PyX Manual

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Abstract

PyX is a Python package for the creation of PostScript, PDF, and SVG files. It combines an abstraction of the PostScript drawing model with a TeX/LaTeX interface. Complex tasks like 2d and 3d plots in publication-ready quality are built out of these primitives.

CHAPTER

ONE

INTRODUCTION

PyX is a Python package for the creation of vector graphics. As such it readily allows one to generate encapsulated PostScript files by providing an abstraction of the PostScript graphics model. Based on this layer and in combination with the full power of the Python language itself, the user can just code any complexity of the figure wanted. PyX distinguishes itself from other similar solutions by its TeX/LaTeX interface that enables one to make direct use of the famous high quality typesetting of these programs.

A major part of PyX on top of the already described basis is the provision of high level functionality for complex tasks like 2d plots in publication-ready quality.

1.1 Organisation of the PyX package

The PyX package is split into several modules, which can be categorised in the following groups

Functionality	Modules
basic graphics functionality	*canvas*, *path*, deco, *style*, *color*, and *connector*
text output via TeX/LaTeX	*text* and *box*
linear transformations and units	*trafo* and *unit*
graph plotting functionality	*graph* (including submodules) and *graph.axis* (including submodules)
EPS file inclusion	*epsfile*

These modules (and some other less import ones) are imported into the module namespace by using

```
from pyx import *
```

at the beginning of the Python program. However, in order to prevent namespace pollution, you may also simply use `import pyx`. Throughout this manual, we shall always assume the presence of the above given import line.

CHAPTER

TWO

BASIC GRAPHICS

2.1 Introduction

The path module allows one to construct PostScript-like *paths*, which are one of the main building blocks for the generation of drawings. A PostScript path is an arbitrary shape consisting of straight lines, arc segments and cubic Bézier curves. Such a path does not have to be connected but may also comprise several disconnected segments, which will be called *subpaths* in the following.

Todo: example for paths and subpaths (figure)

Usually, a path is constructed by passing a list of the path primitives `moveto`, `lineto`, `curveto`, etc., to the constructor of the *`path`* class. The following code snippet, for instance, defines a path *p* that consists of a straight line from the point $(0, 0)$ to the point $(1, 1)$

```
from pyx import *
p = path.path(path.moveto(0, 0), path.lineto(1, 1))
```

Equivalently, one can also use the predefined *`path`* subclass `line` and write

```
p = path.line(0, 0, 1, 1)
```

While already some geometrical operations can be performed with this path (see next section), another PyX object is needed in order to actually being able to draw the path, namely an instance of the *`canvas`* class. By convention, we use the name *c* for this instance:

```
c = canvas.canvas()
```

In order to draw the path on the canvas, we use the `stroke()` method of the *`canvas`* class, i.e.,

```
c.stroke(p)
c.writeEPSfile("line")
```

To complete the example, we have added a `writeEPSfile()` call, which writes the contents of the canvas to the file `line.eps`. Note that an extension `.eps` is added automatically, if not already present in the given filename. Similarly, if you want to generate a PDF or SVG file instead, use

```
c.writePDFfile("line")
```

or

c.writeSVGfile(“line”)

As a second example, let us define a path which consists of more than one subpath:

```
cross = path.path(path.moveto(0, 0), path.rlineto(1, 1),
                  path.moveto(1, 0), path.rlineto(-1, 1))
```

The first subpath is again a straight line from $(0, 0)$ to $(1, 1)$, with the only difference that we now have used the `rlineto` class, whose arguments count relative from the last point in the path. The second `moveto` instance opens a new subpath starting at the point $(1, 0)$ and ending at $(0, 1)$. Note that although both lines intersect at the point $(1/2, 1/2)$, they count as disconnected subpaths. The general rule is that each occurrence of a `moveto` instance opens a new subpath. This means that if one wants to draw a rectangle, one should not use

```
rect1 = path.path(path.moveto(0, 0), path.lineto(0, 1),
                  path.moveto(0, 1), path.lineto(1, 1),
                  path.moveto(1, 1), path.lineto(1, 0),
                  path.moveto(1, 0), path.lineto(0, 0))
```

which would construct a rectangle out of four disconnected subpaths (see Fig. *Rectangle example* a). In a better solution (see Fig. *Rectangle example* b), the pen is not lifted between the first and the last point:

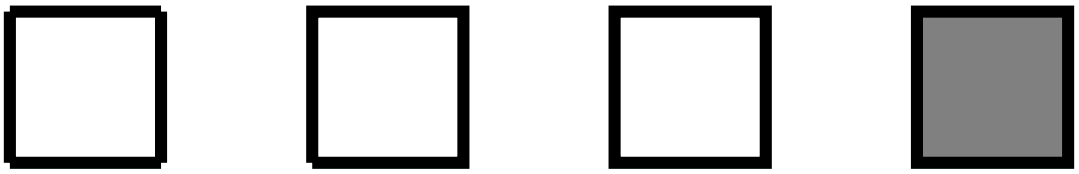


Fig. 1: Rectangle example
Rectangle consisting of (a) four separate lines, (b) one open path, and (c) one closed path. (d) Filling a path always closes it automatically.

```
rect2 = path.path(path.moveto(0, 0), path.lineto(0, 1),
                  path.lineto(1, 1), path.lineto(1, 0),
                  path.lineto(0, 0))
```

However, as one can see in the lower left corner of Fig. *Rectangle example* b, the rectangle is still incomplete. It needs to be closed, which can be done explicitly by using for the last straight line of the rectangle (from the point $(0, 1)$ back to the origin at $(0, 0)$) the `closepath` directive:

```
rect3 = path.path(path.moveto(0, 0), path.lineto(0, 1),
                  path.lineto(1, 1), path.lineto(1, 0),
                  path.closepath())
```

The `closepath` directive adds a straight line from the current point to the first point of the current subpath and furthermore *closes* the sub path, i.e., it joins the beginning and the end of the line segment. This results in the intended rectangle shown in Fig. *Rectangle example* c. Note that filling the path implicitly closes every open subpath, as is shown for a single subpath in Fig. *Rectangle example* d), which results from

```
c.stroke(rect2, [deco.filled([color.grey(0.5)])])
```

Here, we supply as second argument of the `stroke()` method a list which in the present case only consists of a single element, namely the so called decorator `deco.filled`. As its name says, this decorator specifies that the path is not only being stroked but also filled with the given color. More information about decorators, styles and other attributes which can be passed as elements of the list can be found in Sect. *Attributes: Styles and Decorations*. More details on the available path elements can be found in Sect. *Path elements*.

To conclude this section, we should not forget to mention that rectangles are, of course, predefined in PyX, so above we could have as well written

```
rect2 = path.rect(0, 0, 1, 1)
```

Here, the first two arguments specify the origin of the rectangle while the second two arguments define its width and height, respectively. For more details on the predefined paths, we refer the reader to Sect. *Predefined paths*.

2.2 Path operations

Often, one wants to perform geometrical operations with a path before placing it on a canvas by stroking or filling it. For instance, one might want to intersect one path with another one, split the paths at the intersection points, and then join the segments together in a new way. PyX supports such tasks by means of a number of path methods, which we will introduce in the following.

Suppose you want to draw the radii to the intersection points of a circle with a straight line. This task can be done using the following code which results in Fig. *Example: Intersection of circle with line yielding two radii*

```
from pyx import *

c = canvas.canvas()

circle = path.circle(0, 0, 2)
line = path.line(-3, 1, 3, 2)
c.stroke(circle, [style.linewidth.Thick])
c.stroke(line, [style.linewidth.Thick])

isects_circle, isects_line = circle.intersect(line)
for isect in isects_circle:
    isectx, isecty = circle.at(isect)
    c.stroke(path.line(0, 0, isectx, isecty))

c.writePDFfile()
```

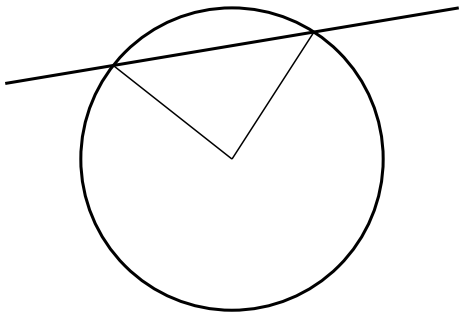


Fig. 2: Example: Intersection of circle with line yielding two radii

Here, the basic elements, a circle around the point $(0, 0)$ with radius 2 and a straight line, are defined. Then, passing the *line*, to the `intersect()` method of *circle*, we obtain a tuple of parameter values of the intersection points. The first element of the tuple is a list of parameter values for the path whose `intersect()` method has been called, the second element is the corresponding list for the path passed as argument to this method. In the present example, we only need one list of parameter values, namely *isects_circle*. Using the `at()` path method to obtain the point corresponding to the parameter value, we draw the radii for the different intersection points.

Another powerful feature of PyX is its ability to split paths at a given set of parameters. For instance, in order to fill in the previous example the segment of the circle delimited by the straight line (cf. Fig. *Example: Intersection of*

circle with line yielding radii and circle segment), one first has to construct a path corresponding to the outline of this segment. The following code snippet yields this *segment*

```
arc1, arc2 = circle.split(isects_circle)
if arc1.arclen() < arc2.arclen():
    arc = arc1
else:
    arc = arc2

isects_line.sort()
line1, line2, line3 = line.split(isects_line)

segment = line2 << arc
```

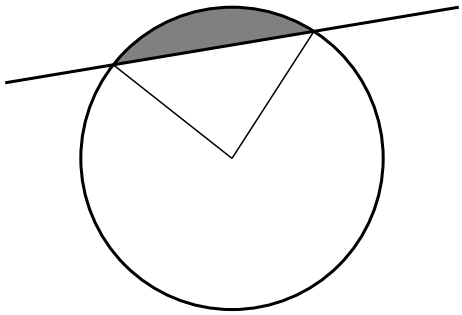


Fig. 3: Example: Intersection of circle with line yielding radii and circle segment

Here, we first split the circle using the `split()` method passing the list of parameters obtained above. Since the circle is closed, this yields two arc segments. We then use the `arclen()`, which returns the arc length of the path, to find the shorter of the two arcs. Before splitting the line, we have to take into account that the `split()` method only accepts a sorted list of parameters. Finally, we join the straight line and the arc segment. For this, we make use of the << operator, which not only adds the paths (which could be done using `line2 + arc`), but also joins the last subpath of *line2* and the first one of *arc*. Thus, *segment* consists of only a single subpath and filling works as expected.

An important issue when operating on paths is the parametrisation used. Internally, PyX uses a parametrisation which uses an interval of length 1 for each path element of a path. For instance, for a simple straight line, the possible parameter values range from 0 to 1, corresponding to the first and last point, respectively, of the line. Appending another straight line, would extend this range to a maximal value of 2.

However, the situation becomes more complicated if more complex objects like a circle are involved. Then, one could be tempted to assume that again the parameter value ranges from 0 to 1, because the predefined circle consists just of one `arc` together with a `closepath` element. However, this is not the case: the actual range is much larger. The reason for this behaviour lies in the internal path handling of PyX: Before performing any non-trivial geometrical operation on a path, it will automatically be converted into an instance of the `normpath` class (see also Sect. *path.normpath*). These so generated paths are already separated in their subpaths and only contain straight lines and Bézier curve segments. XXX explain normpathparams and things like p.begin(), p.end()-1,

A more geometrical way of accessing a point on the path is to use the arc length of the path segment from the first point of the path to the given point. Thus, all PyX path methods that accept a parameter value also allow the user to pass an arc length. For instance,

```
from math import pi

r = 2
pt1 = path.circle(0, 0, r).at(r*pi)
pt2 = path.circle(0, 0, r).at(r*3*pi/2)
```

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```
c.stroke(path.path(path.moveto(*pt1), path.lineto(*pt2)))
```

will draw a straight line from a point at angle 180 degrees (in radians π) to another point at angle 270 degrees (in radians $3\pi/2$) on a circle with radius $r = 2$. Note however, that the mapping from an arc length to a point is in general discontinuous at the beginning and the end of a subpath, and thus PyX does not guarantee any particular result for this boundary case.

More information on the available path methods can be found in Sect. *Class path — PostScript-like paths*.

2.3 Attributes: Styles and Decorations

Attributes define properties of a given object when it is being used. Typically, there are different kinds of attributes which are usually orthogonal to each other, while for one type of attribute, several choices are possible. An example is the stroking of a path. There, linewidth and linestyle are different kind of attributes. The linewidth might be thin, normal, thick, etc., and the linestyle might be solid, dashed etc.

Attributes always occur in lists passed as an optional keyword argument to a method or a function. Usually, attributes are the first keyword argument, so one can just pass the list without specifying the keyword. Again, for the path example, a typical call looks like

```
c.stroke(path, [style.linewidth.Thick, style.linestyle.dashed])
```

Here, we also encounter another feature of PyX's attribute system. For many attributes useful default values are stored as member variables of the actual attribute. For instance, `style.linewidth.Thick` is equivalent to `style.linewidth(0.04, type="w", unit="cm")`, that is 0.04 width cm (see Sect. *Module unit* for more information about PyX's unit system).

Another important feature of PyX attributes is what is call attributed merging. A trivial example is the following:

```
# the following two lines are equivalent
c.stroke(path, [style.linewidth.Thick, style.linewidth.thin])
c.stroke(path, [style.linewidth.thin])
```

Here, the `style.linewidth.thin` attribute overrides the preceding `style.linewidth.Thick` declaration. This is especially important in more complex cases where PyX defines default attributes for a certain operation. When calling the corresponding methods with an attribute list, this list is appended to the list of defaults. This way, the user can easily override certain defaults, while leaving the other default values intact. In addition, every attribute kind defines a special clear attribute, which allows to selectively delete a default value. For path stroking this looks like

```
# the following two lines are equivalent
c.stroke(path, [style.linewidth.Thick, style.linewidth.clear])
c.stroke(path)
```

The clear attribute is also provided by the base classes of the various styles. For instance, `style.strokestyle.clear` clears all strokestyle subclasses i.e. `style.linewidth` and `style.linestyle`. Since all attributes derive from `attr.attr`, you can remove all defaults using `attr.clear`. An overview over the most important attribute types provided by PyX is given in the following table.

Attribute category	description	examples
`deco.deco`	decorator specifying the way the path is drawn	`deco.stroked`, `deco.filled`, `deco.arrow`, `deco.text`
`style.strokestyle`	style used for path stroking	`style.linecap`, `style.linejoin`, `style.miterlimit`, `style.dash`, `style.linestyle`, `style.linewidth`, `color.color`
`style.fillstyle`	style used for path filling	`color.color`, `pattern.pattern`
`style.filltype`	type of path filling	`style.fillrule.nonzero_winding` (default), `style.fillrule.even_odd`
`deformer.deformer`	operations changing the shape of the path	*`deformer.cycloid`*, *`deformer.smoothed`*
`text.textattr`	attributes used for typesetting	*`text.halign`*, *`text.valign`*, *`text.mathmode`*, *`text.phantom`*, *`text.size`*, *`text.parbox`*
`trafo.trafo`	transformations applied when drawing object	*`trafo.mirror`*, *`trafo.rotate`*, *`trafo.scale`*, *`trafo.slant`*, *`trafo.translate`*

Todo: specify which classes in the table are in fact instances

Note that operations usually allow for certain attribute categories only. For example when stroking a path, text attributes are not allowed, while stroke attributes and decorators are. Some attributes might belong to several attribute categories like colours, which are both, stroke and fill attributes.

Last, we discuss another important feature of PyX's attribute system. In order to allow the easy customisation of predefined attributes, it is possible to create a modified attribute by calling of an attribute instance, thereby specifying new parameters. A typical example is to modify the way a path is stroked or filled by constructing appropriate `deco.stroked` or `deco.filled` instances. For instance, the code

```
c.stroke(path, [deco.filled([color.rgb.green])])
```

draws a path filled in green with a black outline. Here, `deco.filled` is already an instance which is modified to fill with the given color. Note that an equivalent version would be

```
c.draw(path, [deco.stroked, deco.filled([color.rgb.green])])
```

In particular, you can see that `deco.stroked` is already an attribute instance, since otherwise you were not allowed to pass it as a parameter to the draw method. Another example where the modification of a decorator is useful are arrows. For instance, the following code draws an arrow head with a more acute angle (compared to the default value of 45 degrees):

```
c.stroke(path, [deco.earrow(angle=30)])
```

Todo: changeable attributes

CHAPTER

THREE

MODULE path

The *path* module defines several important classes which are documented in the present section.

3.1 Class path — PostScript-like paths

class path.**path**(**pathitems*)

This class represents a PostScript like path consisting of the path elements *pathitems*.

All possible path items are described in Sect. *Path elements*. Note that there are restrictions on the first path element and likewise on each path element after a *closepath* directive. In both cases, no current point is defined and the path element has to be an instance of one of the following classes: *moveto*, *arc*, and *arcn*.

Instances of the class *path* provide the following methods (in alphabetic order):

path.**append**(*pathitem*)

Appends a *pathitem* to the end of the path.

path.**arclen**()

Returns the total arc length of the path.[1]

path.**arclentoparam**(*lengths*)

Returns the parameter value(s) corresponding to the arc length(s) *lengths*.[1]

path.**at**(*params*)

Returns the coordinates (as 2-tuple) of the path point(s) corresponding to the parameter value(s) *params*.[1][2]

path.**atbegin**()

Returns the coordinates (as 2-tuple) of the first point of the path.[1]

path.**atend**()

Returns the coordinates (as 2-tuple) of the end point of the path.[1]

path.**bbox**()

Returns the bounding box of the path.

path.**begin**()

Returns the parameter value (a normpathparam instance) of the first point in the path.

path.**curveradius**(*params*)

Returns the curvature radius/radii (or None if infinite) at parameter value(s) *params*.[2] This is the inverse of

[1] This method requires a prior conversion of the path into a *normpath* instance. This is done automatically (using the precision *epsilon* set globally using path.set()). If you need a different *epsilon* for a normpath, you also can perform the conversion manually.

[2] In these methods, *params* may either be a single value or a list. In the latter case, the result of the method will be a list consisting of the results for each parameter. The parameter itself may either be a length (or a number which is then interpreted as a user length) or an instance of the class normpathparam. In the former case, the length refers to the arc length along the path.

the curvature at this parameter. Note that this radius can be negative or positive, depending on the sign of the curvature.[1]

`path.`**`end`**`()`
Returns the parameter value (a `normpathparam` instance) of the last point in the path.

`path.`**`extend`**`(`*pathitems*`)`
Appends the list *pathitems* to the end of the path.

`path.`**`intersect`**`(`*opath*`)`
Returns a tuple consisting of two lists of parameter values corresponding to the intersection points of the path with the other path *opath*, respectively.[1] For intersection points which are not farther apart then *epsilon* (defaulting to 10^{-5} PostScript points), only one is returned.

`path.`**`joined`**`(`*opath*`)`
Appends *opath* to the end of the path, thereby merging the last subpath (which must not be closed) of the path with the first sub path of *opath* and returns the resulting new path.[1] Instead of using the *`joined()`* method, you can also join two paths together with help of the << operator, for instance `p = p1 << p2`.

`path.`**`normpath`**`(`*epsilon=None*`)`
Returns the equivalent *`normpath`*. For the conversion and for later calculations with this *`normpath`* an accuracy of *epsilon* is used. If *epsilon* is *None*, the global *epsilon* of the *`path`* module is used.

`path.`**`paramtoarclen`**`(`*params*`)`
Returns the arc length(s) corresponding to the parameter value(s) *params*.[21]

`path.`**`range`**`()`
Returns the maximal parameter value *param* that is allowed in the path methods.

`path.`**`reversed`**`()`
Returns the reversed path.[1]

`path.`**`rotation`**`(`*params*`)`
Returns a transformation or a list of transformations, which rotate the x-direction to the tangent vector and the y-direction to the normal vector at the parameter value(s) *params*.[21]

`path.`**`split`**`(`*params*`)`
Splits the path at the parameter values *params*, which have to be sorted in ascending order, and returns a corresponding list of *`normpath`* instances.[1]

`path.`**`tangent`**`(`*params*, *length=1*`)`
Return a *`line`* instance or a list of *`line`* instances, corresponding to the tangent vectors at the parameter value(s) *params*.[2] The tangent vector will be scaled to the length *length*.[1]

`path.`**`trafo`**`(`*params*`)`
Returns a transformation or a list of tranformations, which translate the origin to a point on the path corresponding to parameter value(s) *params* and rotate the x-direction to the tangent vector and the y-direction to the normal vector.[1]

`path.`**`transformed`**`(`*trafo*`)`
Returns the path transformed according to the linear transformation *trafo*. Here, `trafo` must be an instance of the *`trafo.trafo`* class.[1]

3.2 Path elements

The class `pathitem` is the superclass of all PostScript path construction primitives. It is never used directly, but only by instantiating its subclasses, which correspond one by one to the PostScript primitives.

Except for the path elements ending in _pt, all coordinates passed to the path elements can be given as number (in which case they are interpreted as user units with the currently set default type) or in PyX lengths.

The following operation move the current point and open a new subpath:

class path.**moveto**(*x*, *y*)
Path element which sets the current point to the absolute coordinates (*x*, *y*). This operation opens a new subpath.

class path.**rmoveto**(*dx*, *dy*)
Path element which moves the current point by (*dx*, *dy*). This operation opens a new subpath.

Drawing a straight line can be accomplished using:

class path.**lineto**(*x*, *y*)
Path element which appends a straight line from the current point to the point with absolute coordinates (*x*, *y*), which becomes the new current point.

class path.**rlineto**(*dx*, *dy*)
Path element which appends a straight line from the current point to the point with relative coordinates (*dx*, *dy*), which becomes the new current point.

For the construction of arc segments, the following three operations are available:

class path.**arc**(*x*, *y*, *r*, *angle1*, *angle2*)
Path element which appends an arc segment in counterclockwise direction with absolute coordinates (*x*, *y*) of the center and radius *r* from *angle1* to *angle2* (in degrees). If before the operation, the current point is defined, a straight line from the current point to the beginning of the arc segment is prepended. Otherwise, a subpath, which thus is the first one in the path, is opened. After the operation, the current point is at the end of the arc segment.

class path.**arcn**(*x*, *y*, *r*, *angle1*, *angle2*)
Same as *arc* but in clockwise direction.

class path.**arct**(*x1*, *y1*, *x2*, *y2*, *r*)
Path element consisting of a line followed by an arc of radius *r*. The arc is part of the circle inscribed to the angle at *x1*, *y1* given by lines in the directions to the current point and to *x2*, *y2*. The initial line connects the current point to the point where the circle touches the line through the current point and *x1*, *y1*. The arc then continues to the point where the circle touches the line through *x1*, *y1* and *x2*, *y2*.

Bézier curves can be constructed using:

class path.**curveto**(*x1*, *y1*, *x2*, *y2*, *x3*, *y3*)
Path element which appends a Bézier curve with the current point as first control point and the other control points (*x1*, *y1*), (*x2*, *y2*), and (*x3*, *y3*).

class path.**rcurveto**(*dx1*, *dy1*, *dx2*, *dy2*, *dx3*, *dy3*)
Path element which appends a Bézier curve with the current point as first control point and the other control points defined relative to the current point by the coordinates (*dx1*, *dy1*), (*dx2*, *dy2*), and (*dx3*, *dy3*).

Note that when calculating the bounding box (see Sect. *bbox*) of Bézier curves, PyX uses for performance reasons the so-called control box, i.e., the smallest rectangle enclosing the four control points of the Bézier curve. In general, this is not the smallest rectangle enclosing the Bézier curve.

Finally, an open subpath can be closed using:

class path.**closepath**
Path element which closes the current subpath.

For performance reasons, two non-PostScript path elements are defined, which perform multiple identical operations:

class path.**multilineto_pt**(*points_pt*)
Path element which appends straight line segments starting from the current point and going through the list of points given in the *points_pt* argument. All coordinates have to be given in PostScript points.

class path.**multicurveto_pt**(*points_pt*)
Path element which appends Bézier curve segments starting from the current point. *points_pt* is a sequence of 6-tuples containing the coordinates of the two control points and the end point of a multicurveto segment.

3.3 Class normpath

The *normpath* class is used internally for all non-trivial path operations, cf. footnote[1] in Sect. *Class path — PostScript-like paths*. It represents a path as a list of subpaths, which are instances of the class *normsubpath*. These *normsubpath*s themselves consist of a list of normsubpathitems which are either straight lines (normline) or Bézier curves (normcurve).

A given path p can easily be converted to the corresponding *normpath* np by:

```
np = p.normpath()
```

Additionally, the accuracy that is used in all *normpath* calculations can be specified by means of the argument *epsilon*, which defaults to 10^{-5}, where units of PostScript points are understood. This default value can also be changed using the module function path.set().

To construct a *normpath* from a list of *normsubpath* instances, they are passed to the *normpath* constructor:

class path.**normpath**(*normsubpaths=[]*)
Construct a *normpath* consisting of *subnormpaths*, which is a list of subnormpath instances.

Instances of *normpath* offer all methods of regular *path* instances, which also have the same semantics. An exception are the methods append() and extend(). While they allow for adding of instances of subnormpath to the *normpath* instance, they also keep the functionality of a regular path and allow for regular path elements to be appended. The latter are converted to the proper normpath representation during addition.

In addition to the *path* methods, a *normpath* instance also offers the following methods, which operate on the instance itself, i.e., modify it in place.

normpath.**join**(*other*)
Join *other*, which has to be a *path* instance, to the *normpath* instance.

normpath.**reverse**()
Reverses the *normpath* instance.

normpath.**transform**(*trafo*)
Transforms the *normpath* instance according to the linear transformation *trafo*.

Finally, we remark that the sum of a *normpath* and a *path* always yields a *normpath*.

3.4 Class normsubpath

class path.**normsubpath**(*normsubpathitems=[]*, *closed=0*, *epsilon=1e-5*)
Construct a *normsubpath* consisting of *normsubpathitems*, which is a list of normsubpathitem instances. If *closed* is set, the *normsubpath* will be closed, thereby appending a straight line segment from the first to the last point, if it is not already present. All calculations with the *normsubpath* are performed with an accuracy of *epsilon* (in units of PostScript points).

Most *normsubpath* methods behave like the ones of a *path*.

Exceptions are:

normsubpath.**append**(*anormsubpathitem*)
Append the *normsubpathitem* to the end of the *normsubpath* instance. This is only possible if the *normsubpath* is not closed, otherwise an NormpathException is raised.

normsubpath.**extend**(*normsubpathitems*)
Extend the *normsubpath* instances by *normsubpathitems*, which has to be a list of normsubpathitem instances. This is only possible if the *normsubpath* is not closed, otherwise an NormpathException is raised.

normsubpath.**close**()
Close the *normsubpath* instance by appending a straight line segment from the first to the last point, if not already present.

3.5 Predefined paths

For convenience, some often used paths are already predefined. All of them are subclasses of the *path* class.

class path.**line**(*x0*, *y0*, *x1*, *y1*)
A straight line from the point (*x0*, *y0*) to the point (*x1*, *y1*).

class path.**curve**(*x0*, *y0*, *x1*, *y1*, *x2*, *y2*, *x3*, *y3*)
A Bézier curve with control points (*x0*, *y0*), . . ., (*x3*, *y3*).

class path.**rect**(*x*, *y*, *w*, *h*)
A closed rectangle with lower left point (*x*, *y*), width *w*, and height *h*.

class path.**circle**(*x*, *y*, *r*)
A closed circle with center (*x*, *y*) and radius *r*.

CHAPTER

FOUR

MODULE METAPOST.PATH

The metapost subpackage provides some of the path functionality of the MetaPost program. The *metapost.path* presents the path construction facility of MetaPost.

Similarly to the normpath, there is a short length *epsilon* (always in Postscript points pt) used as accuracy of numerical operations, such as calculating angles from short path elements, or for omitting such short path elements, etc. The default value is 10^{-5} and can be changed using the module function metapost.set().

4.1 Class path — MetaPost-like paths

class metapost.path.**path**(*pathitems*, *epsilon=None*)

This class represents a MetaPost-like path which is created from the given list of knots and curves/lines. It can find an optimal way through given points.

At points (knots), you can either specify a given tangent direction (angle in degrees) or a certain *curlyness* (relative to the curvature at the other end of a curve), or nothing. In the latter case, both the tangent and the *mock* curvature (an approximation to the real curvature, introduced by J. D. Hobby in MetaPost) will be continuous.

The shape of the cubic Bezier curves between two points is controlled by its *tension*, unless you choose to set the control points manually.

All possible path items are described below. They are either *Knots* or *Links*. Note that there is no explicit *closepath* class. Whether the path is open or closed depends on the type of knots used, begin endpoints or not. Note also that the number of knots and links must be equal for closed paths, and that you cannot create a path comprising closed subpaths.

The *epsilon* argument governs the accuracy of the calculations implied in creating the path (see above). The value *None* means fallback to the default epsilon of the module.

Instances of the class *path* inherit all properties of the Postscript paths in *path*.

4.2 Knots

class metapost.path.**beginknot**(*x*, *y*, *curl=1*, *angle=None*)

The first knot, starting an open path at the coordinates (*x*, *y*). The properties of the curve in that point can either be given by its curlyness (default) or the angle of its tangent vector (in degrees). The *curl* parameter is (as in MetaPost) the ratio of the curvatures at this point and at the other point of the curve connecting it.

class metapost.path.**startknot**(*x*, *y*, *curl=1*, *angle=None*)

Synonym for *beginknot*.

class metapost.path.**endknot**(*x*, *y*, *curl=1*, *angle=None*)

The last knot of an open path. Curlyness and angle are the same as in *beginknot*.

class metapost.path.**smoothknot**(*x*, *y*)
This knot is the standard knot of MetaPost. It guarantees continuous tangent vectors and *mock curvatures* of the two curves it connects.

Note: If one of the links is a line, the knot is changed to a *roughknot* with either a specified angle (if the *keepangles* parameter is set in the line) or with *curl=1*.

class metapost.path.**roughknot**(*x*, *y*, *left_curl=1*, *right_curl=None*, *left_angle=None*, *right_angle=None*)
This knot is a possibly non-smooth knot, connecting two curves or lines. At each side of the knot (left/right) you can specify either the curlyness or the tangent angle.

Note: If one of the links is a line with the *keepangles* parameter set, the angles will be set eplicitly, regardless of any curlyness set.

class metapost.path.**knot**(*x*, *y*)
Synonym for *smoothknot*.

4.3 Links

class metapost.path.**line**(*keepangles=False*)
A straight line which corresponds to the MetaPost command "–". The option *keepangles* will guarantee a continuous tangent. (The curvature may become discontinuous, however.) This behavior is achieved by turning adjacent knots into roughknots with specified angles. Note that a smoothknot and a roughknot with given curlyness do behave differently near a line.

class metapost.path.**tensioncurve**(*ltension=1*, *latleast=False*, *rtension=None*, *ratleast=None*)
The standard type of curve in MetaPost. It corresponds to the MetaPost command ".." or to "..." if the *atleast* parameters are set to True. The tension parameters indicate the tensions at the beginning (l) and the end (r) of the curve. Set the parameters (l/r)atleast to True if you want to avoid inflection points.

class metapost.path.**controlcurve**(*lcontrol*, *rcontrol*)
A cubic Bezier curve which has its control points explicity set, similar to the *path.curveto* class of the Postscript paths. The control points at the beginning (l) and the end (r) must be coordinate pairs (x, y).

class metapost.path.**curve**(*ltension=1*, *latleast=False*, *rtension=None*, *ratleast=None*)
Synonym for *tensioncurve*.

CHAPTER

FIVE

MODULE DEFORMER: PATH DEFORMERS

The *deformer* module provides techniques to generate modulated paths. All classes in the *deformer* module can be used as attributes when drawing/stroking paths onto a canvas. Alternatively new paths can be created by deforming an existing path by means of the `deform()` method.

All classes of the *deformer* module provide the following methods:

class deformer.**deformer**

deformer.**__call__**(*(specific parameters for the class)*)
Returns a deformer with modified parameters

deformer.**deform**(*path*)
Returns the deformed normpath on the basis of the *path*. This method allows using the deformers outside of a drawing call.

The deformer classes are the following:

class deformer.**cycloid**(*radius*, *halfloops=10*, *skipfirst=1*unit.t_cm*, *skiplast=1*unit.t_cm*, *curvesperhloop=3*, *sign=1*, *turnangle=45*)
This deformer creates a cycloid around a path. The outcome looks similar to a 3D spring stretched along the original path.

radius: the radius of the cycloid (this is the radius of the 3D spring)

halfloops: the number of half-loops of the cycloid

skipfirst and *skiplast*: the lengths on the original path not to be bent to a cycloid

curvesperhloop: the number of Bezier curves to approximate a half-loop

sign: for `sign>=0` the cycloid starts to the left of the path, whereas for `sign<0` it starts to the right.

turnangle: the angle of perspective on the 3D spring. At `turnangle=0` results in a sinusoidal curve, whereas for `turnangle=90` one essentially obtains a circle.

class deformer.**smoothed**(*radius*, *softness=1*, *obeycurv=0*, *relskipthres=0.01*)
This deformer creates a smoothed variant of the original path. The smoothing is done on the basis of the corners of the original path, not on a global scope! Therefore, the result might not be what one would draw by hand. At each corner (or wherever two path elements meet) a piece of twice the *radius* is taken out of the original path and replaced by a curve. This curve is determined by the tangent directions and the curvatures at its endpoints. Both are taken from the original path, and therefore, the new curve fits into the gap in a *geometrically smooth* way. Path elements that are shorter than *radius* $\times$ *relskipthres* are ignored.

The new curve smoothing the corner consists either of one or of two Bezier curves, depending on the surrounding path elements. If there are straight lines before and after the new curve, then two Bezier curves are used. This optimises the bending of curves in rectangular boxes or polygons. Here, the curves have an additional degree of freedom that can be set with *softness* $\in (0, 1]$. If one of the concerned path elements is curved, only one Bezier

curve is used that is (not always uniquely) determined by its geometrical constraints. There are, nevertheless, some *caveats*:

A curve that strictly obeys the sign and magnitude of the curvature might not look very smooth in some cases. Especially when connecting a curved with a straight piece, the smoothed path contains unwanted overshootings. To prevent this, the parameter default *obeycurv=0* releases the curvature constraints a little: The curvature may then change its sign (still looks smooth for human eyes) or, in more extreme cases, even its magnitude (does not look so smooth). If you really need a geometrically smooth path on the basis of Bezier curves, then set *obeycurv=1*.

class deformer.**parallel**(*distance, relerr=0.05, sharpoutercorners=0, dointersection=1, checkdistanceparams=[0.5], lookforcurvatures=11*)

This deformer creates a parallel curve to a given path. The result is similar to what is usually referred to as the *set with constant distance* to the set of points on the path. It differs in one important respect, because the *distance* parameter in the deformer is a signed distance. The resulting parallel normpath is constructed on the level of the original pathitems. For each of them a parallel pathitem is constructed. Then, they are connected by circular arcs (or by sharp edges) around the corners of the original path. Later, everything that is nearer to the original path than distance is cut away.

There are some caveats:

- When the original path is too curved then the parallel path would contain points with infinte curvature. The resulting path stops at such points and leaves the too strongly curved piece out.
- When the original path contains on or more self-intersections, then the resulting parallel path is not continuous in the parameterisation of the original path. This may result in the surprising behaviour that a piece that corresponding to a "later" parameter value is followed by an "earlier" one.

The parameters are the following:

distance is the minimal (signed) distance between the original and the parallel paths.

relerr is the allowed relative error in the distance.

sharpoutercorners connects the parallel pathitems by a wegde made of straight lines, instead of taking circular arcs. This preserves the angle of the original corners.

dointersection is a boolean for performing the last step, the intersection step, in the path construction. Setting this to 0 gives the full parallel path, which can be favourable for self-intersecting paths.

checkdistanceparams is a list of parameter values in the interval (0,1) where the distance is checked on each parallel pathitem.

lookforcurvatures is the number of points per normpathitem where its curvature is checked for critical values.

CHAPTER

SIX

MODULE CANVAS

In addition it contains the class `canvas.clip` which allows clipping of the output.

6.1 Class canvas

This is the basic class of the canvas module. Instances of this class collect visual elements like paths, other canvases, TeX or LaTeX elements. A canvas may also be embedded in another one using its `insert` method. This may be useful when you want to apply a transformation on a whole set of operations.

class canvas.**canvas**(*attrs=[]*, *texrunner=None*, *ipython_bboxenlarge=1*unit.t_pt*)

Construct a new canvas, applying the given *attrs*, which can be instances of *trafo.trafo*, `canvas.clip`, `style.strokestyle` or `style.fillstyle`. The *texrunner* argument can be used to specify the texrunner instance used for the *text()* method of the canvas. If not specified, it defaults to *text.defaulttexrunner*. *ipython_bboxenlarge* defines the *bboxenlarge* *document.page* for IPython's *_repr_png_* and *_repr_svg_*.

Paths can be drawn on the canvas using one of the following methods:

canvas.**draw**(*path*, *attrs*)

Draws *path* on the canvas applying the given *attrs*. Depending on the *attrs* the path will be filled, stroked, ornamented, or a combination thereof. For the common first two cases the following two convenience functions are provided.

canvas.**fill**(*path*, *attrs=[]*)

Fills the given *path* on the canvas applying the given *attrs*.

canvas.**stroke**(*path*, *attrs=[]*)

Strokes the given *path* on the canvas applying the given *attrs*.

Arbitrary allowed elements like other *canvas* instances can be inserted in the canvas using

canvas.**insert**(*item*, *attrs=[]*)

Inserts an instance of `base.canvasitem` into the canvas. If *attrs* are present, *item* is inserted into a new *canvas* instance with *attrs* as arguments passed to its constructor. Then this *canvas* instance is inserted itself into the canvas.

Text output on the canvas is possible using

canvas.**text**(*x*, *y*, *text*, *attrs=[]*)

Inserts *text* at position (*x*, *y*) into the canvas applying *attrs*. This is a shortcut for `insert(texrunner.text(x, y, text, attrs))`.

To group drawing operations, layers can be used:

canvas.**layer**(*name*, *above=None*, *below=None*)

This method creates or gets a layer with name *name*.

A layer is a canvas itself and can be used to combine drawing operations for ordering purposes, i.e., what is above and below each other. The layer name *name* is a dotted string, where dots are used to form a hierarchy of layer groups. When inserting a layer, it is put on top of its layer group except when another layer instance of this group is specified by means of the parameters *above* or *below*.

The *canvas* class provides access to the total geometrical size of its element:

canvas.**bbox**()
Returns the bounding box enclosing all elements of the canvas (see Sect. *bbox*).

A canvas also allows to set its TeX runner:

canvas.**settexrunner**(*texrunner*)
Sets a new *texrunner* for the canvas.

The contents of the canvas can be written to a file using the following convenience methods, which wrap the canvas into a single page document.

canvas.**writeEPSfile**(*file*, ***kwargs*)
Writes the canvas to *file* using the EPS format. *file* either has to provide a write method or it is used as a string containing the filename (the extension `.eps` is appended automatically, if it is not present). This method constructs a single page document, passing *kwargs* to the *document.page* constructor for all *kwargs* starting with `page_` (without this prefix) and calls the *writeEPSfile()* method of this *document.document* instance passing the *file* and all *kwargs* starting with `write_` (without this prefix).

canvas.**writePSfile**(*file*, **args*, ***kwargs*)
Similar to *writeEPSfile()* but using the PS format.

canvas.**writePDFfile**(*file*, **args*, ***kwargs*)
Similar to *writeEPSfile()* but using the PDF format.

canvas.**writeSVGfile**(*file*, **args*, ***kwargs*)
Similar to *writeEPSfile()* but using the SVG format.

canvas.**writetofile**(*filename*, **args*, ***kwargs*)
Determine the file type (EPS, PS, PDF, or SVG) from the file extension of *filename* and call the corresponding write method with the given arguments *arg* and *kwargs*.

canvas.**pipeGS**(*device*, *resolution=100*, *gs="gs"*, *gsoptions=[]*, *textalphabits=4*, *graphicsalphabits=4*, *ciecolor=False*, *input="eps"*, ***kwargs*)
This method pipes the content of a canvas to the ghostscript interpreter to generate other output formats. The output is returned by means of a python BytesIO object. *device* specifies a ghostscript output device by a string. Depending on the ghostscript configuration `"png16"`, `"png16m"`, `"png256"`, `"png48"`, `"pngalpha"`, `"pnggray"`, `"pngmono"`, `"jpeg"`, and `"jpeggray"` might be available among others. See the output of `gs --help` and the ghostscript documentation for more information.

resolution specifies the resolution in dpi (dots per inch). *gs* is the name of the ghostscript executable. *gsoptions* is a list of additional options passed to the ghostscript interpreter. *textalphabits* and *graphicsalphabits* are convenient parameters to set the `TextAlphaBits` and `GraphicsAlphaBits` options of ghostscript. The addition of these options can be skipped by setting their values to `None`. *ciecolor* adds the `-dUseCIEColor` flag to improve the CMYK to RGB color conversion. *input* can be either `"eps"` or `"pdf"` to select the input type to be passed to ghostscript (note slightly different features available in the different input types regarding e.g. *epsfile* inclusion and transparency).

kwargs are passed to the *writeEPSfile()* method (not counting the *file* parameter), which is used to generate the input for ghostscript. By that you gain access to the *document.page* constructor arguments.

canvas.**writeGSfile**(*filename=None*, *device=None*, ***kwargs*)
This method is similar to pipeGS, but the content is written into the file *filename*. If filename is None it is auto-guessed from the script name. If filename is "-", the output is written to stdout. In both cases, a device needs to be specified to define the format (and the file suffix in case the filename is created from the script name).

If device is None, but a filename with suffix is given, PNG files will be written using the png16m device and JPG files using the jpeg device.

All other arguments are identical to those of the *canvas.pipeGS()*.

For more information about the possible arguments of the *document.page* constructor, we refer to Sect. *document*.

6.2 Class clip

In addition the canvas module contains the class `canvas.clip` which allows for clipping of the output by passing a clipping instance to the attrs parameter of the canvas constructor.

CHAPTER

SEVEN

MODULE DOCUMENT

The document module contains two classes: *document* and *page*. A *document* consists of one or several *page*s.

7.1 Class page

A *page* is a thin wrapper around a *canvas*, which defines some additional properties of the page.

class document.**page**(*canvas*, *pagename=None*, *paperformat=None*, *rotated=0*, *centered=1*, *fittosize=0*, *margin=1 * unit.t_cm*, *bboxenlarge=1 * unit.t_pt*, *bbox=None*)

Construct a new *page* from the given *canvas* instance. A string *pagename* and the *paperformat* can be defined. See below, for a list of known paper formats. If *rotated* is set, the output is rotated by 90 degrees on the page. If *centered* is set, the output is centered on the given paperformat. If *fittosize* is set, the output is scaled to fill the full page except for a given *margin*. Normally, the bounding box of the canvas is calculated automatically from the bounding box of its elements. Alternatively, you may specify the *bbox* manually. In any case, the bounding box is enlarged on all sides by *bboxenlarge*.

7.2 Class document

class document.**document**(*pages=[]*)

Construct a *document* consisting of a given list of *pages*.

A *document* can be written to a file using one of the following methods:

document.**writeEPSfile**(*file*, *title=None*, *strip_fonts=True*, *text_as_path=False*, *mesh_as_bitmap=False*, *mesh_as_bitmap_resolution=300*)

Write a single page *document* to an EPS file or to stdout if *file* is set to -. *title* is used as the document title, *strip_fonts* enabled font stripping (removal of unused glyphs), *text_as_path* converts all text to paths instead of using fonts in the output, *mesh_as_bitmap* converts meshs (like 3d surface plots) to bitmaps (to reduce complexity in the output) and *mesh_as_bitmap_resolution* is the resolution of this conversion in dots per inch.

document.**writePSfile**(*file*, *writebbox=False*, *title=None*, *strip_fonts=True*, *text_as_path=False*, *mesh_as_bitmap=False*, *mesh_as_bitmap_resolution=300*)

Write *document* to a PS file or to to stdout if *file* is set to -. *writebbox* add the page bounding boxes to the output. All other parameters are identical to the *writeEPSfile()* method.

document.**writePDFfile**(*file*, *title=None*, *author=None*, *subject=None*, *keywords=None*, *fullscreen=False*, *writebbox=False*, *compress=True*, *compresslevel=6*, *strip_fonts=True*, *text_as_path=False*, *mesh_as_bitmap=False*, *mesh_as_bitmap_resolution=300*)

Write *document* to a PDF file or to stdout if *file* is set to -. *author*, *subject*, and *keywords* are used for the document author, subject, and keyword information, respectively. *fullscreen* enabled fullscreen mode when the document is opened, *writebbox* enables writing of the crop box to each page, *compress* enables output stream

compression and *compresslevel* sets the compress level to be used (from 1 to 9). All other parameters are identical to the *writeEPSfile()*.

document.**writeSVGfile**(*file*, *text_as_path=True*, *mesh_as_bitmap_resolution=300*)
Write *document* to a SVG file or to stdout if *file* is set to -. The *text_as_path* and *mesh_as_bitmap_resolution* have the same meaning as in *writeEPSfile()*. However, not the different default for *text_as_path* due to the missing SVG font support by current browsers. In addition, there is no *mesh_as_bitmap* flag, as meshs are always stored using bitmaps in SVG.

document.**writetofile**(*filename*, **args*, ***kwargs*)
Determine the file type (EPS, PS, PDF, or SVG) from the file extension of *filename* and call the corresponding write method with the given arguments *arg* and *kwargs*.

7.3 Class paperformat

class document.**paperformat**(*width*, *height*, *name=None*)
Define a *paperformat* with the given *width* and *height* and the optional *name*.

Predefined paperformats are listed in the following table

instance	name	width	height
document.paperformat.A0	A0	840 mm	1188 mm
document.paperformat.A0b		910 mm	1370 mm
document.paperformat.A1	A1	594 mm	840 mm
document.paperformat.A2	A2	420 mm	594 mm
document.paperformat.A3	A3	297 mm	420 mm
document.paperformat.A4	A4	210 mm	297 mm
document.paperformat.A5	A5	148.5 mm	210 mm
document.paperformat.Letter	Letter	8.5 inch	11 inch
document.paperformat.Legal	Legal	8.5 inch	14 inch

CHAPTER

EIGHT

TEXT

8.1 Rationale

The `text` module is used to create text output. It seamlessly integrates Donald E. Knuths famous TeX typesetting engine[1]. The module is a high-level interface to an extensive stack of TeX and font related functionality in PyX, whose details are way beyond this manual and completely irrelevant for the typical PyX user. However, the basic concept should be described briefly, as it provides important insights into essential properties of the whole machinery.

PyX does not apply any limitations on the text submitted by the user. Instead the text is directly passed to TeX. This has the implication, that the text to be typeset should come from a trusted source or some special security measures should be applied (see *Typesetting insecure text*). PyX just adds a light and transparent wrapper using basic TeX functionality for later identification and output extraction. This procedure enables full access to all TeX features and makes PyX on the other hand dependent on the error handling provided by TeX. However, a detailed and immediate control of the TeX output allows PyX to report problems back to the user as they occur.

While we only talked about TeX so far (and will continue to do so in the rest of this section), it is important to note that the coupling is not limited to plain TeX. Currently, PyX can also use LaTeX for typesetting, and other TeX variants could be added in the future. What PyX really depends on is the ability of the typesetting program to generate DVI[2].

As soon as some text creation is requested or, even before that, a preamble setting or macro definition is submitted, the TeX program is started as a separate process. The input and output is bound to a `SingleRunner` instance. Typically, the process will be kept alive and will be reused for all future typesetting requests until the end of the PyX process. However, there are certain situations when the TeX program needs to be shutdown early, which are be described in detail in the *TeX ipc mode* section.

Whenever PyX sends some commands to the TeX interpreter, it adds an output marker at the end, and waits for this output marker to be echoed in the TeX output. All intermediate output is attributed to the commands just sent and will be analysed for problems. This is done by `texmessage` parsers. Here, a problem could be logged to the PyX logger at warning level, thus be reported to `stderr` by default. This happens for over- or underful boxes or font warnings emitted by TeX. For other unknown problems (*i.e.* output not handled by any of the given `texmessage` parsers), a `TexResultError` is raised, which creates a detailed error report including the traceback, the commands submitted to TeX and the output returned by TeX.

PyX wraps each text to be typeset in a TeX box and adds a shipout of this box to the TeX code before forwarding it to TeX. Thus a page in the DVI file is created containing just this output. Furthermore TeX is asked to output the box extent. By that PyX will immediately know the size of the text without referring to the DVI. This also allows faking the box size by TeX means, as you would expect it.

Once the actual output is requested, PyX reads the content of the DVI file, accessing the page related to the output in question. It then does all the necessary steps to transform the DVI content to the requested output format, like searching for virtual font files, font metrices, font mapping files, and PostScript Type1 fonts to be used in the final output. Here a present limitation has been mentioned: PyX presently can use PostScript Type1 fonts only to generate

[1] https://en.wikipedia.org/wiki/TeX
[2] https://en.wikipedia.org/wiki/Device_independent_file_format

text output. While this is a serious limitation, all the default fonts in TeX are available in Type1 nowadays and current TeX installations are alreadily configured to use them by default.

8.2 TeX interface

class text.**SingleRunner**(*cmd*, *texenc="ascii"*, *usefiles=[]*, *texipc=config.getboolean("text", "texipc", 0)*, *copyinput=None*, *dvitype=False*, *errordetail=errordetail.default*, *texmessages_start=[]*, *texmessages_end=[]*, *texmessages_preamble=[]*, *texmessages_run=[]*)

Base class for the TeX interface.

Note: This class cannot be used directly. It is the base class for all texrunners and provides most of the implementation. Still, to the end user the parameters except for *cmd* are important, as they are preserved in derived classes usually.

Parameters

- **cmd** (*list of str*) – command and arguments to start the TeX interpreter
- **texenc** (*str*) – encoding to use in the communication with the TeX interpreter
- **usefiles** (*list of str*) – list of supplementary files to be copied to and from the temporary working directory (see *Debugging* for usage details)
- **texipc** (*bool*) – *TeX ipc mode* flag.
- **copyinput** (*None or str or file*) – filename or file to be used to store a copy of all the input passed to the TeX interpreter
- **dvitype** (*bool*) – flag to turn on dvitype-like output
- **errordetail** (*errordetail*) – verbosity of the *TexResultError*
- **texmessages_start** (list of *texmessage* parsers) – additional message parsers at interpreter startup
- **texmessages_end** (list of *texmessage* parsers) – additional message parsers at interpreter shutdown
- **texmessages_preamble** (list of *texmessage* parsers) – additional message parsers for preamble output
- **texmessages_run** (list of *texmessage* parsers) – additional message parsers for typset output

texmessages_start_default = [<function texmessage.start>]
default *texmessage* parsers at interpreter startup

texmessages_end_default = [<function texmessage.end>, <function texmessage.font_warnin
default *texmessage* parsers at interpreter shutdown

texmessages_preamble_default = [<function texmessage.load>]
default *texmessage* parsers for preamble output

texmessages_run_default = [<function texmessage.font_warning>, <function texmessage.bo
default *texmessage* parsers for typeset output

preamble(*expr*, *texmessages=[]*)
Execute a preamble.

Parameters

- **expr** (*str*) – expression to be executed
- **texmessages** (list of *texmessage* parsers) – additional message parsers

Preambles must not generate output, but are used to load files, perform settings, define macros, *etc*. In LaTeX mode, preambles are executed before `\begin{document}`. The method can be called multiple times, but only prior to *SingleRunner.text()* and *SingleRunner.text_pt()*.

text_pt(*x_pt*, *y_pt*, *expr*, *textattrs=[]*, *texmessages=[]*, *fontmap=None*, *singlecharmode=False*)
Typeset text.

Parameters

- **x_pt** (*float*) – x position in pts
- **y_pt** (*float*) – y position in pts
- **expr** (*str*) – text to be typeset
- **textattrs** (list of `textattr, :class:`trafo.trafo_pt`, and `style.fillstyle`) – styles and attributes to be applied to the text
- **texmessages** (list of *texmessage* parsers) – additional message parsers
- **fontmap** (*None or fontmap*) – force a fontmap to be used (instead of the default depending on the output format)
- **singlecharmode** (*bool*) – position each character separately

Returns text output insertable into a canvas.

Return type *textbox_pt*

Raises `TexDoneError`: when the TeX interpreter has been terminated already.

text(*x*, *y*, **args*, ***kwargs*)
Typeset text.

This method is identical to *text_pt()* with the only difference of using PyX lengths to position the output.

Parameters

- **x** (*PyX length*) – x position
- **y** (*PyX length*) – y position

class text.**SingleTexRunner**(*cmd=config.getlist("text", "tex", ["tex"]), lfs="10pt", **kwargs*)
Plain TeX interface.

This class adjusts the *SingleRunner* to use plain TeX.

Parameters

- **cmd** (*list of str*) – command and arguments to start the TeX interpreter
- **lfs** (*str or None*) – resemble LaTeX font settings within plain TeX by loading a lfs-file
- **kwargs** – additional arguments passed to *SingleRunner*

An lfs-file is a file defining a set of font commands like `\normalsize` by font selection commands in plain TeX. Several of those files resembling standard settings of LaTeX are distributed along with PyX in the `pyx/data/lfs` directory. This directory also contains a LaTeX file to create lfs files for different settings (LaTeX class, class options, and style files).

class text.**SingleLatexRunner**(*cmd=config.getlist("text", "latex", ["latex"]), docclass="article", docopt=None, pyxgraphics=True, texmessages_docclass=[], texmessages_begindoc=[], **kwargs*)

LaTeX interface.

This class adjusts the *SingleRunner* to use LaTeX.

Parameters

- **cmd** (*list of str*) – command and arguments to start the TeX interpreter in LaTeX mode
- **docclass** (*str*) – document class
- **docopt** (*str or None*) – document loading options
- **pyxgraphics** (*bool*) – activate graphics bundle support, see *Using the graphics-bundle with LaTeX*
- **texmessages_docclass** (list of *texmessage* parsers) – additional message parsers at LaTeX class loading
- **texmessages_begindoc** (list of *texmessage* parsers) – additional message parsers at `\begin{document}`
- **kwargs** – additional arguments passed to *SingleRunner*

texmessages_docclass_default = [<function texmessage.load>]

default *texmessage* parsers at LaTeX class loading

texmessages_begindoc_default = [<function texmessage.load>, <function texmessage.no_au

default *texmessage* parsers at `\begin{document}`

The *SingleRunner* classes described above do not handle restarts of the interpreter when the actuall DVI result is required and is not available via the *TeX ipc mode* feature.

The *MultiRunner* classes below are not derived from *SingleRunner* even though the provide the same functional interface (*MultiRunner.preamble()*, *MultiRunner.text()*, and *MultiRunner.text_pt()*), but instead wrap a *SingleRunner* instance, and provide an automatic (or manual by the *MultiRunner.reset()* function) restart of the interpreter as required.

class text.**MultiRunner**(*cls*, **args*, ***kwargs*)

A restartable *SingleRunner* class

Parameters

- **cls** (*SingleRunner* class) – the class being wrapped
- **args** (*list*) – args at class instantiation
- **kwargs** (*dict*) – keyword args at at class instantiation

preamble(*expr*, *texmessages=[]*)

resembles *SingleRunner.preamble()*

text_pt(**args*, ***kwargs*)

resembles *SingleRunner.text_pt()*

text(**args*, ***kwargs*)

resembles *SingleRunner.text()*

reset(*reinit=False*)
Start a new *SingleRunner* instance

Parameters **reinit** (*bool*) – replay *preamble()* calls on the new instance

After executing this function further preamble calls are allowed, whereas once a text output has been created, *preamble()* calls are forbidden.

class text.**TexRunner**(**args*, ***kwargs*)
A restartable *SingleTexRunner* class

Parameters

- **args** (*list*) – args at class instantiation
- **kwargs** (*dict*) – keyword args at at class instantiation

class text.**LatexRunner**(**args*, ***kwargs*)
A restartable *SingleLatexRunner* class

Parameters

- **args** (*list*) – args at class instantiation
- **kwargs** (*dict*) – keyword args at at class instantiation

class text.**textbox_pt**(*x_pt*, *y_pt*, *left_pt*, *right_pt*, *height_pt*, *depth_pt*, *do_finish*, *fontmap*, *singlecharmode*, *fillstyles*)
Text output.

An instance of this class contains the text output generated by PyX. It is a baseclasses.canvasitem and thus can be inserted into a canvas.

marker(*name*)
Return the position of a marker.

Parameters **name** (*str*) – name of the marker

Returns position of the marker

Return type tuple of two PyX lengths

This method returns the position of the marker of the given name within, previously defined by the \PyXMarker{name} macro in the typeset text. Please do not use the @ character within your name to prevent name clashes with PyX internal uses (although we don't the marker feature internally right now).

Similar to generating actual output, the marker function accesses the DVI output, stopping. The *TeX ipc mode* feature will allow for this access without stopping the TeX interpreter.

textbox_pt.**left**
left extent of the text (PyX length)

textbox_pt.**right**
right extent of the text (PyX length)

textbox_pt.**width**
width of the text (PyX length)

textbox_pt.**height**
height of the text (PyX length)

textbox_pt.**depth**
height of the text (PyX length)

8.3 Module level functionality

The text module provides the public interface of the *SingleRunner* class by module level functions. For that, a module level *MultiRunner* is created and configured by the *set()* function. Each time the *set()* function is called, the existing module level *MultiRunner* is replaced by a new one.

text.**default_runner**
the current *MultiRunner* instance for the module level functions

text.**preamble**
default_runner.preamble (bound method)

text.**text_pt**
default_runner.text_pt (bound method)

text.**text**
default_runner.text (bound method)

text.**reset**
default_runner.reset (bound method)

text.**set**(*cls=TexRunner*, *mode=None*, **args*, ***kwargs*)
Setup a new module level *MultiRunner*

Parameters

- **cls** (*MultiRunner* object, not instance) – the module level *MultiRunner* to be used, i.e. *TexRunner* or *LatexRunner*
- **mode** (*str or None*) – `"tex"` for *TexRunner* or `"latex"` for *LatexRunner* with arbitraty capitalization, overwriting the cls value

  deprecated use the cls argument instead
- **args** (*list*) – args at class instantiation
- **kwargs** (*dict*) – keyword args at at class instantiation

text.**escapestring**(*s*, *replace={" ": "~", "$": "\$", "&": "\&", " "_": "_", "%": "\%", "^": "\string^", "~": "\string~", "<": "{$<$}", ">": "{$>$}", "{": "{${$}", "}": "{$}$}", "\": "{$setminus$}", "|": "{mid}"}*)
Escapes ASCII characters such that they can be typeset by TeX/LaTeX

8.4 TeX output parsers

While running TeX (and variants thereof) a variety of information is written to `stdout` like status messages, details about file access, and also warnings and errors. PyX reads all the output and analyses it. Some of the output is triggered as a direct response to the TeX input and is thus easy to understand for PyX. This includes page output information, but also workflow control information injected by PyX into the input stream. PyX uses it to check the communication and typeset progress. All the other output is handled by a list of *texmessage* parsers, an individual set of functions applied to the TeX output one after the other. Each of the function receives the TeX output as a string and return it back (maybe altered). Such a function must perform one of the following actions in response to the TeX output is receives:

1. If it does not find any text in the TeX output it feals responsible for, it should just return the unchanged string.
2. If it finds a text it is responsible for, and the message is just fine (doesn't need to be communicated to the user), it should just remove this text and return the rest of the TeX output.

3. If the text should be communicated to the user, a message should be written the the pyx logger at warning level, thus being reported to the user on `stderr` by default. Examples are underfull and overfull box warnings or font warnings. In addition, the text should be removed as in 2 above.
4. In case of an error, *TexResultError* should be raised.

This is rather uncommon, that the fourth option is taken directly. Instead, errors can just be kept in the output as PyX considers unhandled TeX output left after applying all given *texmessage* parsers as an error. In addition to the error message, information about the TeX in- and output will be added to the exception description text by the *SingleRunner* according to the *errordetail* setting. The following verbosity levels are available:

class text.**errordetail**
Constants defining the verbosity of the *TexResultError*.

none = 0
Without any input and output.

default = 1
Input and parsed output shortend to 5 lines.

full = 2
Full input and unparsed as well as parsed output.

exception text.**TexResultError**
Error raised by *texmessage* parsers.

To prevent any unhandled TeX output to be reported as an error, *texmessage.warn* or *texmessage.ignore* can be used. To complete the description, here is a list of all available *texmessage* parsers:

class text.**texmessage**
Collection of TeX output parsers.

This class is not meant to be instanciated. Instead, it serves as a namespace for TeX output parsers, which are functions receiving a TeX output and returning parsed output.

In addition, this class also contains some generator functions (namely *texmessage.no_file* and *texmessage.pattern*), which return a function according to the given parameters. They are used to generate some of the parsers in this class and can be used to create others as well.

static start(*msg*)
Validate TeX/LaTeX startup message including scrollmode test.

Example:

```
>>> texmessage.start(r'''
... This is e-TeX (version)
... *! Undefined control sequence.
... <*> \raiseerror
...                 %
... ''')
''
```

static no_file(*fileending*, *qualname=None*)
Generator function to ignore the missing file message for fileending.

static no_aux(*msg*)
Ignore the missing aux file message.

static no_nav(*msg*)
Ignore the missing nav file message.

static end(*msg*)
Validate TeX shutdown message.

static load(*msg*)
Ignore file loading messages.

Removes text starting with a round bracket followed by a filename ignoring all further text until the corresponding closing bracket. Quotes and/or line breaks in the filename are handled as needed for TeX output.

Without quoting the filename, the necessary removal of line breaks is not well defined and the different possibilities are tested to check whether one solution is ok. The last of the examples below checks this behavior.

Examples:

```
>>> texmessage.load(r'''other (text.py) things''')
'other  things'
>>> texmessage.load(r'''other ("text.py") things''')
'other  things'
>>> texmessage.load(r'''other ("tex
... t.py" further (ignored)
... text) things''')
'other  things'
>>> texmessage.load(r'''other (t
... ext
... .py
... fur
... ther (ignored) text) things''')
'other  things'
```

static load_def(*msg*)
Ignore font definition (`*.fd` and `*.def`) loading messages.

static load_graphics(*msg*)
Ignore graphics file (`*.eps`) loading messages.

static ignore(*msg*)
Ignore all messages.

Should be used as a last resort only. You should write a proper TeX output parser function for the output you observe.

static warn(*msg*)
Warn about all messages.

Similar to *ignore*, but writing a warning to the logger about the TeX output. This is considered to be better when you need to get it working quickly as you will still be prompted about the unresolved output, while the processing continues.

static pattern(*p*, *warning*, *qualname=None*)
Warn by regular expression pattern matching.

static box_warning(*msg*)
Warn about overfull/underfull box.

static font_warning(*msg*)
Warn about font substitutions of NFSS.

static package_warning(*msg*)
Warn about generic package messages.

static rerun_warning(*msg*)
Warn about rerun required message.

static nobbl_warning(*msg*)
Warn about no-bbl message.

8.5 TeX/LaTeX attributes

TeX/LaTeX attributes are instances to be passed to a `texrunners` *`text()`* method. They stand for TeX/LaTeX expression fragments and handle dependencies by proper ordering.

class `text`.**halign**(*boxhalign*, *flushhalign*)
Instances of this class set the horizontal alignment of a text box and the contents of a text box to be left, center and right for *boxhalign* and *flushhalign* being `0`, `0.5`, and `1`. Other values are allowed as well, although such an alignment seems quite unusual.

Note that there are two separate classes `boxhalign` and `flushhalign` to set the alignment of the box and its contents independently, but those helper classes can't be cleared independently from each other. Some handy instances available as class members:

`halign`.**boxleft**
Left alignment of the text box, *i.e.* sets *boxhalign* to `0` and doesn't set *flushhalign*.

`halign`.**boxcenter**
Center alignment of the text box, *i.e.* sets *boxhalign* to `0.5` and doesn't set *flushhalign*.

`halign`.**boxright**
Right alignment of the text box, *i.e.* sets *boxhalign* to `1` and doesn't set *flushhalign*.

`halign`.**flushleft**
Left alignment of the content of the text box in a multiline box, *i.e.* sets *flushhalign* to `0` and doesn't set *boxhalign*.

`halign`.**raggedright**
Identical to *`flushleft`*.

`halign`.**flushcenter**
Center alignment of the content of the text box in a multiline box, *i.e.* sets *flushhalign* to `0.5` and doesn't set *boxhalign*.

`halign`.**raggedcenter**
Identical to *`flushcenter`*.

`halign`.**flushright**
Right alignment of the content of the text box in a multiline box, *i.e.* sets *flushhalign* to `1` and doesn't set *boxhalign*.

`halign`.**raggedleft**
Identical to *`flushright`*.

`halign`.**left**
Combines *`boxleft`* and *`flushleft`*, *i.e.* `halign(0, 0)`.

`halign`.**center**
Combines *`boxcenter`* and *`flushcenter`*, *i.e.* `halign(0.5, 0.5)`.

`halign`.**right**
Combines *`boxright`* and *`flushright`*, *i.e.* `halign(1, 1)`.

class `text`.**valign**(*valign*)
Instances of this class set the vertical alignment of a text box to be top, center and bottom for *valign* being `0`, `0.5`, and `1`. Other values are allowed as well, although such an alignment seems quite unusual. See the left side of figure *valign example* for an example.



Fig. 1: valign example

Some handy instances available as class members:

`valign.`**`top`**
`valign(0)`

`valign.`**`middle`**
`valign(0.5)`

`valign.`**`bottom`**
`valign(1)`

`valign.`**`baseline`**
Identical to clearing the vertical alignment by `clear` to emphasise that a baseline alignment is not a box-related alignment. Baseline alignment is the default, *i.e.* no valign is set by default.

`class` `text.`**`parbox`**(*width*, *baseline=top*)
Instances of this class create a box with a finite width, where the typesetter creates multiple lines in. Note, that you can't create multiple lines in TeX/LaTeX without specifying a box width. Since PyX doesn't know a box width, it uses TeXs LR-mode by default, which will always put everything into a single line. Since in a vertical box there are several baselines, you can specify the baseline to be used by the optional *baseline* argument. You can set it to the symbolic names `top`, `parbox.middle`, and `parbox.bottom` only, which are members of *`valign`*. See the right side of figure *valign example* for an example.

Since you need to specify a box width no predefined instances are available as class members.

`class` `text.`**`vshift`**(*lowerratio*, *heightstr="0"*)
Instances of this class lower the output by *lowerratio* of the height of the string *heigthstring*. Note, that you can apply several shifts to sum up the shift result. However, there is still a `clear` class member to remove all vertical shifts.

Some handy instances available as class members:

`vshift.`**`bottomzero`**
`vshift(0)` (this doesn't shift at all)

`vshift.`**`middlezero`**
`vshift(0.5)`

`vshift.`**`topzero`**
`vshift(1)`

`vshift.`**`mathaxis`**
This is a special vertical shift to lower the output by the height of the mathematical axis. The mathematical axis is used by TeX for the vertical alignment in mathematical expressions and is often usefull for vertical alignment.

The corresponding vertical shift is less than *middlezero* and usually fits the height of the minus sign. (It is the height of the minus sign in mathematical mode, since that's that the mathematical axis is all about.)

There is a TeX/LaTeX attribute to switch to TeXs math mode. The appropriate instances `mathmode` and `clearmathmode` (to clear the math mode attribute) are available at module level.

`text.`**`mathmode`**
Enables TeXs mathematical mode in display style.

The *size* class creates TeX/LaTeX attributes for changing the font size.

class `text.`**`size`**(*sizeindex=None*, *sizename=None*, *sizelist=defaultsizelist*)
LaTeX knows several commands to change the font size. The command names are stored in the *sizelist*, which defaults to `["normalsize", "large", "Large", "LARGE", "huge", "Huge", None, "tiny", "scriptsize", "footnotesize", "small"]`.

You can either provide an index *sizeindex* to access an item in *sizelist* or set the command name by *sizename*.

Instances for the LaTeXs default size change commands are available as class members:

`size.`**`tiny`**
`size(-4)`

`size.`**`scriptsize`**
`size(-3)`

`size.`**`footnotesize`**
`size(-2)`

`size.`**`small`**
`size(-1)`

`size.`**`normalsize`**
`size(0)`

`size.`**`large`**
`size(1)`

`size.`**`Large`**
`size(2)`

`size.`**`LARGE`**
`size(3)`

`size.`**`huge`**
`size(4)`

`size.`**`Huge`**
`size(5)`

There is a TeX/LaTeX attribute to create empty text boxes with the size of the material passed in. The appropriate instances `phantom` and `clearphantom` (to clear the phantom attribute) are available at module level.

`text.`**`phantom`**
Skip the text in the box, but keep its size.

8.6 Using the graphics-bundle with LaTeX

The packages in the LaTeX graphics bundle (`color.sty`, `graphics.sty`, `graphicx.sty`, ...) make extensive use of `\\special` commands. PyX defines a clean set of such commands to fit the needs of the LaTeX graphics bundle. This is done via the `pyx.def` driver file, which tells the graphics bundle about the syntax of the `\\special`

commands as expected by PyX. You can install the driver file `pyx.def` into your LaTeX search path and add the content of both files `color.cfg` and `graphics.cfg` to your personal configuration files[3]. After you have installed the `cfg` files, please use the *`text`* module with unset `pyxgraphics` keyword argument which will switch off a convenience hack for less experienced LaTeX users. You can then import the LaTeX graphics bundle packages and related packages (e.g. `rotating`, ...) with the option `pyx`, e.g. `\\usepackage[pyx]{color,graphicx}`. Note that the option `pyx` is only available with unset *pyxgraphics* keyword argument and a properly installed driver file. Otherwise, omit the specification of a driver when loading the packages.

When you define colors in LaTeX via one of the color models `gray`, `cmyk`, `rgb`, `RGB`, `hsb`, then PyX will use the corresponding values (one to four real numbers). In case you use any of the `named` colors in LaTeX, PyX will use the corresponding predefined color (see module `color` and the color table at the end of the manual). The additional LaTeX color model `pyx` allows to use a PyX color expression, such as `color.cmyk(0,0,0,0)` directly in LaTeX. It is passed to PyX.

When importing Encapsulated PostScript files (`eps` files) PyX will rotate, scale and clip your file like you expect it. Other graphic formats can not be imported via the graphics package at the moment.

For reference purpose, the following specials can be handled by PyX at the moment:

`PyX:color_begin (model) (spec)` starts a color. `(model)` is one of `gray`, `cmyk`, `rgb`, `hsb`, `texnamed`, or `pyxcolor`. `(spec)` depends on the model: a name or some numbers

`PyX:color_end` ends a color.

`PyX:epsinclude file= llx= lly= urx= ury= width= height= clip=0/1` includes an Encapsulated PostScript file (`eps` files). The values of `llx` to `ury` are in the files' coordinate system and specify the part of the graphics that should become the specified `width` and `height` in the outcome. The graphics may be clipped. The last three parameters are optional.

`PyX:scale_begin (x) (y)` begins scaling from the current point.

`PyX:scale_end` ends scaling.

`PyX:rotate_begin (angle)` begins rotation around the current point.

`PyX:rotate_end` ends rotation.

8.7 Configuration

While the PyX configuration technically has nothing to do with the text module, we mention it here as part of the text module since its main purpose is the configuration of various aspects related to the typesetting of text.

PyX comes with reasonable defaults which should work out of the box on most TeX installations. The default values are defined in the PyX source code itself and are repeated in the system-wide config file in INI file format located at `pyx/data/pyxrc`. This file also contains a description of each of the listed config values and is read at PyX startup. Thus the system-wide configuration can be adjusted by editing this file.

In addition, a user-specific configuration can be setup by a `~/.pyxrc` on unix-like Systems (including OS X) or `pyxrc` in the directory defined by the environment variable `APPDATA` on MS Windows. This user-specific configuration will overwrite the system-wide settings.

Yet another configuration can be set by the environment variable `PYXRC`. The given file will is loaded on top of the configuration defined in the previous steps.

[3] If you do not know what this is all about, you can just ignore this paragraph. But be sure that the `pyxgraphics` keyword argument is always set!

8.7.1 TeX ipc mode

For output generation of typeset text and to calculate the positions of markers (see *textbox_pt.marker()*) the DVI output of the TeX interpreter must be read. In contrast, the text extent (*textbox_pt.left*, *textbox_pt.right*, *textbox_pt.width*, *textbox_pt.height*, *textbox_pt.depth*) is available without accessing the DVI output, as the TeX interpreter is instructed by PyX to output it to stdout, which is read and analysed at the typesetting step immediately.

Since TeX interpreters usually buffer the DVI output, the interpreter itself needs to be terminated to get the DVI output. As *MultiRunner* instances can start a new interpreter when needed, this does not harm the functionality and happens more or less unnoticable. Still it generates some penalty in terms of execution speed, which can become huge for certain situations (alternation between typesetting and marker access).

One of the effects of the `texipc` option available in almost all present TeX interpreters is to flush the DVI output after each page. As PyX reads the DVI output linearily, it can successfully read all output whithout stopping the TeX interpreter. It is suggested to enable the `texipc` feature in the system-wide configuration if available in the TeX interpreter being used.

8.7.2 Debugging

PyX provides various functionality to collect details about the typesetting process. First off all, PyX reads the output generated by the TeX interpreter while it processes the text provided by the user. If the given *texmessage* parsers do not validate this output, an *TexResultError* is raised immediately. The verbosity of this output can be adjusted by the *errordetail* setting of the *SingleRunner*. This might help in some cases to identify an error in the text passed for typesetting, but for more complicated problems, other help is required.

One possibility is to output the actual code passed to the TeX interpreter. For that you can pass a file name or a file handle to the `copyinput` argument of the *SingleRunner*. You can then process the text by the TeX interpreter yourself to reproduce the issue outside of PyX.

Similarily you can also save the log output from the TeX interpreter. For that you need to pass a log file name (with the suffix `.log`) in the `usefiles` argument (which is a list of files) of the *SingleRunner*. This list of files are saved and restored in the temporary directory used by the TeX interpreter. While originally it is meant to share, for example, a `.aux` file between several runs (for which the temporary directory is different and removed after each run), it can do the same for the `.log` file (where the restore feature is needless, but does not harm). PyX takes care of the proper `\jobname`, hence you can choose the filename arbitrarily with the exception of the suffix, as the suffix is kept during the save and restore.

Still, all this might not help to fully understand the problem you're facing. For example there might be situations, where it is not clear which TeX interpreter is actually used (when several executables are available and the path setup within the Python interpreter differs from the one used on the shell). In those situations it might help to enable some additional logging output created by PyX. PyX uses the logging module from the standard library and logs to a logger named `"pyx"`. By default, various information about executing external programms and locating files will not be echoed, as it is written at info level, but PyX provides a simple convenience function to enable the output of this logging level. Just call the *pyxinfo()* function defined on the PyX package before actually start using the package in your Python program:

`pyx.`**`pyxinfo`**`()`

Make PyX a little verbose (for information or debugging)

This function enables info level on the `"pyx"` logger. It also adds some general information about the Python interpreter, the PyX installation, and the PyX configuration to the logger.

8.7.3 Typesetting insecure text

When typesetting text it is passed to a TeX interpreter unchanged[4]. This is a security problem if the text does not come from a trusted source. While full access to all typesetting features is not considered a problem, you should bear in mind that TeX code can be used to read data from any other file accessible to the TeX process. To surely prevent this process from accessing any other data unrelated to the TeX installation, you can setup a chroot environment for the TeX interpreter and configure PyX to use it. This can be achieved by setting the `chroot` option and adjusting the TeX interpreter call and the `filelocator` configuration in the `pyxrc`.

[4] The text is actually passed as an argument of a TeX command defined by PyX, but this is a minor detail and has no effect regarding possible attacks.

CHAPTER

NINE

GRAPHS

9.1 Introduction

PyX can be used for data and function plotting. At present x-y-graphs and x-y-z-graphs are supported only. However, the component architecture of the graph system described in section *Component architecture* allows for additional graph geometries while reusing most of the existing components.

Creating a graph splits into two basic steps. First you have to create a graph instance. The most simple form would look like:

```
from pyx import *
g = graph.graphxy(width=8)
```

The graph instance `g` created in this example can then be used to actually plot something into the graph. Suppose you have some data in a file `graph.dat` you want to plot. The content of the file could look like:

```
1   2
2   3
3   8
4  13
5  18
6  21
```

To plot these data into the graph `g` you must perform:

```
g.plot(graph.data.file("graph.dat", x=1, y=2))
```

The method `plot()` takes the data to be plotted and optionally a list of graph styles to be used to plot the data. When no styles are provided, a default style defined by the data instance is used. For data read from a file by an instance of *`graph.data.file`*, the default are symbols. When instantiating *`graph.data.file`*, you not only specify the file name, but also a mapping from columns to axis names and other information the styles might make use of (*e.g.* data for error bars to be used by the errorbar style).

While the graph is already created by that, we still need to perform a write of the result into a file. Since the graph instance is a canvas, we can just call its `writeEPSfile()` method.

```
g.writeEPSfile("graph")
```

The result `graph.eps` is shown in figure *A minimalistic plot for the data from file graph.dat.*.

Instead of plotting data from a file, other data source are available as well. For example function data is created and placed into `plot()` by the following line:

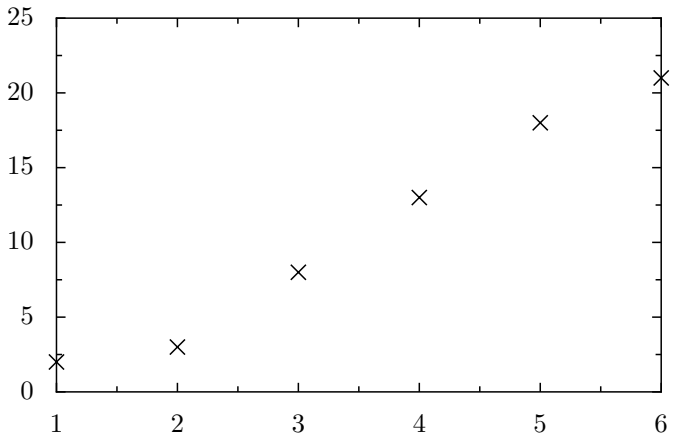


Fig. 1: A minimalistic plot for the data from file `graph.dat`.

```
g.plot(graph.data.function("y(x)=x**2"))
```

You can plot different data in a single graph by calling `plot()` several times before writing the output to a file. Note that a calling `plot()` will fail once a graph was forced to "finish" itself. This happens automatically, when the graph is written to a file. Thus it is not an option to call `plot()` after writing the output. The topic of the finalization of a graph is addressed in more detail in section *graph.graph*. As you can see in figure *Plotting data from a file together with a function.*, a function is plotted as a line by default.

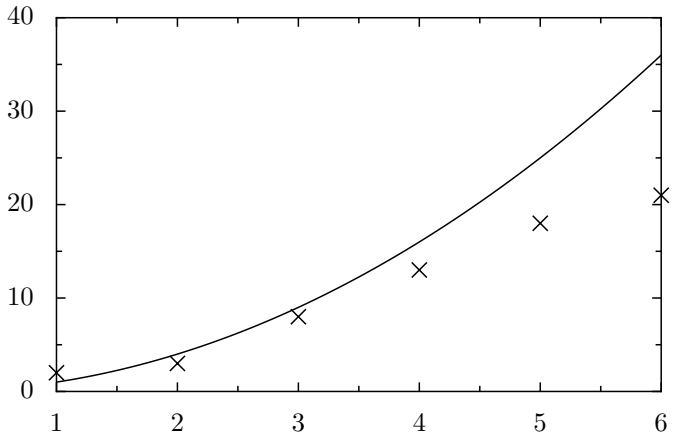


Fig. 2: Plotting data from a file together with a function.

While the axes ranges got adjusted automatically in the previous example, they might be fixed by keyword options in axes constructors. Plotting only a function will need such a setting at least in the variable coordinate. The following code also shows how to set a logathmic axis in y-direction:

```
from pyx import *
g = graph.graphxy(width=8, x=graph.axis.linear(min=-5, max=5),
                           y=graph.axis.logarithmic())
g.plot(graph.data.function("y(x)=exp(x)"))
g.writePDFfile()
```

The result is shown in figure *Plotting a function for a given axis range and use a logarithmic y-axis.*.

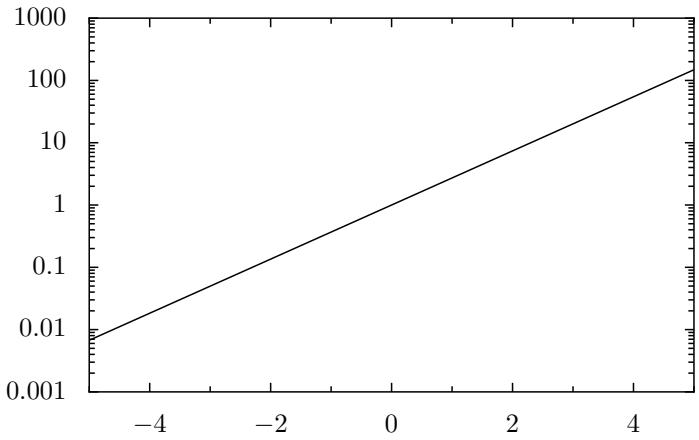


Fig. 3: Plotting a function for a given axis range and use a logarithmic y-axis.

9.2 Component architecture

Creating a graph involves a variety of tasks, which thus can be separated into components without significant additional costs. This structure manifests itself also in the PyX source, where there are different modules for the different tasks. They interact by some well-defined interfaces. They certainly have to be completed and stabilized in their details, but the basic structure came up in the continuous development quite clearly. The basic parts of a graph are:

graph Defines the geometry of the graph by means of graph coordinates with range [0:1]. Keeps lists of plotted data, axes *etc.*

data Produces or prepares data to be plotted in graphs.

style Performs the plotting of the data into the graph. It gets data, converts them via the axes into graph coordinates and uses the graph to finally plot the data with respect to the graph geometry methods.

key Responsible for the graph keys.

axis Creates axes for the graph, which take care of the mapping from data values to graph coordinates. Because axes are also responsible for creating ticks and labels, showing up in the graph themselves and other things, this task is splitted into several independent subtasks. Axes are discussed separately in chapter `axis`.

9.3 Module `graph.graph`: Graph geometry

The classes *`graphxy`* and *`graphxyz`* are part of the module *`graph.graph`*. However, there are shortcuts to access the classes via `graph.graphxy` and `graph.graphxyz`, respectively.

class graph.graph.**graphxy**(*xpos=0*, *ypos=0*, *width=None*, *height=None*, *ratio=goldenmean*, *key=None*, *backgroundattrs=None*, *axesdist=0.8*unit.v_cm*, *xaxisat=None*, *yaxisat=None*, ***axes*)

This class provides an x-y-graph. A graph instance is also a fully functional canvas.

The position of the graph on its own canvas is specified by *xpos* and *ypos*. The size of the graph is specified by *width*, *height*, and *ratio*. These parameters define the size of the graph area not taking into account the additional space needed for the axes. Note that you have to specify at least *width* or *height*. *ratio* will be used as the ratio between *width* and *height* when only one of these is provided.

key can be set to a *`graph.key.key`* instance to create an automatic graph key. `None` omits the graph key.

backgroundattrs is a list of attributes for drawing the background of the graph. Allowed are decorators, strokestyles, and fillstyles. `None` disables background drawing.

axisdist is the distance between axes drawn at the same side of a graph.

xaxisat and *yaxisat* specify a value at the y and x axis, where the corresponding axis should be moved to. It's a shortcut for corresonding calls of *axisatv()* described below. Moving an axis by *xaxisat* or *yaxisat* disables the automatic creation of a linked axis at the opposite side of the graph.

***axes* receives axes instances. Allowed keywords (axes names) are `x`, `x2`, `x3`, *etc.* and `y`, `y2`, `y3`, *etc.* When not providing an `x` or `y` axis, linear axes instances will be used automatically. When not providing a `x2` or `y2` axis, linked axes to the `x` and `y` axes are created automatically and *vice versa*. As an exception, a linked axis is not created automatically when the axis is placed at a specific position by *xaxisat* or *yaxisat*. You can disable the automatic creation of axes by setting the linked axes to `None`. The even numbered axes are plotted at the top (`x` axes) and right (`y` axes) while the others are plotted at the bottom (`x` axes) and left (`y` axes) in ascending order each.

Some instance attributes might be useful for outside read-access. Those are:

`graphxy.`**`axes`**
A dictionary mapping axes names to the `anchoredaxis` instances.

To actually plot something into the graph, the following instance method `plot()` is provided:

`graphxy.`**`plot`**(*data*, *styles=None*)
Adds *data* to the list of data to be plotted. Sets *styles* to be used for plotting the data. When *styles* is `None`, the default styles for the data as provided by *data* is used.

data should be an instance of any of the data described in section *graph.data*.

When the same combination of styles (*i.e.* the same references) are used several times within the same graph instance, the styles are kindly asked by the graph to iterate their appearance. Its up to the styles how this is performed.

Instead of calling the plot method several times with different *data* but the same style, you can use a list (or something iterateable) for *data*.

While a graph instance only collects data initially, at a certain point it must create the whole plot. Once this is done, further calls of `plot()` will fail. Usually you do not need to take care about the finalization of the graph, because it happens automatically once you write the plot into a file. However, sometimes position methods (described below) are nice to be accessible. For that, at least the layout of the graph must have been finished. However, the drawing order is based on canvas layers and thus the order in which the `do()`-methods are called will not alter the output. Multiple calls to any of the `do()`-methods have no effect (only the first call counts). The orginal order in which the `do()`-methods are called is:

`graphxy.`**`dolayout`**`()`
Fixes the layout of the graph. As part of this work, the ranges of the axes are fitted to the data when the axes ranges are allowed to adjust themselves to the data ranges. The other `do()`-methods ensure, that this method is always called first.

`graphxy.`**`dobackground`**`()`
Draws the background.

`graphxy.`**`doaxes`**`()`
Inserts the axes.

`graphxy.`**`doplotitem`**(*plotitem*)
Plots the plotitem as returned by the graphs plot method.

`graphxy.`**`doplot`**`()`
Plots all (remaining) plotitems.

graphxy.**dokeyitem**()
Inserts a plotitem in the graph key as returned by the graphs plot method.

graphxy.**dokey**()
Inserts the graph key.

graphxy.**finish**()
Finishes the graph by calling all pending do()-methods. This is done automatically, when the output is created.

The graph provides some methods to access its geometry:

graphxy.**pos**(*x*, *y*, *xaxis=None*, *yaxis=None*)
Returns the given point at *x* and *y* as a tuple (xpos, ypos) at the graph canvas. *x* and *y* are anchoredaxis instances for the two axes *xaxis* and *yaxis*. When *xaxis* or *yaxis* are None, the axes with names x and y are used. This method fails if called before *dolayout()*.

graphxy.**vpos**(*vx*, *vy*)
Returns the given point at *vx* and *vy* as a tuple (xpos, ypos) at the graph canvas. *vx* and *vy* are graph coordinates with range [0:1].

graphxy.**vgeodesic**(*vx1*, *vy1*, *vx2*, *vy2*)
Returns the geodesic between points *vx1*, *vy1* and *vx2*, *vy2* as a path. All parameters are in graph coordinates with range [0:1]. For *graphxy* this is a straight line.

graphxy.**vgeodesic_el**(*vx1*, *vy1*, *vx2*, *vy2*)
Like *vgeodesic()* but this method returns the path element to connect the two points.

Further geometry information is available by the axes instance variable, with is a dictionary mapping axis names to anchoredaxis instances. Shortcuts to the anchoredaxis positioner methods for the x- and y-axis become available after dolayout() as *graphxy* methods Xbasepath, Xvbasepath, Xgridpath, Xvgridpath, Xtickpoint, Xvtickpoint, Xtickdirection, and Xvtickdirection where the prefix X stands for x and y.

graphxy.**axistrafo**(*axis*, *t*)
This method can be used to apply a transformation *t* to an anchoredaxis instance *axis* to modify the axis position and the like. This method fails when called on a not yet finished axis, i.e. it should be used after *dolayout()*.

graphxy.**axisatv**(*axis*, *v*)
This method calls *axistrafo()* with a transformation to move the axis *axis* to a graph position *v* (in graph coordinates).

The class *graphxyz* is very similar to the *graphxy* class, except for its additional dimension. In the following documentation only the differences to the *graphxy* class are described.

class graph.graph.**graphxyz**(*xpos=0*, *ypos=0*, *size=None*, *xscale=1*, *yscale=1*, *zscale=1/goldenmean*, *xy12axesat=None*, *xy12axesatname="z"*, *projector=central(10, -30, 30)*, *key=None*, ***axes*)
This class provides an x-y-z-graph.

The position of the graph on its own canvas is specified by *xpos* and *ypos*. The size of the graph is specified by *size* and the length factors *xscale*, *yscale*, and *zscale*. The final size of the graph depends on the projector *projector*, which is called with x, y, and z values up to *xscale*, *yscale*, and *zscale* respectively and scaling the result by *size*. For a parallel projector changing *size* is thus identical to changing *xscale*, *yscale*, and *zscale* by the same factor. For the central projector the projectors internal distance would also need to be changed by this factor. Thus *size* changes the size of the whole graph without changing the projection.

xy12axesat moves the xy-plane of the axes x, x2, y, y2 to the given value at the axis *xy12axesatname*.

projector defines the conversion of 3d coordinates to 2d coordinates. It can be an instance of *central* or *parallel* described below.

***axes* receives axes instances as for *graphxy*. The graphxyz allows for 4 axes per graph dimension `x`, `x2`, `x3`, `x4`, `y`, `y2`, `y3`, `y4`, `z`, `z2`, `z3`, and `z4`. The x-y-plane is the horizontal plane at the bottom and the `x`, `x2`, `y`, and `y2` axes are placed at the boundary of this plane with `x` and `y` always being in front. `x3`, `x4`, `y3`, and `y4` are handled similar, but for the top plane of the graph. The `z` axis is placed at the origin of the `x` and `y` dimension, whereas `z2` is placed at the final point of the `x` dimension, `z3` at the final point of the `y` dimension and `z4` at the final point of the `x` and `y` dimension together.

`graphxyz.`**`central`**
The central attribute of the graphxyz is the *central* class. See the class description below.

`graphxyz.`**`parallel`**
The parallel attribute of the graphxyz is the *parallel* class. See the class description below.

Regarding the 3d to 2d transformation the methods `pos()`, `vpos()`, `vgeodesic()`, and `vgeodesic_el()` are available as for class *graphxy* and just take an additional argument for the dimension. Note that a similar transformation method (3d to 2d) is available as part of the projector as well already, but only the graph acknowledges its size, the scaling and the internal tranformation of the graph coordinates to the scaled coordinates. As the projector also implements a `zindex()` and a `angle()` method, those are also available at the graph level in the graph coordinate variant (i.e. having an additional v in its name and using values from 0 to 1 per dimension).

`graphxyz.`**`vzindex`**(*vx*, *vy*, *vz*)
The depths of the point defined by *vx*, *vy*, and *vz* scaled to a range [-1:1] where 1 is closest to the viewer. All arguments passed to the method are in graph coordinates with range [0:1].

`graphxyz.`**`vangle`**(*vx1*, *vy1*, *vz1*, *vx2*, *vy2*, *vz2*, *vx3*, *vy3*, *vz3*)
The cosine of the angle of the view ray thru point `(vx1, vy1, vz1)` and the plane defined by the points `(vx1, vy1, vz1)`, `(vx2, vy2, vz2)`, and `(vx3, vy3, vz3)`. All arguments passed to the method are in graph coordinates with range [0:1].

There are two projector classes *central* and *parallel*:

`class` `graph.graph.`**`central`**(*distance*, *phi*, *theta*, *anglefactor=math.pi/180*)
Instances of this class implement a central projection for the given parameters.

distance is the distance of the viewer from the origin. Note that the *graphxyz* class uses the range `-xscale` to `xscale`, `-yscale` to `yscale`, and `-zscale` to `zscale` for the coordinates `x`, `y`, and `z`. As those scales are of the order of one (by default), the distance should be of the order of 10 to give nice results. Smaller distances increase the central projection character while for huge distances the central projection becomes identical to the parallel projection.

`phi` is the angle of the viewer in the x-y-plane and `theta` is the angle of the viewer to the x-y-plane. The standard notation for spheric coordinates are used. The angles are multiplied by *anglefactor* which is initialized to do a degree in radiant transformation such that you can specify `phi` and `theta` in degree while the internal computation is always done in radiants.

`class` `graph.graph.`**`parallel`**(*phi*, *theta*, *anglefactor=math.pi/180*)
Instances of this class implement a parallel projection for the given parameters. There is no distance for that transformation (compared to the central projection). All other parameters are identical to the *central* class.

9.4 Module `graph.data`: Graph data

The following classes provide data for the `plot()` method of a graph. The classes are implemented in *graph.data*.

`class` `graph.data.`**`file`**(*filename*, *commentpattern=defaultcommentpattern*, *columnpattern=defaultcolumnpattern*, *stringpattern=defaultstringpattern*, *skiphead=0*, *skiptail=0*, *every=1*, *title=notitle*, *context={}*, *copy=1*, *replacedollar=1*, *columncallback="__column__"*, ***columns*)

This class reads data from a file and makes them available to the graph system. *filename* is the name of the file to be read. The data should be organized in columns.

The arguments *commentpattern*, *columnpattern*, and *stringpattern* are responsible for identifying the data in each line of the file. Lines matching *commentpattern* are ignored except for the column name search of the last non- empty comment line before the data. By default a line starting with one of the characters `'#'`, `'%'`, or `'!'` as well as an empty line is treated as a comment.

A non-comment line is analysed by repeatedly matching *stringpattern* and, whenever the stringpattern does not match, by *columnpattern*. When the *stringpattern* matches, the result is taken as the value for the next column without further transformations. When *columnpattern* matches, it is tried to convert the result to a float. When this fails the result is taken as a string as well. By default, you can write strings with spaces surrounded by `'"'` immediately surrounded by spaces or begin/end of line in the data file. Otherwise `'"'` is not taken to be special.

skiphead and *skiptail* are numbers of data lines to be ignored at the beginning and end of the file while *every* selects only every *every* line from the data.

title is the title of the data to be used in the graph key. A default title is constructed out of *filename* and ***columns*. You may set *title* to `None` to disable the title.

Finally, *columns* define columns out of the existing columns from the file by a column number or a mathematical expression (see below). When *copy* is set the names of the columns in the file (file column names) and the freshly created columns having the names of the dictionary key (data column names) are passed as data to the graph styles. The data columns may hide file columns when names are equal. For unset *copy* the file columns are not available to the graph styles.

File column names occur when the data file contains a comment line immediately in front of the data (except for empty or empty comment lines). This line will be parsed skipping the matched comment identifier as if the line would be regular data, but it will not be converted to floats even if it would be possible to convert the items. The result is taken as file column names, *i.e.* a string representation for the columns in the file.

The values of ***columns* can refer to column numbers in the file starting at `1`. The column `0` is also available and contains the line number starting from `1` not counting comment lines, but lines skipped by *skiphead*, *skiptail*, and *every*. Furthermore values of ***columns* can be strings: file column names or complex mathematical expressions. To refer to columns within mathematical expressions you can also use file column names when they are valid variable identifiers. Equal named items in context will then be hidden. Alternatively columns can be access by the syntax `$<number>` when *replacedollar* is set. They will be translated into function calls to *columncallback*, which is a function to access column data by index or name.

context allows for accessing external variables and functions when evaluating mathematical expressions for columns. Additionally to the identifiers in *context*, the file column names, the *columncallback* function and the functions shown in the table "builtins in math expressions" at the end of the section are available.

Example:

```
graph.data.file("test.dat", a=1, b="B", c="2*B+$3")
```

with `test.dat` looking like:

```
# A   B C
1.234 1 2
5.678 3 4
```

The columns with name `"a"`, `"b"`, `"c"` will become `"[1.234, 5.678]"`, `"[1.0, 3.0]"`, and `"[4.0, 10.0]"`, respectively. The columns `"A"`, `"B"`, `"C"` will be available as well, since *copy* is enabled by default.

When creating several data instances accessing the same file, the file is read only once. There is an inherent caching of the file contents.

For the sake of completeness we list the default patterns:

file.**defaultcommentpattern**
re.compile(r"(#+|!+|%+)\s*")

file.**defaultcolumnpattern**
re.compile(r"\"(.*?)\"(\s+|$)")

file.**defaultstringpattern**
re.compile(r"(.*?)(\s+|$)")

class graph.data.**function**(*expression*, *title=notitle*, *min=None*, *max=None*, *points=100*, *context={}*)
This class creates graph data from a function. *expression* is the mathematical expression of the function. It must also contain the result variable name including the variable the function depends on by assignment. A typical example looks like "y(x)=sin(x)".

title is the title of the data to be used in the graph key. By default *expression* is used. You may set *title* to None to disable the title.

min and *max* give the range of the variable. If not set, the range spans the whole axis range. The axis range might be set explicitly or implicitly by ranges of other data. *points* is the number of points for which the function is calculated. The points are choosen linearly in terms of graph coordinates.

context allows for accessing external variables and functions. Additionally to the identifiers in *context*, the variable name and the functions shown in the table "builtins in math expressions" at the end of the section are available.

class graph.data.**paramfunction**(*varname*, *min*, *max*, *expression*, *title=notitle*, *points=100*, *context={}*)
This class creates graph data from a parametric function. *varname* is the parameter of the function. *min* and *max* give the range for that variable. *points* is the number of points for which the function is calculated. The points are choosen lineary in terms of the parameter.

expression is the mathematical expression for the parametric function. It contains an assignment of a tuple of functions to a tuple of variables. A typical example looks like "x, y = cos(k), sin(k)".

title is the title of the data to be used in the graph key. By default *expression* is used. You may set *title* to None to disable the title.

context allows for accessing external variables and functions. Additionally to the identifiers in *context*, *varname* and the functions shown in the table "builtins in math expressions" at the end of the section are available.

class graph.data.**values**(*title="user provided values"*, ***columns*)
This class creates graph data from externally provided data. Each column is a list of values to be used for that column.

title is the title of the data to be used in the graph key.

class graph.data.**points**(*data*, *title="user provided points"*, *addlinenumbers=1*, ***columns*)
This class creates graph data from externally provided data. *data* is a list of lines, where each line is a list of data values for the columns.

title is the title of the data to be used in the graph key.

The keywords of ***columns* become the data column names. The values are the column numbers starting from one, when *addlinenumbers* is turned on (the zeroth column is added to contain a line number in that case), while the column numbers starts from zero, when *addlinenumbers* is switched off.

class graph.data.**data**(*data*, *title=notitle*, *context=*, *copy=1*, *replacedollar=1*, *columncallback="__column__"*, ***columns*)
This class provides graph data out of other graph data. *data* is the source of the data. All other parameters work like the equally called parameters in *graph.data.file*. Indeed, the latter is built on top of this class by reading the file and caching its contents in a graph.data.list instance.

class graph.data.**conffile**(*filename*, *title=notitle*, *context=*, *copy=1*, *replacedollar=1*, *columncallback="__column__"*, ***columns*)

This class reads data from a config file with the file name *filename*. The format of a config file is described within the documentation of the `ConfigParser` module of the Python Standard Library.

Each section of the config file becomes a data line. The options in a section are the columns. The name of the options will be used as file column names. All other parameters work as in *graph.data.file* and *graph.data.data* since they all use the same code.

class graph.data.**cbdfile**(*filename*, *minrank=None*, *maxrank=None*, *title=notitle*, *context=*, *copy=1*, *replacedollar=1*, *columncallback="__column__"*, ***columns*)

This is an experimental class to read map data from cbd-files. See http://sepwww.stanford.edu/ftp/World_Map/ for some world-map data.

The builtins in math expressions are listed in the following table:

name	value
`neg`	`lambda x: -x`
`abs`	`lambda x: x < 0 and -x or x`
`sgn`	`lambda x: x < 0 and -1 or 1`
`sqrt`	`math.sqrt`
`exp`	`math.exp`
`log`	`math.log`
`sin`	`math.sin`
`cos`	`math.cos`
`tan`	`math.tan`
`asin`	`math.asin`
`acos`	`math.acos`
`atan`	`math.atan`
`sind`	`lambda x: math.sin(math.pi/180*x)`
`cosd`	`lambda x: math.cos(math.pi/180*x)`
`tand`	`lambda x: math.tan(math.pi/180*x)`
`asind`	`lambda x: 180/math.pi*math.asin(x)`
`acosd`	`lambda x: 180/math.pi*math.acos(x)`
`atand`	`lambda x: 180/math.pi*math.atan(x)`
`norm`	`lambda x, y: math.hypot(x, y)`
`splitatvalue`	see the `splitatvalue` description below
`pi`	`math.pi`
`e`	`math.e`

`math` refers to Pythons `math` module. The `splitatvalue` function is defined as:

graph.data.**splitatvalue**(*value*, **splitpoints*)

This method returns a tuple `(section, value)`. The section is calculated by comparing *value* with the values of splitpoints. If *splitpoints* contains only a single item, `section` is `0` when value is lower or equal this item and `1` else. For multiple splitpoints, `section` is `0` when its lower or equal the first item, `None` when its bigger than the first item but lower or equal the second item, `1` when its even bigger the second item, but lower or equal the third item. It continues to alter between `None` and `2`, `3`, etc.

9.5 Module `graph.style`: Graph styles

Please note that we are talking about graph styles here. Those are responsible for plotting symbols, lines, bars and whatever else into a graph. Do not mix it up with path styles like the line width, the line style (solid, dashed, dotted *etc.*) and others.

The following classes provide styles to be used at the `plot()` method of a graph. The plot method accepts a list of styles. By that you can combine several styles at the very same time.

Some of the styles below are hidden styles. Those do not create any output, but they perform internal data handling and thus help on modularization of the styles. Usually, a visible style will depend on data provided by one or more hidden styles but most of the time it is not necessary to specify the hidden styles manually. The hidden styles register themself to be the default for providing certain internal data.

class `graph.style.`**pos**(*usenames={}*, *epsilon=1e-10*)
This class is a hidden style providing a position in the graph. It needs a data column for each graph dimension. For that the column names need to be equal to an axis name, or a name translation from axis names to column names need to be given by *usenames*. Data points are considered to be out of graph when their position in graph coordinates exceeds the range [0:1] by more than *epsilon*.

class `graph.style.`**range**(*usenames={}*, *epsilon=1e-10*)
This class is a hidden style providing an errorbar range. It needs data column names constructed out of a axis name `X` for each dimension errorbar data should be provided as follows:

data name	description
`Xmin`	minimal value
`Xmax`	maximal value
`dX`	minimal and maximal delta
`dXmin`	minimal delta
`dXmax`	maximal delta

When delta data are provided the style will also read column data for the axis name `X` itself. *usenames* allows to insert a translation dictionary from axis names to the identifiers `X`.

epsilon is a comparison precision when checking for invalid errorbar ranges.

class `graph.style.`**symbol**(*symbol=changecross*, *size=0.2*unit.v_cm*, *symbolattrs=[]*)
This class is a style for plotting symbols in a graph. *symbol* refers to a (changeable) symbol function with the prototype `symbol(c, x_pt, y_pt, size_pt, attrs)` and draws the symbol into the canvas `c` at the position `(x_pt, y_pt)` with size `size_pt` and attributes `attrs`. Some predefined symbols are available in member variables listed below. The symbol is drawn at size *size* using *symbolattrs*. *symbolattrs* is merged with `defaultsymbolattrs` which is a list containing the decorator `deco.stroked`. An instance of *symbol* is the default style for all graph data classes described in section *graph.data* except for `function` and `paramfunction`.

The class *symbol* provides some symbol functions as member variables, namely:

`symbol.`**cross**
A cross. Should be used for stroking only.

`symbol.`**plus**
A plus. Should be used for stroking only.

`symbol.`**square**
A square. Might be stroked or filled or both.

`symbol.`**triangle**
A triangle. Might be stroked or filled or both.

`symbol.`**circle**
A circle. Might be stroked or filled or both.

`symbol.`**diamond**
A diamond. Might be stroked or filled or both.

symbol provides some changeable symbol functions as member variables, namely:

symbol.**changecross**
attr.changelist([cross, plus, square, triangle, circle, diamond])

symbol.**changeplus**
attr.changelist([plus, square, triangle, circle, diamond, cross])

symbol.**changesquare**
attr.changelist([square, triangle, circle, diamond, cross, plus])

symbol.**changetriangle**
attr.changelist([triangle, circle, diamond, cross, plus, square])

symbol.**changecircle**
attr.changelist([circle, diamond, cross, plus, square, triangle])

symbol.**changediamond**
attr.changelist([diamond, cross, plus, square, triangle, circle])

symbol.**changesquaretwice**
attr.changelist([square, square, triangle, triangle, circle, circle, diamond, diamond])

symbol.**changetriangletwice**
attr.changelist([triangle, triangle, circle, circle, diamond, diamond, square, square])

symbol.**changecircletwice**
attr.changelist([circle, circle, diamond, diamond, square, square, triangle, triangle])

symbol.**changediamondtwice**
attr.changelist([diamond, diamond, square, square, triangle, triangle, circle, circle])

The class *symbol* provides two changeable decorators for alternated filling and stroking. Those are especially useful in combination with the change()-twice()-symbol methods above. They are:

symbol.**changestrokedfilled**
attr.changelist([deco.stroked, deco.filled])

symbol.**changefilledstroked**
attr.changelist([deco.filled, deco.stroked])

class graph.style.**line**(*lineattrs=[]*, *epsilon=1e-10*)
This class is a style to stroke lines in a graph. *lineattrs* is merged with defaultlineattrs which is a list containing the member variable changelinestyle as described below. An instance of *line* is the default style of the graph data classes function and paramfunction described in section *graph.data*. *epsilon* is a precision in graph coordinates for line clipping.

The class *line* provides a changeable line style. Its definition is:

line.**changelinestyle**
attr.changelist([style.linestyle.solid, style.linestyle.dashed, style.linestyle.dotted, style.linestyle.dashdotted])

class graph.style.**impulses**(*lineattrs=[]*, *fromvalue=0*, *frompathattrs=[]*, *valueaxisindex=1*)
This class is a style to plot impulses. *lineattrs* is merged with defaultlineattrs which is a list containing the member variable changelinestyle of the *line* class. *fromvalue* is the baseline value of the impulses. When set to None, the impulses will start at the baseline. When fromvalue is set, *frompathattrs* are the stroke attributes used to show the impulses baseline path.

class graph.style.**errorbar**(*size=0.1*unit.v_cm*, *errorbarattrs=[]*, *epsilon=1e-10*)
This class is a style to stroke errorbars in a graph. *size* is the size of the caps of the errorbars and *errorbarattrs* are the stroke attributes. Errorbars and error caps are considered to be out of the graph when their position in graph coordinates exceeds the range [0:1] by more that *epsilon*. Out of graph caps are omitted and the errorbars are cut to the valid graph range.

class graph.style.**text**(*textname="text"*, *dxname=None*, *dyname=None*, *dxunit=0.3*unit.v_cm*, *dyunit=0.3*unit.v_cm*, *textdx=0*unit.v_cm*, *textdy=0.3*unit.v_cm*, *textattrs=[]*)

This class is a style to stroke text in a graph. The text to be written has to be provided in the data column named `textname`. *textdx* and *textdy* are the position of the text with respect to the position in the graph. Alternatively you can specify a `dxname` and a `dyname` and provide appropriate data in those columns to be taken in units of *dxunit* and *dyunit* to specify the position of the text for each point separately. *textattrs* are text attributes for the output of the text. Those attributes are merged with the default attributes `textmodule.halign.center` and `textmodule.vshift.mathaxis`.

class graph.style.**arrow**(*linelength=0.25*unit.v_cm*, *arrowsize=0.15*unit.v_cm*, *lineattrs=[]*, *arrowattrs=[]*, *arrowpos=0.5*, *epsilon=1e-10*, *decorator=deco.earrow*)

This class is a style to plot short lines with arrows into a two-dimensional graph to a given graph position. The arrow parameters are defined by two additional data columns named `size` and `angle` define the size and angle for each arrow. `size` is taken as a factor to *arrowsize* and *linelength*, the size of the arrow and the length of the line the arrow is plotted at. `angle` is the angle the arrow points to with respect to a horizontal line. The `angle` is taken in degrees and used in mathematically positive sense. *lineattrs* and *arrowattrs* are styles for the arrow line and arrow head, respectively. *arrowpos* defines the position of the arrow line with respect to the position at the graph. The default `0.5` means centered at the graph position, whereas `0` and `1` creates the arrows to start or end at the graph position, respectively. *epsilon* is used as a cutoff for short arrows in order to prevent numerical instabilities. *decorator* defines the decorator to be added to the line.

class graph.style.**rect**(*colorname="color"*, *gradient=color.gradient.Grey*, *coloraxis=None*, *keygraph=_autokeygraph*)

This class is a style to plot colored rectangles into a two-dimensional graph. The size of the rectangles is taken from the data provided by the *range* style. The additional data column named *colorname* specifies the color of the rectangle defined by *gradient*. The translation of the data values to the gradient is done by the *coloraxis*, which is set to be a linear axis if not provided by *coloraxis*. A key graph, a graphx instance, is generated automatically to indicate the color scale if not provided by *keygraph*. If a *keygraph* is given, its `x` axis defines the color conversion and *coloraxis* is ignored.

class graph.style.**histogram**(*lineattrs=[]*, *steps=0*, *fromvalue=0*, *frompathattrs=[]*, *fillable=0*, *rectkey=0*, *autohistogramaxisindex=0*, *autohistogrampointpos=0.5*, *epsilon=1e-10*)

This class is a style to plot histograms. *lineattrs* is merged with `defaultlineattrs` which is `[deco.stroked]`. When *steps* is set, the histrogram is plotted as steps instead of the default being a boxed histogram. *fromvalue* is the baseline value of the histogram. When set to `None`, the histogram will start at the baseline. When fromvalue is set, *frompathattrs* are the stroke attributes used to show the histogram baseline path.

The *fillable* flag changes the stoke line of the histogram to make it fillable properly. This is important on non-steped histograms or on histograms, which hit the graph boundary. *rectkey* can be set to generate a rectanglar area instead of a line in the graph key.

In the most general case, a histogram is defined by a range specification (like for an errorbar) in one graph dimension (say, along the x-axis) and a value for the other graph dimension. This allows for the widths of the histogram boxes being variable. Often, however, all histogram bin ranges are equally sized, and instead of passing the range, the position of the bin along the x-axis fully specifies the histogram - assuming that there are at least two bins. This common case is supported via two parameters: *autohistogramaxisindex*, which defines the index of the independent histogram axis (in the case just described this would be `0` designating the x axis). *autohistogrampointpos*, defines the relative position of the center of the histogram bin: `0.5` means that the bin is centered at the values passed to the style, `0` (`1`) means that the bin is aligned at the right-(left-)hand side.

XXX describe, how to specify general histograms with varying bin widths

Positions of the histograms are considered to be out of graph when they exceed the graph coordinate range [0:1] by more than *epsilon*.

class graph.style.**barpos**(*fromvalue=None*, *frompathattrs=[]*, *epsilon=1e-10*)

This class is a hidden style providing position information in a bar graph. Those graphs need to contain a

specialized axis, namely a bar axis. The data column for this bar axis is named `Xname` where `X` is an axis name. In the other graph dimension the data column name must be equal to an axis name. To plot several bars in a single graph side by side, you need to have a nested bar axis and provide a tuple as data for nested bar axis.

The bars start at *fromvalue* when provided. The *fromvalue* is marked by a gridline stroked using *frompathattrs*. Thus this hidden style might actually create some output. The value of a bar axis is considered to be out of graph when its position in graph coordinates exceeds the range [0:1] by more than *epsilon*.

class graph.style.**stackedbarpos**(*stackname*, *addontop=0*, *epsilon=1e-10*)

This class is a hidden style providing position information in a bar graph by stacking a new bar on top of another bar. The value of the new bar is taken from the data column named *stackname*. When *addontop* is set, the values is taken relative to the previous top of the bar.

class graph.style.**bar**(*barattrs=[]*, *epsilon=1e-10*, *gradient=color.gradient.RedBlack*)

This class draws bars in a bar graph. The bars are filled using *barattrs*. *barattrs* is merged with `defaultbarattrs` which is a list containing `[color.gradient.Rainbow, deco.stroked([color.grey.black])]`.

The bar style has limited support for 3d graphs: Occlusion does not work properly on stacked bars or multiple dataset. *epsilon* is used in 3d to prevent numerical instabilities on bars without hight. When *gradient* is not `None` it is used to calculate a lighting coloring taking into account the angle between the view ray and the bar and the distance between viewer and bar. The precise conversion is defined in the `lighting()` method.

class graph.style.**changebar**(*barattrs=[]*)

This style works like the *bar* style, but instead of the *barattrs* to be changed on subsequent data instances the *barattrs* are changed for each value within a single data instance. In the result the style can't be applied to several data instances and does not support 3d. The style raises an error instead.

class graph.style.**gridpos**(*index1=0*, *index2=1*, *gridlines1=1*, *gridlines2=1*, *gridattrs=[]*, *epsilon=1e-10*)

This class is a hidden style providing rectangular grid information out of graph positions for graph dimensions *index1* and *index2*. Data points are considered to be out of graph when their position in graph coordinates exceeds the range [0:1] by more than *epsilon*. Data points are merged to a single graph coordinate value when their difference in graph coordinates is below *epsilon*.

class graph.style.**grid**(*gridlines1=1*, *gridlines2=1*, *gridattrs=[]*, *epsilon=1e-10*)

Strokes a rectangular grid in the first grid direction, when *gridlines1* is set and in the second grid direction, when *gridlines2* is set. *gridattrs* is merged with `defaultgridattrs` which is a list containing the member variable `changelinestyle` of the *line* class. *epsilon* is a precision in graph coordinates for line clipping.

class graph.style.**surface**(*gridlines1=0.05*, *gridlines2=0.05*, *gridcolor=None*, *backcolor=color.gray.black*, ***kwargs*)

Draws a surface of a rectangular grid. Each rectangle is divided into 4 triangles.

If a *gridcolor* is set, the rectangular grid is marked by small stripes of the relative (compared to each rectangle) size of *gridlines1* and *gridlines2* for the first and second grid direction, respectively.

backcolor is used to fill triangles shown from the back. If *backcolor* is set to `None`, back sides are not drawn differently from the front sides.

The surface is encoded using a single mesh. While this is quite space efficient, it has the following implications:

- All colors must use the same color space.
- **HSB colors are not allowed, whereas Gray, RGB, and CMYK are allowed. You can** convert HSB colors into a different color space by means of `rgbgradient` and class:*cmykgradient* before passing it to the surface style.
- **The grid itself is also constructed out of triangles. The grid is transformed** along with the triangles thus looking quite different from a stroked grid (as done by the grid style).
- Occlusion is handled by proper painting order.

- Color changes are continuous (in the selected color space) for each triangle.

  Further arguments are identical to the *graph.style.rect* style. However, if no *colorname* column exists, the surface style falls back to a lighting coloring taking into account the angle between the view ray and the triangle and the distance between viewer and triangle. The precise conversion is defined in the `lighting()` method.

density(epsilon=1e-10, **kwargs):
Density plots can be created by the density style. It is similar to a surface plot in 2d, but it does not use a mesh, but a bitmap representation instead. Due to that difference, the file size is smaller and no color interpolation takes place. Furthermore the style can be used with equidistantly spaced data only (after conversion by the axis, so logarithmic raw data and such are possible using proper axes). Further arguments are identical to the *graph.style.rect* style.

9.6 Module graph.key: Graph keys

The following class provides a key, whose instances can be passed to the constructor keyword argument `key` of a graph. The class is implemented in *graph.key*.

class graph.key.**key**(*dist=0.2*unit.v_cm*, *pos="tr"*, *hpos=None*, *vpos=None*, *hinside=1*, *vinside=1*, *hdist=0.6*unit.v_cm*, *vdist=0.4*unit.v_cm*, *symbolwidth=0.5*unit.v_cm*, *symbolheight=0.25*unit.v_cm*, *symbolspace=0.2*unit.v_cm*, *textattrs=[]*, *columns=1*, *columndist=0.5*unit.v_cm*, *border=0.3*unit.v_cm*, *keyattrs=None*)

This class writes the title of the data in a plot together with a small illustration of the style. The style is responsible for its illustration.

dist is a visual length and a distance between the key entries. *pos* is the position of the key with respect to the graph. Allowed values are combinations of `"t"` (top), `"m"` (middle) and `"b"` (bottom) with `"l"` (left), `"c"` (center) and `"r"` (right). Alternatively, you may use *hpos* and *vpos* to specify the relative position using the range [0:1]. *hdist* and *vdist* are the distances from the specified corner of the graph. *hinside* and *vinside* are numbers to be set to 0 or 1 to define whether the key should be placed horizontally and vertically inside of the graph or not.

symbolwidth and *symbolheight* are passed to the style to control the size of the style illustration. *symbolspace* is the space between the illustration and the text. *textattrs* are attributes for the text creation. They are merged with `[text.vshift.mathaxis]`.

columns is a number of columns of the graph key and *columndist* is the distance between those columns.

When *keyattrs* is set to contain some draw attributes, the graph key is enlarged by *border* and the key area is drawn using *keyattrs*.

CHAPTER

TEN

AXES

10.1 Component architecture

Axes are a fundamental component of graphs although there might be applications outside of the graph system. Internally axes are constructed out of components, which handle different tasks axes need to fulfill:

axis Implements the conversion of a data value to a graph coordinate of range [0:1]. It does also handle the proper usage of the components in complicated tasks (*i.e.* combine the partitioner, texter, painter and rater to find the best partitioning).

An anchoredaxis is a container to combine an axis with an positioner and provide a storage area for all kind of axis data. That way axis instances are reusable (they do not store any data locally). The anchoredaxis and the positioner are created by a graph corresponding to its geometry.

tick Ticks are plotted along the axis. They might be labeled with text as well.

partitioner, we use "parter" as a short form Creates one or several choices of tick lists suitable to a certain axis range.

texter Creates labels for ticks when they are not set manually.

painter Responsible for painting the axis.

rater Calculate ratings, which can be used to select the best suitable partitioning.

positioner Defines the position of an axis.

The names above map directly to modules which are provided in the directory `graph/axis` except for the anchoredaxis, which is part of the axis module as well. Sometimes it might be convenient to import the axis directory directly rather than to access iit through the graph. This would look like:

```
from pyx import *
graph.axis.painter() # and the like

from pyx.graph import axis
axis.painter() # this is shorter ...
```

In most cases different implementations are available through different classes, which can be combined in various ways. There are various axis examples distributed with PyX, where you can see some of the features of the axis with a few lines of code each. Hence we can here directly come to the reference of the available components.

10.2 Module `graph.axis.axis`: Axes

The following classes are part of the module *`graph.axis.axis`*. However, there is a shortcut to access those classes via `graph.axis` directly.

Instances of the following classes can be passed to the ***axes* keyword arguments of a graph. Those instances should only be used once.

class graph.axis.axis.**linear**(*min=None*, *max=None*, *reverse=0*, *divisor=None*, *title=None*, *parter=parter.autolinear()*, *manualticks=[]*, *density=1*, *maxworse=2*, *rater=rater.linear()*, *texter=texter.mixed()*, *painter=painter.regular()*, *linkpainter=painter.linked()*, *fallbackrange=None*)

This class provides a linear axis. *min* and *max* define the axis range. When not set, they are adjusted automatically by the data to be plotted in the graph. Note, that some data might want to access the range of an axis (*e.g.* the `function` class when no range was provided there) or you need to specify a range when using the axis without plugging it into a graph (*e.g.* when drawing an axis along a path). In cases where the data provides a range of zero (e.g. a when plotting a constant function), then a *fallbackrange* can be set to guarantee a minimal range of the axis.

reverse can be set to indicate a reversed axis starting with bigger values first. Alternatively you can fix the axis range by *min* and *max* accordingly. When divisor is set, it is taken to divide all data range and position informations while creating ticks. You can create ticks not taking into account a factor by that. *title* is the title of the axis.

parter is a partitioner instance, which creates suitable ticks for the axis range. Those ticks are merged with ticks manually given by *manualticks* before proceeding with rating, painting *etc.* Manually placed ticks win against those created by the partitioner. For automatic partitioners, which are able to calculate several possible tick lists for a given axis range, the *density* is a (linear) factor to favour more or less ticks. It should not be stressed to much (its likely, that the result would be unappropriate or not at all valid in terms of rating label distances). But within a range of say 0.5 to 2 (even bigger for large graphs) it can help to get less or more ticks than the default would lead to. *maxworse* is the number of trials with more and less ticks when a better rating was already found. *rater* is a rater instance, which rates the ticks and the label distances for being best suitable. It also takes into account *density*. The rater is only needed, when the partitioner creates several tick lists.

texter is a texter instance. It creates labels for those ticks, which claim to have a label, but do not have a label string set already. Ticks created by partitioners typically receive their label strings by texters. The *painter* is finally used to construct the output. Note, that usually several output constructions are needed, since the rater is also used to rate the distances between the labels for an optimum. The *linkedpainter* is used as the axis painter, when automatic link axes are created by the `createlinked()` method.

class graph.axis.axis.**lin**(...)

This class is an abbreviation of *linear* described above.

class graph.axis.axis.**logarithmic**(*min=None*, *max=None*, *reverse=0*, *divisor=None*, *title=None*, *parter=parter.autologarithmic()*, *manualticks=[]*, *density=1*, *maxworse=2*, *rater=rater.logarithmic()*, *texter=texter.mixed()*, *painter=painter.regular()*, *linkpainter=painter.linked()*, *fallbackrange=None*)

This class provides a logarithmic axis. All parameters work like *linear*. Only two parameters have a different default: *parter* and *rater*. Furthermore and most importantly, the mapping between data and graph coordinates is logarithmic.

class graph.axis.axis.**log**(...)

This class is an abbreviation of *logarithmic* described above.

class graph.axis.axis.**bar**(*subaxes=None*, *defaultsubaxis=linear(painter=None*, *linkpainter=None*, *parter=None*, *texter=None)*, *dist=0.5*, *firstdist=None*, *lastdist=None*, *title=None*, *reverse=0*, *painter=painter.bar()*, *linkpainter=painter.linkedbar()*)

This class provides an axis suitable for a bar style. It handles a discrete set of values and maps them to distinct ranges in graph coordinates. For that, the axis gets a tuple of two values.

The first item is taken to be one of the discrete values valid on this axis. The discrete values can be any hashable type and the order of the subaxes is defined by the order the data is received or the inverse of that when *reverse* is set.

The second item is passed to the corresponding subaxis. The result of the conversion done by the subaxis is mapped to the graph coordinate range reserved for this subaxis. This range is defined by a size attribute of the subaxis, which can be added to any axis. (see the sized linear axes described below for some axes already having a size argument). When no size information is available for a subaxis, a size value of 1 is used. The baraxis itself calculates its size by suming up the sizes of its subaxes plus *firstdist*, *lastdist* and *dist* times the number of subaxes minus 1.

subaxes should be a list or a dictionary mapping a discrete value of the bar axis to the corresponding subaxis. When no subaxes are set or data is received for an unknown discrete axis value, instances of defaultsubaxis are used as the subaxis for this discrete value.

dist is used as the spacing between the ranges for each distinct value. It is measured in the same units as the subaxis results, thus the default value of `0.5` means half the width between the distinct values as the width for each distinct value. *firstdist* and *lastdist* are used before the first and after the last value. When set to `None`, half of *dist* is used.

title is the title of the split axes and *painter* is a specialized painter for an bar axis and *linkpainter* is used as the painter, when automatic link axes are created by the `createlinked()` method.

class graph.axis.axis.**nestedbar**(*subaxes=None*, *defaultsubaxis=bar(dist=0*, *painter=None*, *linkpainter=None)*, *dist=0.5*, *firstdist=None*, *lastdist=None*, *title=None*, *reverse=0*, *painter=painter.bar()*, *linkpainter=painter.linkedbar()*)

This class is identical to the bar axis except for the different default value for defaultsubaxis.

class graph.axis.axis.**split**(*subaxes=None*, *defaultsubaxis=linear()*, *dist=0.5*, *firstdist=0*, *lastdist=0*, *title=None*, *reverse=0*, *painter=painter.split()*, *linkpainter=painter.linkedsplit()*)

This class is identical to the bar axis except for the different default value for defaultsubaxis, firstdist, lastdist, painter, and linkedpainter.

Sometimes you want to alter the default size of 1 of the subaxes. For that you have to add a size attribute to the axis data. The two classes `sizedlinear` and `autosizedlinear` do that for linear axes. Their short names are `sizedlin` and `autosizedlin`. `sizedlinear` extends the usual linear axis by an first argument *size*. `autosizedlinear` creates the size out of its data range automatically but sets an `autolinear` parter with *extendtick* being `None` in order to disable automatic range modifications while painting the axis.

The `axis` module also contains classes implementing so called anchored axes, which combine an axis with an positioner and a storage place for axis related data. Since these features are not interesting for the average PyX user, we'll not go into all the details of their parameters and except for some handy axis position methods:

class graph.axis.axis.**anchoredaxis**

anchoredaxis.**basepath**(*x1=None*, *x2=None*)

Returns a path instance for the base path. *x1* and *x2* define the axis range, the base path should cover. For `None` the beginning and end of the path is taken, which might cover a longer range, when the axis is embedded as a subaxis. For that case, a `None` value extends the range to the point of the middle between two subaxes or the beginning or end of the whole axis, when the subaxis is the first or last of the subaxes.

anchoredaxis.**vbasepath**(*v1=None*, *v2=None*)

Like *basepath()* but in graph coordinates.

anchoredaxis.**gridpath**(*x*)

Returns a path instance for the grid path at position *x*. Might return `None` when no grid path is available.

anchoredaxis.**vgridpath**(*v*)

Like *gridpath()* but in graph coordinates.

anchoredaxis.**tickpoint**(*x*)
Returns the position of *x* as a tuple `(x, y)`.

anchoredaxis.**vtickpoint**(*v*)
Like *tickpoint()* but in graph coordinates.

anchoredaxis.**tickdirection**(*x*)
Returns the direction of a tick at *x* as a tuple `(dx, dy)`. The tick direction points inside of the graph.

anchoredaxis.**vtickdirection**(*v*)
Like *tickdirection()* but in graph coordinates.

anchoredaxis.**vtickdirection**(*v*)
Like *tickdirection()* but in graph coordinates.

However, there are two anchored axes implementations *linkedaxis* and *anchoredpathaxis* which are available to the user to create special forms of anchored axes.

class graph.axis.axis.**linkedaxis**(*linkedaxis=None*, *errorname="manual-linked"*, *painter=_marker*)
This class implements an anchored axis to be passed to a graph constructor to manually link the axis to another anchored axis instance *linkedaxis*. Note that you can skip setting the value of *linkedaxis* in the constructor, but set it later on by the *setlinkedaxis()* method described below. *errorname* is printed within error messages when the data is used and some problem occurs. *painter* is used for painting the linked axis instead of the *linkedpainter* provided by the *linkedaxis*.

linkedaxis.**setlinkedaxis**(*linkedaxis*)
This method can be used to set the *linkedaxis* after constructing the axis. By that you can create several graph instances with cycled linked axes.

class graph.axis.axis.**anchoredpathaxis**(*path*, *axis*, *direction=1*)
This class implements an anchored axis the path *path*. *direction* defines the direction of the ticks. Allowed values are `1` (left) and `-1` (right).

The *anchoredpathaxis* contains as any anchored axis after calling its `create()` method the painted axis in the *canvas* member attribute. The function `pathaxis()` has the same signature like the *anchoredpathaxis* class, but immediately creates the axis and returns the painted axis.

10.3 Module graph.axis.tick: Axes ticks

The following classes are part of the module *graph.axis.tick*.

class graph.axis.tick.**rational**(*x*, *power=1*, *floatprecision=10*)
This class implements a rational number with infinite precision. For that it stores two integers, the numerator `num` and a denominator `denom`. Note that the implementation of rational number arithmetics is not at all complete and designed for its special use case of axis partitioning in PyX preventing any roundoff errors.

x is the value of the rational created by a conversion from one of the following input values:

- **A float. It is converted to a rational with finite precision determined by** *floatprecision*.
- **A string, which is parsed to a rational number with full precision. It is also** allowed to provide a fraction like `"1/3"`.
- **A sequence of two integers. Those integers are taken as numerator and** denominator of the rational.
- **An instance defining instance variables `num` and `denom` like**

  rational itself.

power is an integer to calculate `x**power`. This is useful at certain places in partitioners.

class graph.axis.tick.**tick**(*x*, *ticklevel=0*, *labellevel=0*, *label=None*, *labelattrs=[]*, *power=1*, *floatprecision=10*)

This class implements ticks based on rational numbers. Instances of this class can be passed to the `manualticks` parameter of a regular axis.

The parameters *x*, *power*, and *floatprecision* share its meaning with *rational*.

A tick has a tick level (*i.e.* markers at the axis path) and a label lavel (*e.i.* place text at the axis path), *ticklevel* and *labellevel*. These are non-negative integers or *None*. A value of `0` means a regular tick or label, `1` stands for a subtick or sublabel, `2` for subsubtick or subsublabel and so on. `None` means omitting the tick or label. *label* is the text of the label. When not set, it can be created automatically by a texter. *labelattrs* are the attributes for the labels.

10.4 Module graph.axis.parter: Axes partitioners

The following classes are part of the module *graph.axis.parter*. Instances of the classes can be passed to the parter keyword argument of regular axes.

class graph.axis.parter.**linear**(*tickdists=None*, *labeldists=None*, *extendtick=0*, *extendlabel=None*, *epsilon=1e-10*)

Instances of this class creates equally spaced tick lists. The distances between the ticks, subticks, subsubticks *etc.* starting from a tick at zero are given as first, second, third *etc.* item of the list *tickdists*. For a tick position, the lowest level wins, *i.e.* for `[2, 1]` even numbers will have ticks whereas subticks are placed at odd integer. The items of *tickdists* might be strings, floats or tuples as described for the *pos* parameter of class `tick`.

labeldists works equally for placing labels. When *labeldists* is kept `None`, labels will be placed at each tick position, but sublabels *etc.* will not be used. This copy behaviour is also available *vice versa* and can be disabled by an empty list.

extendtick can be set to a tick level for including the next tick of that level when the data exceeds the range covered by the ticks by more than *epsilon*. *epsilon* is taken relative to the axis range. *extendtick* is disabled when set to `None` or for fixed range axes. *extendlabel* works similar to *extendtick* but for labels.

class graph.axis.parter.**lin**(...)

This class is an abbreviation of *linear* described above.

class graph.axis.parter.**autolinear**(*variants=defaultvariants*, *extendtick=0*, *epsilon=1e-10*)

Instances of this class creates equally spaced tick lists, where the distance between the ticks is adjusted to the range of the axis automatically. Variants are a list of possible choices for *tickdists* of *linear*. Further variants are build out of these by multiplying or dividing all the values by multiples of `10`. *variants* should be ordered that way, that the number of ticks for a given range will decrease, hence the distances between the ticks should increase within the *variants* list. *extendtick* and *epsilon* have the same meaning as in *linear*.

autolinear.**defaultvariants**

```
[[tick.rational((1, 1)), tick.rational((1, 2))], [tick.rational((2, 1)),
tick.rational((1, 1))], [tick.rational((5, 2)), tick.rational((5, 4))],
[tick.rational((5, 1)), tick.rational((5, 2))]]
```

class graph.axis.parter.**autolin**(...)

This class is an abbreviation of *autolinear* described above.

class graph.axis.parter.**preexp**(*pres*, *exp*)

This is a storage class defining positions of ticks on a logarithmic scale. It contains a list *pres* of positions p_i and *exp*, a multiplicator m. Valid tick positions are defined by $p_i m^n$ for any integer n.

class graph.axis.parter.**logarithmic**(*tickpreexps=None*, *labelpreexps=None*, *extendtick=0*, *extendlabel=None*, *epsilon=1e-10*)

Instances of this class creates tick lists suitable to logarithmic axes. The positions of the ticks, subticks, sub-

subticks *etc.* are defined by the first, second, third *etc.* item of the list *tickpreexps*, which are all *preexp* instances.

labelpreexps works equally for placing labels. When *labelpreexps* is kept `None`, labels will be placed at each tick position, but sublabels *etc.* will not be used. This copy behaviour is also available *vice versa* and can be disabled by an empty list.

extendtick, *extendlabel* and *epsilon* have the same meaning as in *linear*.

Some *preexp* instances for the use in *logarithmic* are available as instance variables (should be used read-only):

`logarithmic.`**`pre1exp5`**
`preexp([tick.rational((1, 1))], 100000)`

`logarithmic.`**`pre1exp4`**
`preexp([tick.rational((1, 1))], 10000)`

`logarithmic.`**`pre1exp3`**
`preexp([tick.rational((1, 1))], 1000)`

`logarithmic.`**`pre1exp2`**
`preexp([tick.rational((1, 1))], 100)`

`logarithmic.`**`pre1exp`**
`preexp([tick.rational((1, 1))], 10)`

`logarithmic.`**`pre125exp`**
`preexp([tick.rational((1, 1)), tick.rational((2, 1)), tick.rational((5, 1))], 10)`

`logarithmic.`**`pre1to9exp`**
`preexp([tick.rational((1, 1)) for x in range(1, 10)], 10)`

class `graph.axis.parter.`**`log`**`(...)`
This class is an abbreviation of *logarithmic* described above.

class `graph.axis.parter.`**`autologarithmic`**`(`*variants=defaultvariants*, *extendtick=0*, *extendlabel=None*, *epsilon=1e-10*`)`
Instances of this class creates tick lists suitable to logarithmic axes, where the distance between the ticks is adjusted to the range of the axis automatically. Variants are a list of tuples with possible choices for *tickpreexps* and *labelpreexps* of *logarithmic*. *variants* should be ordered that way, that the number of ticks for a given range will decrease within the *variants* list.

extendtick, *extendlabel* and *epsilon* have the same meaning as in *linear*.

`autologarithmic.`**`defaultvariants`**
`[([log.pre1exp, log.pre1to9exp], [log.pre1exp, log.pre125exp]), ([log.pre1exp, log.pre1to9exp], None), ([log.pre1exp2, log.pre1exp], None), ([log.pre1exp3, log.pre1exp], None), ([log.pre1exp4, log.pre1exp], None), ([log.pre1exp5, log.pre1exp], None)]`

class `graph.axis.parter.`**`autolog`**`(...)`
This class is an abbreviation of *autologarithmic* described above.

10.5 Module `graph.axis.texter`: Axes texter

The following classes are part of the module *graph.axis.texter*. Instances of the classes can be passed to the texter keyword argument of regular axes. Texters are used to define the label text for ticks, which request to have a

label, but for which no label text has been specified so far. A typical case are ticks created by partitioners described above.

class graph.axis.texter.**decimal**(*prefix=""*, *infix=""*, *suffix=""*, *equalprecision=0*, *decimalsep="."*, *thousandsep=""*, *thousandthpartsep=""*, *plus=""*, *minus="-"*, *period=r"\overline{%s}"*, *labelattrs=[text.mathmode]*)

Instances of this class create decimal formatted labels.

The strings *prefix*, *infix*, and *suffix* are added to the label at the beginning, immediately after the plus or minus, and at the end, respectively. *decimalsep*, *thousandsep*, and *thousandthpartsep* are strings used to separate integer from fractional part and three-digit groups in the integer and fractional part. The strings *plus* and *minus* are inserted in front of the unsigned value for non-negative and negative numbers, respectively.

The format string *period* should generate a period. It must contain one string insert operators `%s` for the period.

labelattrs is a list of attributes to be added to the label attributes given in the painter. It should be used to setup TeX features like `text.mathmode`. Text format options like `text.size` should instead be set at the painter.

class graph.axis.texter.**exponential**(*plus=""*, *minus="-"*, *mantissaexp=r"{{%s}\cdot10^{%s}}"*, *skipexp0=r"{%s}"*, *skipexp1=None*, *nomantissaexp=r"{10^{%s}}"*, *minusnomantissaexp=r"{-10^{%s}}"*, *mantissamin=tick.rational((1, 1))*, *mantissamax=tick.rational((10L, 1))*, *skipmantissa1=0*, *skipallmantissa1=1*, *mantissatexter=decimal()*)

Instances of this class create decimal formatted labels with an exponential.

The strings *plus* and *minus* are inserted in front of the unsigned value of the exponent.

The format string *mantissaexp* should generate the exponent. It must contain two string insert operators `%s`, the first for the mantissa and the second for the exponent. An alternative to the default is `r"{{%s}{\rme}{%s}}"`.

The format string *skipexp0* is used to skip exponent `0` and must contain one string insert operator `%s` for the mantissa. `None` turns off the special handling of exponent `0`. The format string *skipexp1* is similar to *skipexp0*, but for exponent `1`.

The format string *nomantissaexp* is used to skip the mantissa `1` and must contain one string insert operator `%s` for the exponent. `None` turns off the special handling of mantissa `1`. The format string *minusnomantissaexp* is similar to *nomantissaexp*, but for mantissa `-1`.

The `tick.rational` instances *mantissamin*< *mantissamax* are minimum (including) and maximum (excluding) of the mantissa.

The boolean *skipmantissa1* enables the skipping of any mantissa equals `1` and `-1`, when *minusnomantissaexp* is set. When the boolean *skipallmantissa1* is set, a mantissa equals `1` is skipped only, when all mantissa values are `1`. Skipping of a mantissa is stronger than the skipping of an exponent.

mantissatexter is a texter instance for the mantissa.

class graph.axis.texter.**mixed**(*smallestdecimal=tick.rational((1, 1000))*, *biggestdecimal=tick.rational((9999, 1))*, *equaldecision=1*, *decimal=decimal()*, *exponential=exponential()*)

Instances of this class create decimal formatted labels with an exponential, when the unsigned values are small or large compared to *1*.

The rational instances *smallestdecimal* and *biggestdecimal* are the smallest and biggest decimal values, where the decimal texter should be used. The sign of the value is ignored here. For a tick at zero the decimal texter is considered best as well. *equaldecision* is a boolean to indicate whether the decision for the decimal or exponential texter should be done globally for all ticks.

decimal and *exponential* are a decimal and an exponential texter instance, respectively.

class graph.axis.texter.**rational**(*prefix=""*, *infix=""*, *suffix=""*, *numprefix=""*, *numinfix=""*, *numsuffix=""*, *denomprefix=""*, *denominfix=""*, *denomsuffix=""*, *plus=""*, *minus="-"*, *minuspos=0*, *over=r"%s\over%s"*, *equaldenom=0*, *skip1=1*, *skipnum0=1*, *skipnum1=1*, *skipdenom1=1*, *labelattrs=[text.mathmode]*)

Instances of this class create labels formated as fractions.

The strings *prefix*, *infix*, and *suffix* are added to the label at the beginning, immediately after the plus or minus, and at the end, respectively. The strings *numprefix*, *numinfix*, and *numsuffix* are added to the labels numerator accordingly whereas *denomprefix*, *denominfix*, and *denomsuffix* do the same for the denominator.

The strings *plus* and *minus* are inserted in front of the unsigned value. The position of the sign is defined by *minuspos* with values `1` (at the numerator), `0` (in front of the fraction), and `-1` (at the denominator).

The format string *over* should generate the fraction. It must contain two string insert operators `%s`, the first for the numerator and the second for the denominator. An alternative to the default is `"{{%s}/{%s}}"`.

Usually, the numerator and denominator are canceled, while, when *equaldenom* is set, the least common multiple of all denominators is used.

The boolean *skip1* indicates, that only the prefix, plus or minus, the infix and the suffix should be printed, when the value is `1` or `-1` and at least one of *prefix*, *infix* and *suffix* is present.

The boolean *skipnum0* indicates, that only a `0` is printed when the numerator is zero.

skipnum1 is like *skip1* but for the numerator.

skipdenom1 skips the denominator, when it is `1` taking into account *denomprefix*, *denominfix*, *denomsuffix minuspos* and the sign of the number.

labelattrs has the same meaning as for *decimal*.

10.6 Module `graph.axis.painter`: Axes painter

The following classes are part of the module *graph.axis.painter*. Instances of the painter classes can be passed to the painter keyword argument of regular axes.

class graph.axis.painter.**rotatetext**(*direction*, *epsilon=1e-10*)

This helper class is used in direction arguments of the painters below to prevent axis labels and titles being written upside down. In those cases the text will be rotated by 180 degrees. *direction* is an angle to be used relative to the tick direction. *epsilon* is the value by which 90 degrees can be exceeded before an 180 degree rotation is performed.

The following two class variables are initialized for the most common applications:

rotatetext.**parallel**
: `rotatetext(90)`

rotatetext.**orthogonal**
: `rotatetext(180)`

class graph.axis.painter.**ticklength**(*initial*, *factor*)

This helper class provides changeable PyX lengths starting from an initial value *initial* multiplied by *factor* again and again. The resulting lengths are thus a geometric series.

There are some class variables initialized with suitable values for tick stroking. They are named `ticklength.SHORT`, `ticklength.SHORt`, ..., `ticklength.short`, `ticklength.normal`, `ticklength.long`, ..., `ticklength.LONG`. `ticklength.normal` is initialized with a length of `0.12` and the reciprocal of the golden

mean as `factor` whereas the others have a modified initial value obtained by multiplication with or division by appropriate multiples of $\sqrt{2}$.

class graph.axis.painter.**regular**(*innerticklength=ticklength.normal*, *outerticklength=None*, *tickattrs=[]*, *gridattrs=None*, *basepathattrs=[]*, *labeldist="0.3 cm"*, *labelattrs=[]*, *labeldirection=None*, *labelhequalize=0*, *labelvequalize=1*, *titledist="0.3 cm"*, *titleattrs=[]*, *titledirection=rotatetext.parallel*, *titlepos=0.5*, *texrunner=None*)

Instances of this class are painters for regular axes like linear and logarithmic axes.

innerticklength and *outerticklength* are visual PyX lengths of the ticks, subticks, subsubticks *etc.* plotted along the axis inside and outside of the graph. Provide changeable attributes to modify the lengths of ticks compared to subticks *etc.* `None` turns off the ticks inside and outside the graph, respectively.

tickattrs and *gridattrs* are changeable stroke attributes for the ticks and the grid, where `None` turns off the feature. *basepathattrs* are stroke attributes for the axis or `None` to turn it off. *basepathattrs* is merged with `[style.linecap.square]`.

labeldist is the distance of the labels from the axis base path as a visual PyX length. *labelattrs* is a list of text attributes for the labels. It is merged with `[text.halign.center, text.vshift.mathaxis]`. *labeldirection* is an instance of *rotatetext* to rotate the labels relative to the axis tick direction or `None`.

The boolean values *labelhequalize* and *labelvequalize* force an equal alignment of all labels for straight vertical and horizontal axes, respectively.

titledist is the distance of the title from the rest of the axis as a visual PyX length. *titleattrs* is a list of text attributes for the title. It is merged with `[text.halign.center, text.vshift.mathaxis]`. *titledirection* is an instance of *rotatetext* to rotate the title relative to the axis tick direction or `None`. *titlepos* is the position of the title in graph coordinates.

texrunner is the texrunner instance to create axis text like the axis title or labels. When not set the texrunner of the graph instance is taken to create the text.

class graph.axis.painter.**linked**(*innerticklength=ticklength.short*, *outerticklength=None*, *tickattrs=[]*, *gridattrs=None*, *basepathattrs=[]*, *labeldist="0.3 cm"*, *labelattrs=None*, *labeldirection=None*, *labelhequalize=0*, *labelvequalize=1*, *titledist="0.3 cm"*, *titleattrs=None*, *titledirection=rotatetext.parallel*, *titlepos=0.5*, *texrunner=None*)

This class is identical to *regular* up to the default values of *labelattrs* and *titleattrs*. By turning off those features, this painter is suitable for linked axes.

class graph.axis.painter.**bar**(*innerticklength=None*, *outerticklength=None*, *tickattrs=[]*, *basepathattrs=[]*, *namedist="0.3 cm"*, *nameattrs=[]*, *namedirection=None*, *namepos=0.5*, *namehequalize=0*, *namevequalize=1*, *titledist="0.3 cm"*, *titleattrs=[]*, *titledirection=rotatetext.parallel*, *titlepos=0.5*, *texrunner=None*)

Instances of this class are suitable painters for bar axes.

innerticklength and *outerticklength* are visual PyX lengths to mark the different bar regions along the axis inside and outside of the graph. `None` turns off the ticks inside and outside the graph, respectively. *tickattrs* are stroke attributes for the ticks or `None` to turn all ticks off.

The parameters with prefix *name* are identical to their *label* counterparts in *regular*. All other parameters have the same meaning as in *regular*.

class graph.axis.painter.**linkedbar**(*innerticklength=None*, *outerticklength=None*, *tickattrs=[]*, *basepathattrs=[]*, *namedist="0.3 cm"*, *nameattrs=None*, *namedirection=None*, *namepos=0.5*, *namehequalize=0*, *namevequalize=1*, *titledist="0.3 cm"*, *titleattrs=None*, *titledirection=rotatetext.parallel*, *titlepos=0.5*, *texrunner=None*)

This class is identical to *bar* up to the default values of *nameattrs* and *titleattrs*. By turning off those features, this painter is suitable for linked bar axes.

class graph.axis.painter.**split**(*breaklinesdist="0.05 cm"*, *breaklineslength="0.5 cm"*, *breaklinesangle=-60*, *titledist="0.3 cm"*, *titleattrs=[]*, *titledirection=rotatetext.parallel*, *titlepos=0.5*, *texrunner=None*)

Instances of this class are suitable painters for split axes.

breaklinesdist and *breaklineslength* are the distance between axes break markers in visual PyX lengths. *breaklinesangle* is the angle of the axis break marker with respect to the base path of the axis. All other parameters have the same meaning as in *regular*.

class graph.axis.painter.**linkedsplit**(*breaklinesdist="0.05 cm"*, *breaklineslength="0.5 cm"*, *breaklinesangle=-60*, *titledist="0.3 cm"*, *titleattrs=None*, *titledirection=rotatetext.parallel*, *titlepos=0.5*, *texrunner=None*)

This class is identical to *split* up to the default value of *titleattrs*. By turning off this feature, this painter is suitable for linked split axes.

10.7 Module graph.axis.rater: Axes rater

The rating of axes is implemented in *graph.axis.rater*. When an axis partitioning scheme returns several partitioning possibilities, the partitions need to be rated by a positive number. The axis partitioning rated lowest is considered best.

The rating consists of two steps. The first takes into account only the number of ticks, subticks, labels and so on in comparison to optimal numbers. Additionally, the extension of the axis range by ticks and labels is taken into account. This rating leads to a preselection of possible partitions. In the second step, after the layout of preferred partitionings has been calculated, the distance of the labels in a partition is taken into account as well at a smaller weight factor by default. Thereby partitions with overlapping labels will be rejected completely. Exceptionally sparse or dense labels will receive a bad rating as well.

class graph.axis.rater.**cube**(*opt*, *left=None*, *right=None*, *weight=1*)

Instances of this class provide a number rater. *opt* is the optimal value. When not provided, *left* is set to `0` and *right* is set to `3*opt`. Weight is a multiplicator to the result.

The rater calculates `width*((x-opt)/(other-opt))**3` to rate the value `x`, where `other` is *left* (x``<*opt*) or *right* (``x>*opt*).

class graph.axis.rater.**distance**(*opt*, *weight=0.1*)

Instances of this class provide a rater for a list of numbers. The purpose is to rate the distance between label boxes. *opt* is the optimal value.

The rater calculates the sum of `weight*(opt/x-1)` (x``<*opt*) or ``weight*(x/opt-1)` (x>*opt*) for all elements `x` of the list. It returns this value divided by the number of elements in the list.

class graph.axis.rater.**rater**(*ticks*, *labels*, *range*, *distance*)

Instances of this class are raters for axes partitionings.

ticks and *labels* are both lists of number rater instances, where the first items are used for the number of ticks and labels, the second items are used for the number of subticks (including the ticks) and sublabels (including the labels) and so on until the end of the list is reached or no corresponding ticks are available.

range is a number rater instance which rates the range of the ticks relative to the range of the data.

distance is an distance rater instance.

class graph.axis.rater.**linear**(*ticks=[cube(4), cube(10, weight=0.5)], labels=[cube(4)], range=cube(1, weight=2), distance=distance("1 cm")*)
This class is suitable to rate partitionings of linear axes. It is equal to *rater* but defines predefined values for the arguments.

class graph.axis.rater.**lin**(...)
This class is an abbreviation of *linear* described above.

class graph.axis.rater.**logarithmic**(*ticks=[cube(5, right=20), cube(20, right=100, weight=0.5)], labels=[cube(5, right=20), cube(5, right=20, weight=0.5)], range=cube(1, weight=2), distance=distance("1 cm")*)
This class is suitable to rate partitionings of logarithmic axes. It is equal to *rater* but defines predefined values for the arguments.

class graph.axis.rater.**log**(...)
This class is an abbreviation of *logarithmic* described above.

10.8 Module graph.axis.positioner: Axes positioners

The position of an axis is defined by an instance of a class providing the following methods:

class graph.axis.positioners.**positioner**

positioner.**vbasepath**(*v1=None*, *v2=None*)
Returns a path instance for the base path. *v1* and *v2* define the axis range in graph coordinates the base path should cover.

positioner.**vgridpath**(*v*)
Returns a path instance for the grid path at position *v* in graph coordinates. The method might return `None` when no grid path is available (for an axis along a path for example).

positioner.**vtickpoint_pt**(*v*)
Returns the position of *v* in graph coordinates as a tuple `(x, y)` in points.

positioner.**vtickdirection**(*v*)
Returns the direction of a tick at *v* in graph coordinates as a tuple `(dx, dy)`. The tick direction points inside of the graph.

The module contains several implementations of those positioners, but since the positioner instances are created by graphs etc. as needed, the details are not interesting for the average PyX user.

CHAPTER

ELEVEN

MODULE BOX: CONVEX BOX HANDLING

This module has a quite internal character, but might still be useful from the users point of view. It might also get further enhanced to cover a broader range of standard arranging problems.

In the context of this module a box is a convex polygon having optionally a center coordinate, which plays an important role for the box alignment. The center might not at all be central, but it should be within the box. The convexity is necessary in order to keep the problems to be solved by this module quite a bit easier and unambiguous.

Directions (for the alignment etc.) are usually provided as pairs (dx, dy) within this module. It is required, that at least one of these two numbers is unequal to zero. No further assumptions are taken.

11.1 Polygon

A polygon is the most general case of a box. It is an instance of the class `polygon`. The constructor takes a list of points (which are (x, y) tuples) in the keyword argument `corners` and optionally another (x, y) tuple as the keyword argument `center`. The corners have to be ordered counterclockwise. In the following list some methods of this `polygon` class are explained:

`path(centerradius=None, bezierradius=None, beziersoftness=1):` returns a path of the box; the center might be marked by a small circle of radius `centerradius`; the corners might be rounded using the parameters `bezierradius` and `beziersoftness`. For each corner of the box there may be one value for beziersoftness and two bezierradii. For convenience, it is not necessary to specify the whole list (for beziersoftness) and the whole list of lists (bezierradius) here. You may give a single value and/or a 2-tuple instead.

`transform(*trafos):` performs a list of transformations to the box

`reltransform(*trafos):` performs a list of transformations to the box relative to the box center

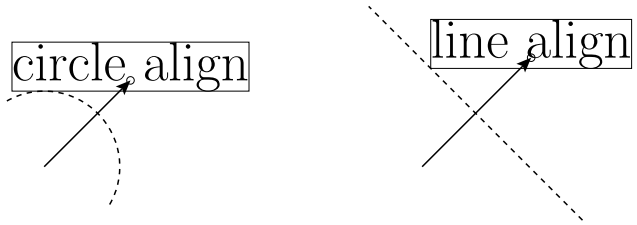


Fig. 1: circle and line alignment examples (equal direction and distance)

`circlealignvector(a, dx, dy):` returns a vector (a tuple (x, y)) to align the box at a circle with radius `a` in the direction (`dx`, `dy`); see figure *circle and line alignment examples (equal direction and distance)*

`linealignvector(a, dx, dy):` as above, but align at a line with distance `a`

circlealign(a, dx, dy): as circlealignvector, but perform the alignment instead of returning the vector

linealign(a, dx, dy): as linealignvector, but perform the alignment instead of returning the vector

extent(dx, dy): extent of the box in the direction (dx, dy)

pointdistance(x, y): distance of the point (x, y) to the box; the point must be outside of the box

boxdistance(other): distance of the box to the box other; when the boxes are overlapping, BoxCrossError is raised

bbox(): returns a bounding box instance appropriate to the box

11.2 Functions working on a box list

circlealignequal(boxes, a, dx, dy): Performs a circle alignment of the boxes boxes using the parameters a, dx, and dy as in the circlealign method. For the length of the alignment vector its largest value is taken for all cases.

linealignequal(boxes, a, dx, dy): as above, but performing a line alignment

tile(boxes, a, dx, dy): tiles the boxes boxes with a distance a between the boxes (in addition the maximal box extent in the given direction (dx, dy) is taken into account)

11.3 Rectangular boxes

For easier creation of rectangular boxes, the module provides the specialized class rect. Its constructor first takes four parameters, namely the x, y position and the box width and height. Additionally, for the definition of the position of the center, two keyword arguments are available. The parameter relcenter takes a tuple containing a relative x, y position of the center (they are relative to the box extent, thus values between 0 and 1 should be used). The parameter abscenter takes a tuple containing the x and y position of the center. This values are measured with respect to the lower left corner of the box. By default, the center of the rectangular box is set to this lower left corner.

CHAPTER

TWELVE

MODULE CONNECTOR

This module provides classes for connecting two `box`-instances with lines, arcs or curves. All constructors of the following connector-classes take two `box`-instances as the two first arguments. They return a connecting path from the first to the second box. The overall geometry of the path is such that is starts/ends at the boxes' centers. It is then cut by the boxes' outlines. The resulting `connector` will additionally be shortened by lengths given in the *boxdists* (a list of two lengths, default `[0,0]`).

Angle keywords can be either absolute or relative. The absolute angles refer to the angle between x-axis and the running tangent of the connector, while the relative angles are between the direct connecting line of the box-centers and the running tangent (see figure. *The angle-parameters of the connector.arc (left panel) and the connector.curve (right panel) classes.*).

The bulge-keywords parameterize the deviation of the connector from the connecting line. It has different meanings for different connectors (see figure. *The angle-parameters of the connector.arc (left panel) and the connector.curve (right panel) classes.*).

12.1 Class `line`

The constructor of the `line` class accepts only boxes and the *boxdists*.

12.2 Class `arc`

The constructor takes either the *relangle* or a combination of *relbulge* and *absbulge*. The "bulge" is meant to be a hint for the greatest distance between the connecting arc and the straight connection between the box-centers. (Default: `relangle=45`, `relbulge=None`, `absbulge=None`)

Note that the bulge-keywords override the angle-keyword.

If both *relbulge* and *absbulge* are given, they will be added.

12.3 Class `curve`

The constructor takes both angle- and bulge-keywords. Here, the bulges are used as distances between the control points of the cubic Beziér-curve. For the signs of the angle- and bulge-keywords refer to figure *The angle-parameters of the connector.arc (left panel) and the connector.curve (right panel) classes.*.

absangle1 or *relangle1* — *absangle2* or *relangle2*, where the absolute angle overrides the relative if both are given. (Default: `relangle1=45`, `relangle2=45`, `absangle1=None`, `absangle2=None`)

absbulge and *relbulge*, where they will be added if both are given. — (Default: `absbulge=None`, `relbulge=0.39`; these default values produce output similar to the defaults of `arc`.)

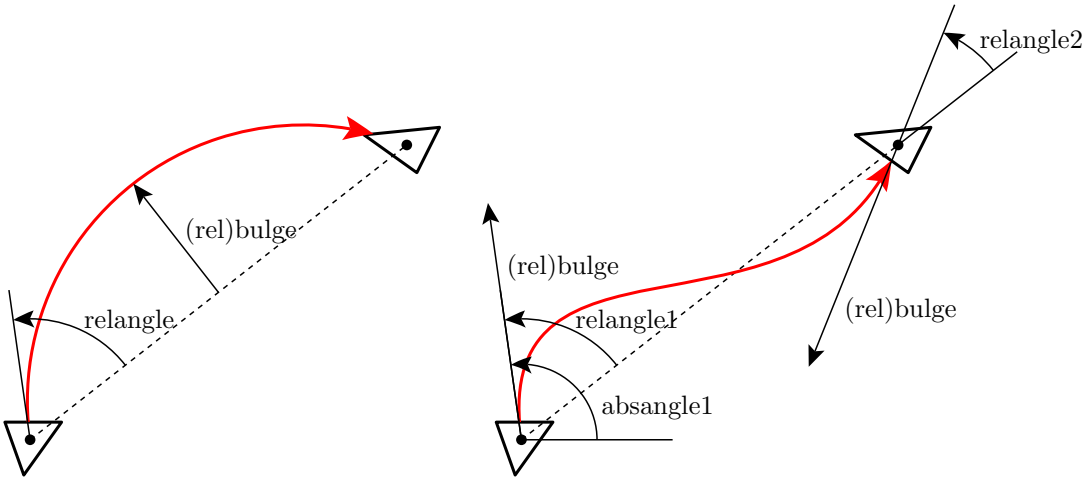


Fig. 1: The angle-parameters of the connector.arc (left panel) and the connector.curve (right panel) classes.

12.4 Class `twolines`

This class returns two connected straight lines. There is a vast variety of combinations for angle- and length-keywords. The user has to make sure to provide a non-ambiguous set of keywords:

absangle1 or *relangle1* for the first angle, — *relangleM* for the middle angle and — *absangle2* or *relangle2* for the ending angle. Again, the absolute angle overrides the relative if both are given. (Default: all five angles are `None`)

length1 and *length2* for the lengths of the connecting lines. (Default: `None`)

CHAPTER

THIRTEEN

MODULE `EPSFILE`: EPS FILE INCLUSION

With the help of the `epsfile.epsfile` class, you can easily embed another EPS file in your canvas, thereby scaling, aligning the content at discretion. The most simple example looks like

```
from pyx import *
c = canvas.canvas()
c.insert(epsfile.epsfile(0, 0, "file.eps"))
c.writeEPSfile("output")
```

All relevant parameters are passed to the `epsfile.epsfile` constructor. They are summarized in the following table:

argument name	description
`x`	x-coordinate of position.
`y`	y-coordinate of position.
`filename`	Name of the EPS file (including a possible extension).
`width=None`	Desired width of EPS graphics or `None` for original width. Cannot be combined with scale specification.
`height=None`	Desired height of EPS graphics or `None` for original height. Cannot be combined with scale specification.
`scale=None`	Scaling factor for EPS graphics or `None` for no scaling. Cannot be combined with width or height specification.
`align="bl"`	Alignment of EPS graphics. The first character specifies the vertical alignment: `b` for bottom, `c` for center, and `t` for top. The second character fixes the horizontal alignment: `l` for left, `c` for center `r` for right.
`clip=1`	Clip to bounding box of EPS file?
`translatebbox=1`	Use lower left corner of bounding box of EPS file? Set to 0 with care.
`bbox=None`	If given, use `bbox` instance instead of bounding box of EPS file.
`kpsearch=0`	Search for file using the kpathsea library.

CHAPTER

FOURTEEN

MODULE `SVGFILE`: SVG FILE INCLUSION

With the help of the `svgfile.svgfile` class, you can easily embed another SVG file in your canvas, thereby scaling, aligning the content at discretion. The most simple example looks like

```
from pyx import *
c = canvas.canvas()
c.insert(svgfile.svgfile(0, 0, "file.svg"))
c.writeSVGfile("output")
```

All relevant parameters are passed to the `svgfile.svgfile` constructor. They are summarized in the following table:

argument name	description
`x`	x-coordinate of position.
`y`	y-coordinate of position.
`filename`	Name of the SVG file.
`width=None`	Desired width of SVG graphics or `None` for original width.
`height=None`	Desired height of SVG graphics or `None` for original height.
`ratio=None`	For a given width or height set the other dimension with the given ratio. If `None` and either width or height is set, the other dimension is scaled proportionally, which is different from a ratio `1`.
`parsed=False`	Parsed mode flag, see below.
`resolution=96`	SVG resolution in "dpi", see below.

In parsed mode a filled PyX canvas containing the SVG data is created. At the moment the parser handles paths with styles, transformations, canvas nesting etc. but no other SVG constructs. While some features might be added in the future, the parsed mode will probably always have limitations, like not being able to take into account CSS styling and other things. On the other hand the parsed mode has some major advantages. You can access the paths as PyX paths within the canvas and you can output the parsed SVG data to PostScript and PDF.

Even though SVG is a vector format, inserting an SVG file depends on a resolution most of the time. This resolution defines the unit scale, when no unit like `pt`, `in`, `mm`, or `cm` is used. This user unit is meant to be pixels, thus viewer programs are adviced to use the screen resolution. Tools to SVG files often use 90 dpi as in the w3.org SVG Recommendation. However, note that Adobe (R) Illustrator (R) uses 72 dpi. In browsers 96 dpi is commonly used, which is thus set as the default. However, all this might vary between plattforms and configurations.

Note that the SVG output of PyX defines the its size using units. Still, when reading such a file in un-parsed mode PyX need to make assumtions on how the final viewer will insert (i.e. scale and position) the SVG file, thus needing a resolution. Only in parsed mode it becomes resolution independent.

Unfortunately it is rather uncommon to store the size of the SVG in coordinates with units. You then need to provide the correct resolution in both modes, parsed and unparsed, to get proper alignment.

CHAPTER

FIFTEEN

BITMAPS

15.1 Introduction

PyX focuses on the creation of scaleable vector graphics. However, PyX also allows for the output of bitmap images. Still, the support for creation and handling of bitmap images is quite limited. On the other hand the interfaces are built that way, that its trivial to combine PyX with the "Python Image Library", also known as "PIL".

The creation of a bitmap can be performed out of some unpacked binary data by first creating image instances:

```
from pyx import *
image_bw = bitmap.image(2, 2, "L", "\0\377\377\0")
image_rgb = bitmap.image(3, 2, "RGB", "\77\77\77\177\177\177\277\277\277"
                                      "\377\0\0\0\377\0\0\0\377")
```

Now `image_bw` is a 2×2 grayscale image. The bitmap data is provided by a string, which contains two black (`"\0" == chr(0)`) and two white (`"\377" == chr(255)`) pixels. Currently the values per (colour) channel is fixed to 8 bits. The coloured image `image_rgb` has 3×2 pixels containing a row of 3 different gray values and a row of the three colours red, green, and blue.

The images can then be wrapped into `bitmap` instances by:

```
bitmap_bw = bitmap.bitmap(0, 1, image_bw, height=0.8)
bitmap_rgb = bitmap.bitmap(0, 0, image_rgb, height=0.8)
```

When constructing a `bitmap` instance you have to specify a certain position by the first two arguments fixing the bitmaps lower left corner. Some optional arguments control further properties. Since in this example there is no information about the dpi-value of the images, we have to specify at least a `width` or a `height` of the bitmap.

The bitmaps are now to be inserted into a canvas:

```
c = canvas.canvas()
c.insert(bitmap_bw)
c.insert(bitmap_rgb)
c.writeEPSfile("bitmap")
```

Figure *An introductory bitmap example.* shows the resulting output.

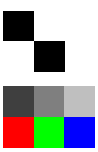


Fig. 1: An introductory bitmap example.

15.2 Bitmap `module`: Bitmap support

class bitmap.**image**(*width*, *height*, *mode*, *data*, *compressed=None*)

This class is a container for image data. *width* and *height* are the size of the image in pixel. *mode* is one of `"L"`, `" RGB"` or `"CMYK"` for grayscale, rgb, or cmyk colours, respectively. *data* is the bitmap data as a string, where each single character represents a colour value with ordinal range `0` to `255`. Each pixel is described by the appropriate number of colour components according to *mode*. The pixels are listed row by row one after the other starting at the upper left corner of the image.

compressed might be set to `" Flate"` or `"DCT"` to provide already compressed data. Note that those data will be passed to PostScript without further checks, *i.e.* this option is for experts only.

class bitmap.**jpegimage**(*file*)

This class is specialized to read data from a JPEG/JFIF-file. *file* is either an open file handle (it only has to provide a `read()` method; the file should be opened in binary mode) or a string. In the latter case *jpegimage* will try to open a file named like *file* for reading.

The contents of the file is checked for some JPEG/JFIF format markers in order to identify the size and dpi resolution of the image for further usage. These checks will typically fail for invalid data. The data are not uncompressed, but directly inserted into the output stream (for invalid data the result will be invalid PostScript). Thus there is no quality loss by recompressing the data as it would occur when recompressing the uncompressed stream with the lossy jpeg compression method.

class bitmap.**bitmap**(*xpos*, *ypos*, *image*, *width=None*, *height=None*, *ratio=None*, *storedata=0*, *maxstrlen=4093*, *compressmode="Flate"*, *flatecompresslevel=6*, *dctquality=75*, *dctoptimize=1*, *dctprogression=0*)

xpos and *ypos* are the position of the lower left corner of the image. This position might be modified by some additional transformations when inserting the bitmap into a canvas. *image* is an instance of *image* or *jpegimage* but it can also be an image instance from the "Python Image Library".

width, *height*, and *ratio* adjust the size of the image. At least *width* or *height* needs to be given, when no dpi information is available from *image*.

storedata is a flag indicating, that the (still compressed) image data should be put into the printers memory instead of writing it as a stream into the PostScript file. While this feature consumes memory of the PostScript interpreter, it allows for multiple usage of the image without including the image data several times in the PostScript file.

maxstrlen defines a maximal string length when *storedata* is enabled. Since the data must be kept in the PostScript interpreters memory, it is stored in strings. While most interpreters do not allow for an arbitrary string length (a common limit is 65535 characters), a limit for the string length is set. When more data need to be stored, a list of strings will be used. Note that lists are also subject to some implementation limits. Since a typical value is 65535 entries, in combination a huge amount of memory can be used.

Valid values for *compressmode* currently are `"Flate"` (zlib compression), `"DCT"` (jpeg compression), or `None` (disabling the compression). The zlib compression makes use of the zlib module as it is part of the standard Python distribution. The jpeg compression is available for those *image* instances only, which support the creation of a jpeg-compressed stream, *e.g.* images from the "Python Image Library" with jpeg support installed. The compression must be disabled when the image data is already compressed.

flatecompresslevel is a parameter of the zlib compression. *dctquality*, *dctoptimize*, and *dctprogression* are parameters of the jpeg compression. Note, that the progression feature of the jpeg compression should be turned off in order to produce valid PostScript. Also the optimization feature is known to produce errors on certain printers.

CHAPTER

SIXTEEN

MODULE BBOX

The bbox` module contains the definition of the *bbox* class representing bounding boxes of graphical elements like paths, canvases, etc. used in PyX. Usually, you obtain bbox instances as return values of the corresponding bbox() method, but you may also construct a bounding box by yourself.

16.1 bbox constructor

The bbox constructor accepts the following keyword arguments

keyword	description
llx	None (default) for $-\infty$ or x-position of the lower left corner of the bbox (in user units)
lly	None (default) for $-\infty$ or y-position of the lower left corner of the bbox (in user units)
urx	None (default) for ∞ or x-position of the upper right corner of the bbox (in user units)
ury	None (default) for ∞ or y-position of the upper right corner of the bbox (in user units)

16.2 bbox methods

bbox method	function
intersects(other)	returns 1 if the bbox instance and other intersect with each other.
transformed(self, trafo)	returns self transformed by transformation trafo.
enlarged(all=0, bottom=None, left=None, top=None, right=None)	return the bounding box enlarged by the given amount (in visual units). all is the default for all other directions, which is used whenever None is given for the corresponding direction.
path() or rect()	return the path corresponding to the bounding box rectangle.
height()	returns the height of the bounding box (in PyX lengths).
width()	returns the width of the bounding box (in PyX lengths).
top()	returns the y-position of the top of the bounding box (in PyX lengths).
bottom()	returns the y-position of the bottom of the bounding box (in PyX lengths).
left()	returns the x-position of the left side of the bounding box (in PyX lengths).
right()	returns the x-position of the right side of the bounding box (in PyX lengths).

Furthermore, two bounding boxes can be added (giving the bounding box enclosing both) and multiplied (giving the intersection of both bounding boxes).

CHAPTER

SEVENTEEN

MODULE color

17.1 Color models

PostScript provides different color models. They are available to PyX by different color classes, which just pass the colors down to the PostScript level. This implies, that there are no conversion routines between different color models available. However, some color model conversion routines are included in Python's standard library in the module `colorsym`. Furthermore also the comparison of colors within a color model is not supported, but might be added in future versions at least for checking color identity and for ordering gray colors.

There is a class for each of the supported color models, namely `gray`, `rgb`, `cmyk`, and `hsb`. The constructors take variables appropriate for the color model. Additionally, a list of named colors is given in appendix *Appendix: Named colors*.

17.2 Example

```
from pyx import *

c = canvas.canvas()

c.fill(path.rect(0, 0, 7, 3), [color.gray(0.8)])
c.fill(path.rect(1, 1, 1, 1), [color.rgb.red])
c.fill(path.rect(3, 1, 1, 1), [color.rgb.green])
c.fill(path.rect(5, 1, 1, 1), [color.rgb.blue])

c.writeEPSfile("color")
```

The file `color.eps` is created and looks like:

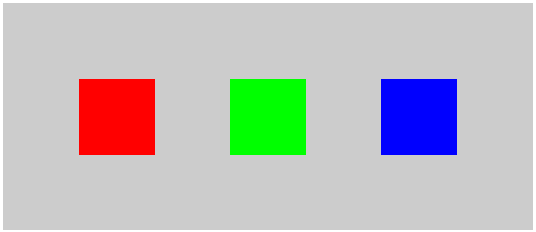


Fig. 1: Color example

17.3 Color gradients

The color module provides a class `gradient` for continous transitions between colors. A list of named gradients is available in appendix *Appendix: Named gradients*.

Note that all predefined non-gray gradients are defined in the RGB color space, except for *gradient.Rainbow*, *gradient.ReverseRainbow*, *gradient.Hue*, and *gradient.ReverseHue*, which are naturally defined in the HSB color space. Converted RGB and CMYK versions of these latter gradients are also defined under the names *rgbgradient.Rainbow* and *cmykgradient.Rainbow*, etc.

class color.**gradient**
This class defines the methods for the `gradient`.

getcolor(*parameter*)
Returns the color that corresponds to *parameter* (must be between *min* and *max*).

select(*index*, *n_indices*)
When a total number of *n_indices* different colors is needed from the gradient, this method returns the *index*-th color.

class color.**functiongradient_cmyk**(*f_c*, *f_m*, *f_y*, *f_k*)

class color.**functiongradient_gray**(*f_gray*)

class color.**functiongradient_hsb**(*f_g*, *f_s*, *f_b*)

class color.**functiongradient_rgb**(*f_r*, *f_g*, *f_b*)
This class provides an arbitray transition between colors of the same color model.

The functions *f_c*, etc. map the values [0, 1] to the respective components of the color model.

color.**lineargradient_cmyk**(*mincolor*, *maxcolor*)

color.**lineargradient_gray**(*mincolor*, *maxcolor*)

color.**lineargradient_hsb**(*mincolor*, *maxcolor*)

color.**lineargradient_rgb**(*mincolor*, *maxcolor*)
These factory functors for the corresponding *functiongradient_* classes provide a linear transition between two given instances of the same color class. The linear interpolation is performed on the color components of the specific color model.

mincolor and *maxcolor* must be colors of the corresponding color class.

class rgbgradient(gradient)
This class takes an arbitrary gradient and converts it into one in the RGB color model. This is useful for instance in bitmap output, where only certain color models are supported in Postscript/PDF.

class cmykgradient(gradient)
This class takes an arbitrary gradient and converts it into one in the CMYK color mode. This is useful for instance in bitmap output, where only certain color models are supported in Postscript/PDF.

17.4 Transparency

class color.**transparency**(*value*)
Instances of this class will make drawing operations (stroking, filling) to become partially transparent. *value* defines the transparency factor in the range `0` (opaque) to `1` (transparent).

Transparency is available in PDF output only since it is not supported by PostScript. However, for certain ghostscript devices (for example the pdf backend as used by ps2pdf) proprietary PostScript extension allows for

transparency in PostScript code too. PyX creates such PostScript proprietary code, but issues a warning when doing so.

CHAPTER

EIGHTEEN

MODULE pattern

This module contains the pattern.pattern class, whichs allows the definition of PostScript Tiling patterns (cf. Sect. 4.9 of the PostScript Language Reference Manual) which may then be used to fill paths. In addition, a number of predefined hatch patterns are included.

18.1 Class pattern

The classes pattern.pattern and *canvas.canvas* differ only in their constructor and in the absence of a writeEPSfile() method in the former. The *pattern* constructor accepts the following keyword arguments:

keyword	description
painttype	1 (default) for coloured patterns or 2 for uncoloured patterns
tilingtype	1 (default) for constant spacing tilings (patterns are spaced constantly by a multiple of a device pixel), 2 for undistorted pattern cell, whereby the spacing may vary by as much as one device pixel, or 3 for constant spacing and faster tiling which behaves as tiling type 1 but with additional distortion allowed to permit a more efficient implementation.
xstep	desired horizontal spacing between pattern cells, use None (default) for automatic calculation from pattern bounding box.
ystep	desired vertical spacing between pattern cells, use None (default) for automatic calculation from pattern bounding box.
bbox	bounding box of pattern. Use None for an automatic determination of the bounding box (including an enlargement by bboxenlarge pts on each side.)
trafo	additional transformation applied to pattern or None (default). This may be used to rotate the pattern or to shift its phase (by a translation).
bboxenlarge	enlargement when using the automatic bounding box determination; default is 5 pts.

After you have created a pattern instance, you define the pattern shape by drawing in it like in an ordinary canvas. To use the pattern, you simply pass the pattern instance to a stroke(), fill(), draw() or set() method of the canvas, just like you would do with a colour, etc.

CHAPTER

NINETEEN

MODULE unit

With the unit module PyX makes available classes and functions for the specification and manipulation of lengths. As usual, lengths consist of a number together with a measurement unit, e.g., 1 cm, 50 points, 0.42 inch. In addition, lengths in PyX are composed of the five types "true", "user", "visual", "width", and "TeX", e.g., 1 user cm, 50 true points, 0.42 visual + 0.2 width inch. As their names indicate, they serve different purposes. True lengths are not scalable and are mainly used for return values of PyX functions. The other length types can be rescaled by the user and differ with respect to the type of object they are applied to:

user length: used for lengths of graphical objects like positions etc.

visual length: used for sizes of visual elements, like arrows, graph symbols, axis ticks, etc.

width length: used for line widths

TeX length: used for all TeX and LaTeX output

When not specified otherwise, all types of lengths are interpreted in terms of a default unit, which, by default, is 1 cm. You may change this default unit by using the module level function

unit.**set**(*uscale=None*, *vscale=None*, *wscale=None*, *xscale=None*, *defaultunit=None*)
When *uscale*, *vscale*, *wscale*, or *xscale* is not *None*, the corresponding scaling factor(s) is redefined to the given number. When *defaultunit* is not *None*, the default unit is set to the given value, which has to be one of "cm", "mm", "inch", or "pt".

For instance, if you only want thicker lines for a publication version of your figure, you can just rescale all width lengths using

```
unit.set(wscale=2)
```

Or suppose, you are used to specify length in imperial units. In this, admittedly rather unfortunate case, just use

```
unit.set(defaultunit="inch")
```

at the beginning of your program.

19.1 Class length

class unit.**length**(*f*, *type="u"*, *unit=None*)
The constructor of the *length* class expects as its first argument a number *f*, which represents the prefactor of the given length. By default this length is interpreted as a user length (type="u") in units of the current default unit (see *set()* function of the *unit* module). Optionally, a different *type* may be specified, namely "u" for user lengths, "v" for visual lengths, "w" for width lengths, "x" for TeX length, and "t" for true lengths. Furthermore, a different unit may be specified using the *unit* argument. Allowed values are "cm", "mm", "inch", and "pt".

Instances of the *length* class support addition and substraction either by another *length* or by a number which is then interpeted as being a user length in default units, multiplication by a number and division either by another *length* in which case a float is returned or by a number in which case a *length* instance is returned. When two lengths are compared, they are first converted to meters (using the currently set scaling), and then the resulting values are compared.

19.2 Predefined length instances

A number of `length` instances are already predefined, which only differ in there values for `type` and `unit`. They are summarized in the following table

name	type	unit
`m`	user	m
`cm`	user	cm
`mm`	user	mm
`inch`	user	inch
`pt`	user	points
`t_m`	true	m
`t_cm`	true	cm
`t_mm`	true	mm
`t_inch`	true	inch
`t_pt`	true	points
`u_m`	user	m
`u_cm`	user	cm
`u_mm`	user	mm
`u_inch`	user	inch
`u_pt`	user	points
`v_m`	visual	m
`v_cm`	visual	cm
`v_mm`	visual	mm
`v_inch`	visual	inch
`v_pt`	visual	points
`w_m`	width	m
`w_cm`	width	cm
`w_mm`	width	mm
`w_inch`	width	inch
`w_pt`	width	points
`x_m`	TeX	m
`x_cm`	TeX	cm
`x_mm`	TeX	mm
`x_inch`	TeX	inch
`x_pt`	TeX	points

Thus, in order to specify, e.g., a length of 5 width points, just use `5*unit.w_pt`.

19.3 Conversion functions

If you want to know the value of a PyX length in certain units, you may use the predefined conversion functions which are given in the following table

function	result
`tom(l)`	`l` in units of m
`tocm(l)`	`l` in units of cm
`tomm(l)`	`l` in units of mm
`toinch(l)`	`l` in units of inch
`topt(l)`	`l` in units of points

If `l` is not yet a `length` instance but a number, it first is interpreted as a user length in the default units.

CHAPTER

TWENTY

MODULE `trafo`: LINEAR TRANSFORMATIONS

With the `trafo` module PyX supports linear transformations, which can then be applied to canvases, Bézier paths and other objects. It consists of the main class `trafo` representing a general linear transformation and subclasses thereof, which provide special operations like translation, rotation, scaling, and mirroring.

20.1 Class `trafo`

The `trafo` class represents a general linear transformation, which is defined for a vector $\vec{x}$ as

$$\vec{x}' = \mathsf{A}\,\vec{x} + \vec{b}\,,$$

where A is the transformation matrix and $\vec{b}$ the translation vector. The transformation matrix must not be singular, *i.e.* we require $\det \mathsf{A} \neq 0$.

Multiple `trafo` instances can be multiplied, corresponding to a consecutive application of the respective transformation. Note that `trafo1*trafo2` means that `trafo1` is applied after `trafo2`, *i.e.* the new transformation is given by $\mathsf{A} = \mathsf{A}_1\mathsf{A}_2$ and $\vec{b} = \mathsf{A}_1\vec{b}_2 + \vec{b}_1$. Use the `trafo` methods described below, if you prefer thinking the other way round. The inverse of a transformation can be obtained via the `trafo` method `inverse()`, defined by the inverse A^{-1} of the transformation matrix and the translation vector $-\mathsf{A}^{-1}\vec{b}$.

class `trafo.`**trafo**(*matrix=((1, 0), (0, 1))*, *vector=(0, 0)*)
create new `trafo` instance with transformation `matrix` and `vector`

`trafo.`**apply**(*x*, *y*)
apply `trafo` to point vector $(\mathtt{x}, \mathtt{y})$.

`trafo.`**inverse**()
returns inverse transformation of `trafo`.

`trafo.`**mirrored**(*angle*)
returns `trafo` followed by mirroring at line through $(0, 0)$ with direction `angle` in degrees.

`trafo.`**rotated**(*angle*, *x=None*, *y=None*)
returns `trafo` followed by rotation by `angle` degrees around point $(\mathtt{x}, \mathtt{y})$, or $(0, 0)$, if not given.

`trafo.`**scaled**(*sx*, *sy=None*, *x=None*, *y=None*)
returns `trafo` followed by scaling with scaling factor `sx` in x-direction, `sy` in y-direction ($\mathtt{sy} = \mathtt{sx}$, if not given) with scaling center $(\mathtt{x}, \mathtt{y})$, or $(0, 0)$, if not given.

`trafo.`**slanted**(*a*, *angle=0*, *x=None*, *y=None*)
returns `trafo` followed by slant by `angle` around point $(\mathtt{x}, \mathtt{y})$, or $(0, 0)$, if not given.

`trafo.`**translated**(*x*, *y*)
returns `trafo` followed by translation by vector $(\mathtt{x}, \mathtt{y})$.

20.2 Subclasses of `trafo`

The `trafo` module provides a number of subclasses of the `trafo` class, each of which corresponds to one `trafo` method.

class `trafo.`**mirror**(*angle*)
mirroring at line through $(0, 0)$ with direction `angle` in degrees.

class `trafo.`**rotate**(*angle*, *x=None*, *y=None*)
rotation by `angle` degrees around point $(\mathtt{x}, \mathtt{y})$, or $(0, 0)$, if not given.

class `trafo.`**scale**(*sx*, *sy=None*, *x=None*, *y=None*)
scaling with scaling factor `sx` in x-direction, `sy` in y-direction ($\mathtt{sy} = \mathtt{sx}$, if not given) with scaling center $(\mathtt{x}, \mathtt{y})$, or $(0, 0)$, if not given.

class `trafo.`**slant**(*a*, *angle=0*, *x=None*, *y=None*)
slant by `angle` around point $(\mathtt{x}, \mathtt{y})$, or $(0, 0)$, if not given.

class `trafo.`**translate**(*x*, *y*)
translation by vector $(\mathtt{x}, \mathtt{y})$.

CHAPTER

TWENTYONE

APPENDIX: NAMED COLORS



Fig. 1: Names colors

CHAPTER

TWENTYTWO

APPENDIX: NAMED GRADIENTS

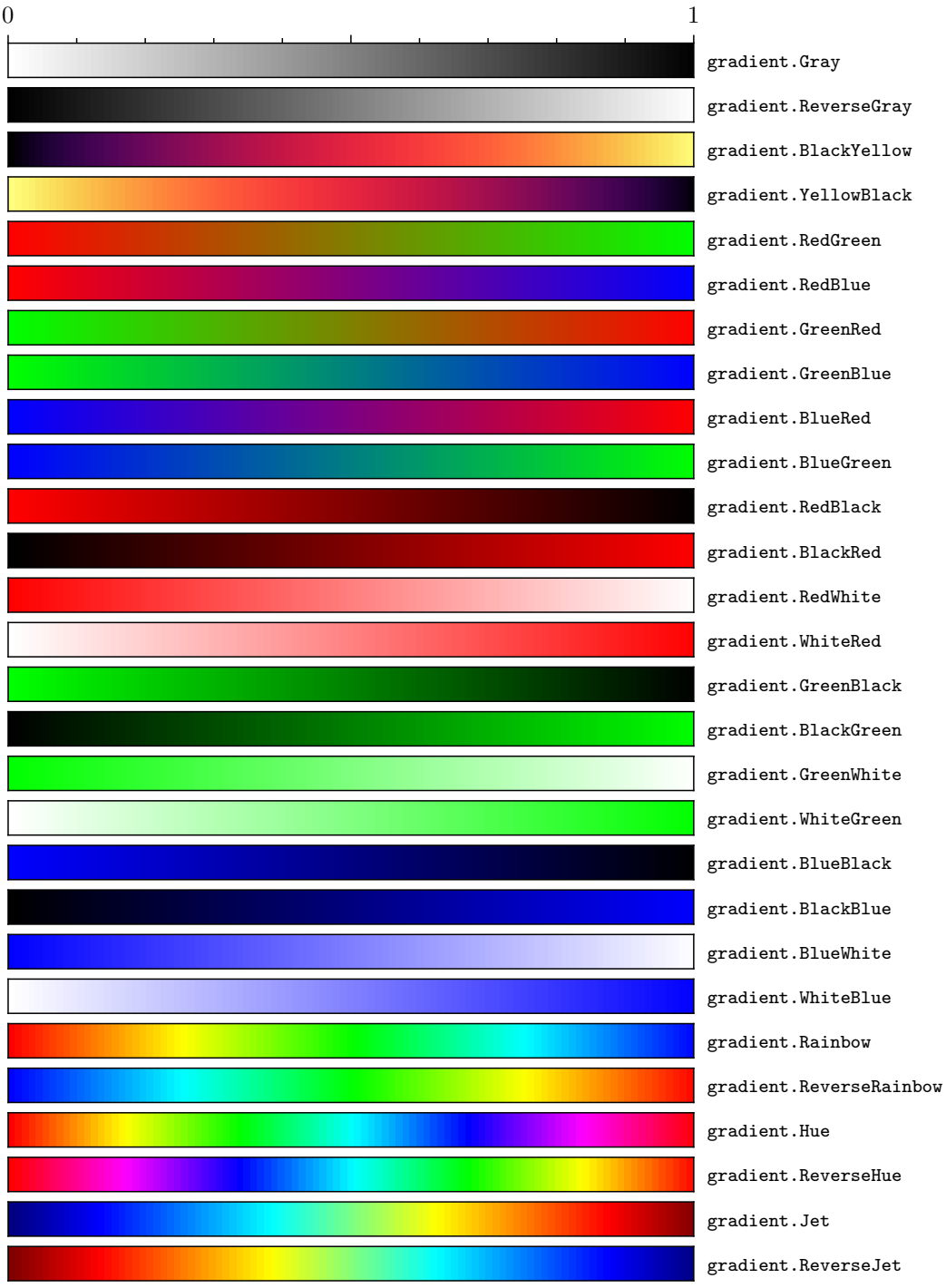


Fig. 1: Named gradients

CHAPTER

TWENTYTHREE

APPENDIX: PATH STYLES

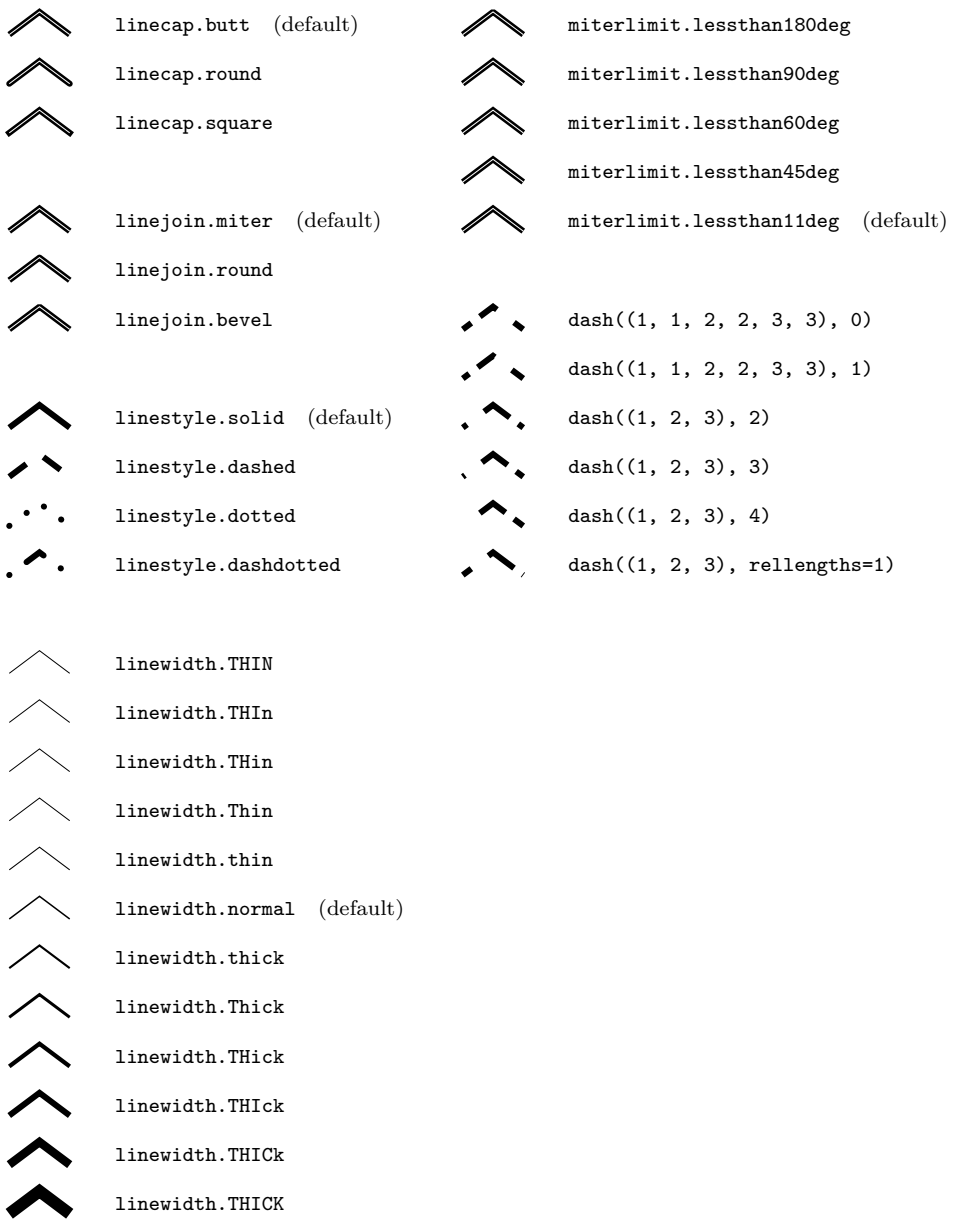


Fig. 1: path styles

CHAPTER

TWENTYFOUR

APPENDIX: ARROWS IN DECO MODULE

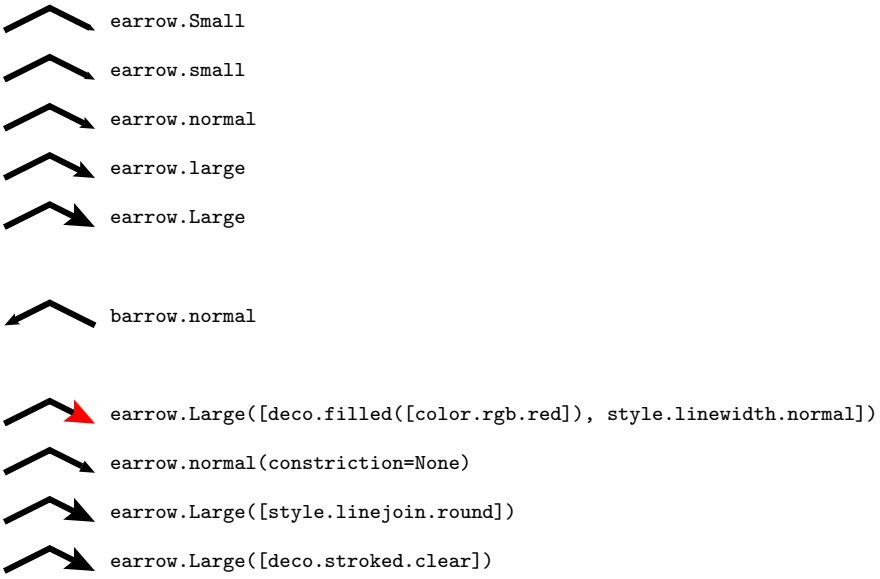


Fig. 1: Arrows in deco module

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