77:1And-77:1UsingDists28And{28}
\CbezierBetween20,0And40,0WithDirs-77:1And77:1UsingDists28And{28}}
\end{picture}
```

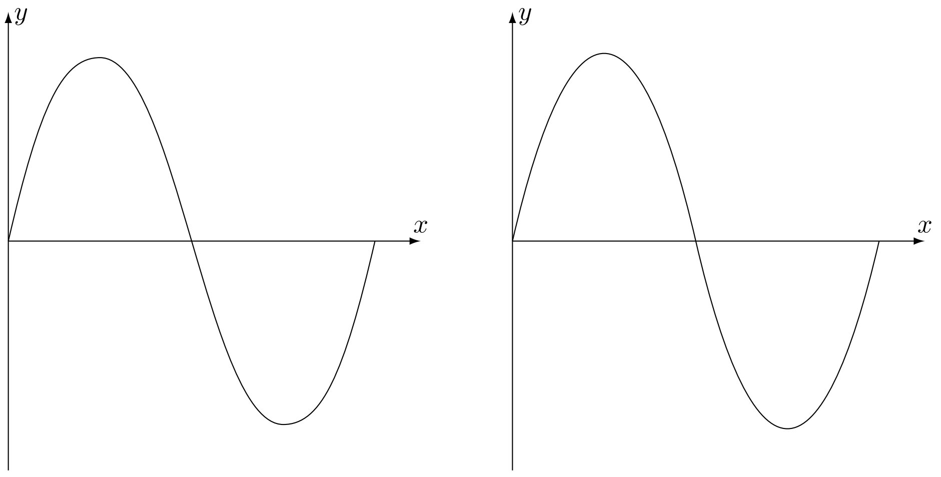


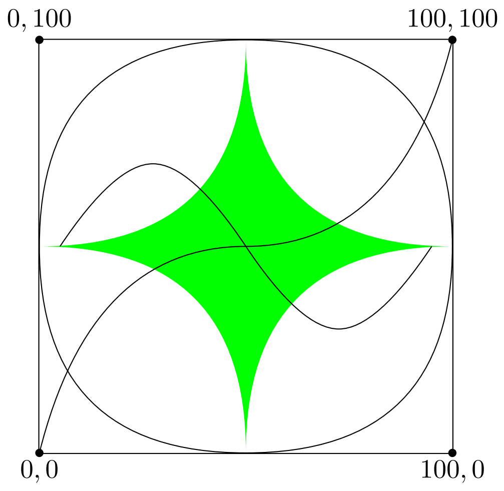
Figure 15: A sequence of arcs; the left figure has been drawn with the `\Curve` command with a sequence of four couples of point-direction arguments; the right figure has been drawn with two commands `\CbezierBetween` that include also the specification of the control points

curve2e) extended with respect to the original `\multiput` is defined by using some L3 functions; in particular the cycling counter is accessible to the LaTeX commands and it is stepped forward from 1 to the value specified in the proper command argument (in the original command it starts from that value and is stepped down to zero). See the figure on page 18 to inspect its usage. It is important to notice that if the command`\rotatebox` has to be used, as in the example of figure 18, the package `graphics` should be also loaded, because `curve2e` does not do it.

15. This implementation of `curve2e` includes an extension to package `xfp`, in the sense that adds two more L3 commands: `\fptest` and `\fpdowhile` to the two already contained and documented in the latter package. The syntax of such new commands is the following

    `\fptext`{⟨*test*⟩}{⟨*true*⟩}{⟨*false*⟩}
    and
    `\fpdowhile`⟨*test*⟩⟨*operations to be repeated*⟩

```
\unitlength=0.0045\textwidth
\begin{picture}(100,100)
\put(0,0){\framebox(100,100){}}
\put(50,50){%
  \Qurve(0,-50)<1,0>(50,0)<0,1>(0,50)<-1,0>(-50,0)<0,-1>(0,-50)<1,0>
\color{green}
  \Qurve*(0,-50)<0,1>(50,0)<1,0>[-1,0](0,50)<0,1>[0,-1](-50,0)<-1,0>[1,0](0,-50)<0,-1>
}
\Qurve(0,0)<1,4>(50,50)<1,0>(100,100)<1,4>
\put(5,50){\Qurve(0,0)<1,1.5>(22.5,20)<1,0>(45,0)<1,-1.5>%
(67.5,-20)<1,0>(90,0)<1,1.5>}
\Zbox(0,0)[tc]{0,0}\Zbox(100,0)[tc]{100,0}
\Zbox(100,100)[bc]{100,100}\Zbox(0,100)[bc]{0,100}
\Pall[2](0,0)\Pall[2](100,0)\Pall[2](100,100)\Pall[2](0,100)
\end{picture}
\hfill
\begin{picture}(100,100)
\put(0,0){\framebox(100,100){}}
\put(50,50){%
\Qurve(0,-50)<1,0>(50,0)<0,1>(0,50)<-1,0>(-50,0)<0,-1>(0,-50)<1,0>
\Curve(0,-50)<1,0>(50,0)<0,1>(0,50)<-1,0>(-50,0)<0,-1>(0,-50)<1,0>}
\Zbox(50,50)[t]{O}\Pall[2](50,50)\put(50,50){\Vector(45:50)}\Zbox(67,70)[tl]{R}
\end{picture}
```



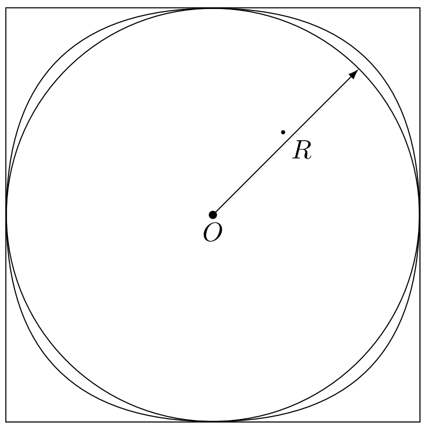


Figure 16: Several graphs drawn with quadratic Bézier splines. On the right a quadratic spline circle is compared with a cubic line circle.

The macro `\fptest` requires two further arguments that contain what to do if the ⟨*test*⟩ is true, and what to do if the ⟨*test*⟩ is false. The ⟨*test*⟩ is a logical expressions that connects math relation expressions, even floating point ones, by means of *logical operators*; such operators are `||`, `&&`, and `!`, respectively for OR, AND, NOT; for example `!<` means "not lower than", which is equivalent to "equal or grater than". The logical expression is parsed left to right and normal parentheses may be used to alter this sequence. The logical operators work also between logical variables, therefore the ⟨*test*⟩ may contain an interesting mixture of relation and logical operators.
Before using `\fpdowhile` the arguments the ⟨*test*⟩ depends from must be set so that the test is true; during the execution of the ⟨*operations*

```
\unitlength=0.01\linewidth
\begin{picture}(100,100)
\GraphGrid(100,100)
\multiput(0,0)(10,10){11}{\circle*{2}}
\color{blue!70!white}
\multiput(0,0)(10,0){11}{\circle*{2}}%
  [\GetCoord(\R)\X\Y
  \edef\X{\fpeval{\X+10}}
  \edef\Y{\fpeval{(\X/10)**2}}
  \CopyVect\X,\Y to\R]
\color{magenta}
\multiput(0,0)(10,1){11}{\circle*{2}}%
  [\GetCoord(\R)\X\Y
   \edef\X{\fpeval{\X+10}}
   \edef\Y{\fpeval{sind(\X*1.8)*100}}
   \CopyVect\X\Y to\R]
\color{green!80!black}
\multiput(50,50)(-15:5){11}}{%
\polygon*(-1,-1)(1,-1)(1,1)(-1,1)}
\end{picture}
```

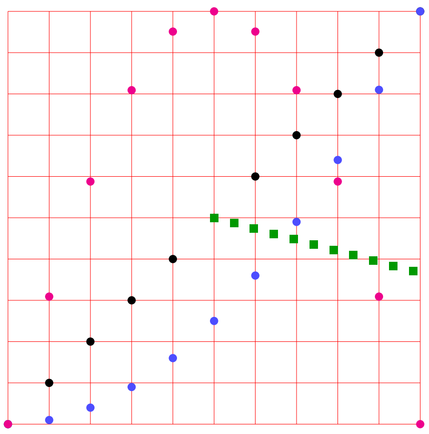


Figure 17: Some examples of the ⟨*handler*⟩ optional argument

```
\unitlength=0.0095\linewidth
\begin{picture}(100,100)
\GraphGrid(100,100)
\put(50,50){\thicklines\circle{100}}
\xmultiput[50,50](60:40)(-30:1){12}%
  {\makebox(0,0){\circle*{2}}}%
  [\MultVect\R by\D to\R]%
\xmultiput[50,50](60:46)(-30:1){12}%
  {\ArgOfVect\R to\Ang
  \rotatebox{\fpeval{\Ang-90}}%
  {\makebox(0,0)[b]{\Roman{multicnt}}}}%
  [\Multvect{\R}{\D}\R]
\end{picture}
```

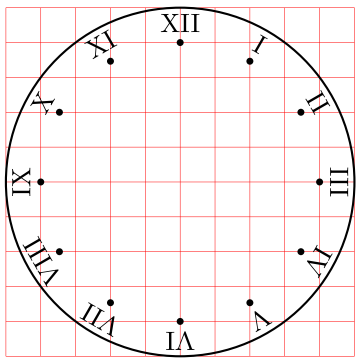


Figure 18: Usage example of the `\xmultiput` command

to be repeated⟩ there must be some setting that eventually renders the ⟨*test*⟩ false. The user should pay attention to set the elements that ⟨*test*⟩ depends from, because the risk is to enter an infinite loop and end up with some error message stating that the working memory of the program is full.

Nevertheless such commands are very useful also for drawing graphics; the `xmultiput` already makes use of such L3 functions.

As an example of use, we show how to plot a mathematical function expressed in parametric form:

$$\begin{cases} x = f_1(t) \\ y = f_2(t) \end{cases}$$

The plot is executed with a piecewise linear approximation of the curve; if the t steps are sufficiently small, the plot turns out to be very nice; here

we show an example where we plot a Lissajous curve with two sinusoids of different period.
We start by defining the Lissajous function with arguments to specify the parameter t, the sinusoid amplitudes A_1, A_2, the respective "frequencies", by means of integer multiples of a unit pulsation, N_1, N_2, and the initial phases ϕ_1, ϕ_2 of such sinusoids. It is better to keep apart the input of the curve coefficients from the actual curve argument/parameter and output point coordinates:

```
\def\LissajousCoefs#1,#2,#3,#4,#5,#6!{%
\edef\LAu{#1}\edef\LNu{#2}\edef\LFu{#3}%
\edef\LAd{#4}\edef\LNd{#5}\edef\LFd{#6}}

\def\LissajousCode#1#2{%
\edef\X{\fpeval{\LAu*cosd(\LNu*#1+\LFu)}}%
\edef\Y{\fpeval{\LAd*cosd(\LNd*#1+\LFd)}}%
\CopyVect\X,\Y to#2\ignorespaces}
```

As it is shown, the coefficients are specified as a comma separated list; the `!` list terminator is taken care by the actual drawing command.
Then the curve drawing command requires the coefficient specification only the first time it is used; some messages[2] are output if the coefficients have been "forgotten".

```
\NewDocumentCommand\Lissajous{m o m}{%
\IfValueTF{#2}{\LissajousCoefs#2!\relax
\LissajousCode{#1}{#3}}%
{\ifcsname LAu\endcsname
\LissajousCode{#1}{#3}%
\else\PackageError{curve2e}%
  {This Lissajous' curve coefficients\MessageBreak
   are missing}{Nothing done}\fi}%
\ignorespaces}
```

The syntax is the following:

`\Lissajous{`$\langle in\rangle$`}[`$\langle A_1\rangle$`,`$\langle N_1\rangle$`,`$\langle \phi_1\rangle$`,`$\langle A_2\rangle$`,`$\langle N_2\rangle$`,`$\langle \phi_2\rangle$`]`$\langle P_{\text{out}}\rangle$

where $\langle P_{\text{out}}\rangle$ is a macro that gets defined with the cartesian coordinates of the computed output point.Arguments $\langle in\rangle$ (the t parameter) and $\langle out\rangle$ (the computed coordinates) need not be enclosed within braces if they are given as macros; actually the code shown in figure 19 shows such procedure that renders the input code simpler to read.
After this definition the diagram is plotted in figure 19.
For the independent variable t, the parameter of the Lissajous parametric equations, it is better to work with degrees instead of radians, and with integer numbers, so that the whole range from 0° to 360° is certainly

[2]Here it would be better to have available a "Macro Error" message; such a macro is not available, but it would be possible to define it by means of the `\GenericError` macro provided by the LaTeX2e kernel. Here we skip this definition in order to avoid overloading this documentation with such details.

```
\unitlength=0.01\linewidth
\begin{picture}(100,100)(-50,-50)
\GraphGrid(-50,-50)(100,100)
\VECTOR(-50,0)(50,0)\Pbox(50,0)[tr]{x}[0]
\VECTOR(0,-50)(0,50)\Pbox(0,50)[tr]{y}[0]
\Pbox(0,0)[tr]{O}[2]
%
{\countdef\I=2560 \I=0
\fpdowhile{\I !> 360}{%
  \fptest{\I=0}%
     {\Lissajous\I[40,2,90,40,3,0]\Pout
       \moveto(\Pout)}%
     {\Lissajous\I\Pout
       \lineto(\Pout)}%
  \advance\I by1}\strokepath}%
\end{picture}
```

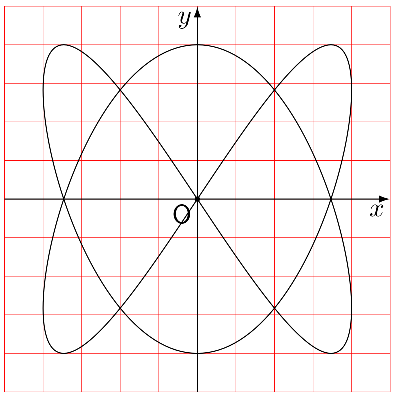


Figure 19: A Lissajous diagram

spanned. Notice the braces that include the code for the Lissajous diagram; they may be useful to render that group suitable to be `\put` somewhere else than with its center at the origin of the canvas axes, and/or to be used as the second argument of a `\rotatebox`{⟨*angle*⟩} command so as to rotate the whole diagram.

4 Remark

In spite of the relative simplicity of the macros contained in this package, the described macros, as well as the original ones included in the pict2e package, they allow to produce fine drawings that were unconceivable with the original LaTeX picture environment. Leslie Lamport himself announced an extension to his environment when LaTeX 2$_\varepsilon$ was first released in 1994; in the `latexnews` news-letter of December 2003, the first implementation of Lamport's extension was announced; the first version of this package curve2e was issued in 2006. It was time to have a better drawing environment; this package is a simple attempt to follow the initial path while further extending the drawing facilities.

There are other packages in the CTAN archives that deal with tracing curves of various kinds. PSTricks and pgf/tikz are the most powerful ones. And they are becoming the standard for programmed drawing. Their documentation is huge and the multitude of extra modules to perform special tasks is countless. Therefore they are difficult to use; when the user gets used to their particular syntax and got sufficient familiarity with several modules, s/he can uses these bundles very comfortably.

This difficulty in getting a TikZ or PS expert is why I think a simpler drawing machinery should be appreciated; I admit it: I like the *picture* environment; and I like to deal with simple codes so as to create my own macros.

But there is also curves that is intended to draw almost anything by using little dots or other symbols partially superimposed to one another. It uses only quadratic Bézier curves and the curve tracing is eased by specifying only the curve nodes, without specifying the control nodes; with a suitable option to the package call, it is possible to reduce the memory usage by using short straight segments drawn with the PostScript facilities offered by the `dvips` driver.

Another package, ebezier performs about the same as curve2e but draws its Bézier curves by using little dots partially superimposed to one another. The documentation is quite interesting since it explains very clearly what exactly are the Bézier splines. Apparently ebezier should be used only for DVI output without recourse to PostScript or PDF machinery.

The picture package extends the performance of the *picture* environment (extended with pict2e) by accepting coordinates and lengths in real absolute dimensions, not only as multiples of `\unitlength`; it provides commands to extend that functionality to other packages. In certain circumstances it may be very useful.

Package xpicture builds over the *picture* LaTeX environment so as to allow to draw the usual curves that are part of an introductory analytic geometry course; lines, circles, parabolas, ellipses, hyperbolas, and polynomials; the syntax is rather comfortable, although it is not a simple extension of the *picture* own syntax; for all these curves it uses the quadratic Bézier splines.

Package hobby extends the cubic Bézier spline handling with the algorithms John Hobby created for METAFONT and METAPOST. But by now this package interfaces very well with `tikz`; it has not (yet) been adapted to the common *picture* environment extended with pict2e, and, why not, with curve2e.

5 Acknowledgements

I wish to express my deepest thanks to Michel Goosens who spotted some errors and very kindly submitted them to me so that I was able to correct them.

Josef Tkadlec and the author collaborated extensively in order to implement a better real long division so as to get correctly the quotient fractional part and to avoid as much as possible any numeric overflow; many Josef's ideas are incorporated in the macro that was implemented in the previous version of this package, although the macro used by Josef was slightly different. Both versions aim/aimed at a better accuracy and at widening the operand ranges. In this version of curve2e we abandoned our long division macro, and substituted it with the floating point division provided by the `xfp` package.

Daniele Degiorgi spotted a fault in the kernel definition of `\linethickness` that heavily influenced also curve2e; see in the code documentation `curve2e.pdf` file.

Thanks also to Jin-Hwan Cho and Juho Lee who suggested a small but crucial modification in order to have curve2e work smoothly also with XeTeX (XeLaTeX). Actually if pict2e, version 0.2x or later dated 2009/08/05 or later, is being used, such modification is not necessary any more, but it is true that it becomes imperative when legacy versions were used.