The spath3 Package: Documentation

Andrew Stacey
loopspace@mathforge.org

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1 Introduction

The `spath3` package was originally designed as a low-level package for manipulating the *soft paths* defined by PGF/TikZ. Soft paths form one stage of the stack of translations between what the author writes in the `tikzpicture` environments in their LaTeX document and what is eventually written to the output file. Most of the complicated processing has been done by the time a soft path is constructed, but it is still very definitely a TeX object and there has not, for example, been any consideration as to what the eventual output file format is (such as PDF, DVI, or SVG). So it is very amenable to being modified at this stage and this package provides a set of routines for doing so.

The original purpose was to provide a common core on which other packages would be built. Indeed, the packages `calligraphy`, `knots`, and `penrose` all use this package. However, over time I've found myself wanting to use the routines of this package at a higher level and so have designed some user-level interfaces. This document documents those.

To clarify some terminology used in this document (and more generally, this package), I regard paths as being composed of *segments* and *components*. A *segment* is a minimal drawing piece. Thus it might be a straight line or a Bézier curve. A *component* is a minimal connected section of the path. So every component starts with a move command and continues until the next move command. For ease of implementation (and to enable a copperplate pen in the calligraphy package!), an isolated move is considered as a component.

There are no doubt bugs in this package, and useful things that I haven't implemented. If you have found one of either of these, please let me know! The best way is to open an issue at the code repository on github, at https://github.com/loopspace/spath3.

2 TikZ Keys

```
\usetikzlibrary{spath3}
```

The `spath3` TikZ library defines a set of keys that can be issued to muck about with soft paths. These are all defined in the `spath` family, so all the following keys should be prefixed by `spath/`, or the key `spath/.cd` needs to be used beforehand (but note that as yet I haven't implemented sending unknown keys back to the main `tikz` directory).

The keys try to gracefully fail if the path doesn't exist or is empty. The intention is that the document should still compile with a warning in the log file (and on the console output). If this doesn't happen, please report it.

2.1 Saving and Using Soft Paths

`save` `save=⟨name⟩`
`save␣global` `save global=⟨name⟩`

Saves the current path with name ⟨*name*⟩. This delays until the path is fully constructed so can be issued in the options to the main command.

Soft paths constructed this way are local to the group in which the path command is issued. The `global` version saves the path globally which is useful when the original path is inside a scope or even another tikzpicture.

The soft path is actually stored in a macro constructed from the name. There are a couple of reasons for using a *name* rather than a macro directly. One is so that it is compatible with the `intersections` library – by default both this package and that save their paths in the same underlying macro. The other is to provide a way to link a soft path with a set of TikZ styles (this is particularly useful when splitting the path into components).

`clone` `clone={⟨target⟩}{⟨source⟩}`
`clone␣globally` `clone globally={⟨target⟩}{⟨source⟩}`

Clones one soft path into another. In the second, the clone is global (the original need not be).

`restore` `restore=⟨name⟩`
`restore␣reverse` `restore reverse=⟨name⟩`

Restores a previously saved soft path to the current path. The `reverse` version reverses the soft path first. This happens immediately so can be issued in the options to the main command and then the path can be extended with normal drawing commands. Any keys that affect the soft path directly should be applied *before* this one.

One thing should be noted about transformations. By the time a soft path is built, all available transformations have been applied. This means that when re-inserting a soft path back into a high level command (such as `\draw`), the effect of existing transformations might produce some confusing effects. When restoring a path then the library tries to set up various internals of TikZ correctly, but there may be some things I've overlooked or not accounted for particularly with regard to existing transformations; if you spot anything working oddly then please report it to me.

Restoring a path also sets things right for positioning nodes along the path. Using the `pos=D` key on a node positions that node at a particular point on the path. Exactly how the parameter is interpreted is the same as for the `spath` coordinate system described in Section 2.8.

append	append=⟨*name*⟩
append␣reverse	append reverse=⟨*name*⟩
append␣no␣move	append no move=⟨*name*⟩
append␣reverse␣no␣move	append reverse no move=⟨*name*⟩

This inserts a soft path, or its reverse, into the path at the current point, it is therefore more suited to being used part way through a path construction. In a sense, it is a little like a `pic` in that it enables the user to construct a path segment early to be reused at various places.

The path is *welded* on to the current path, meaning that the intervening `move` is removed. This is particularly useful for creating filled regions. The first two versions translate the path so that it starts at the last point on the existing path, the second two versions don't do this translation (the intention being that in such a case the translation is omitted because it is *unnecessary* rather than simply not wanted because the effect of removing the intervening move will adjust the initial segment of the appended path otherwise).

As with restoring a path, the last point and node positioning machinery is established. The positioning is relative to the appended part of the path, not the full path.

insert	insert=⟨*name*⟩
insert␣reverse	insert reverse=⟨*name*⟩

Like `append` except that it doesn't remove the intervening `move` and doesn't translate the inserted path. The `reverse` version reverses the path first.

to	to={⟨*name*⟩}

This defines a `to` path from a soft path, so it inserts the soft path into the current path to span the gap between the start and end. The path is transformed by rotation, translation, and uniform scaling so that it exactly spans the gap required by the `to` syntax. (If the start and end point of the soft path are very close together then it won't span the gap.)

2.2 Transformation Routines

The following keys all apply some sort of transformation to the soft path. They do not render the path, but simply adjust it. The global versions apply their transformation globally, otherwise it is local to the current group (or scope).

reverse	reverse=⟨*name*⟩
reverse␣global	reverse globally=⟨*name*⟩

Reverses the soft path in place. If you want to use the original path and its reversal in the same path (for example, for constructing a region to fill) then use the `clone` key to copy it first.

translate	translate={⟨*name*⟩}{⟨*x-dimen*⟩}{⟨*y-dimen*⟩}
translate␣global	translate globally={⟨*name*⟩}{⟨*x-dimen*⟩}{⟨*y-dimen*⟩}

Translates the soft path by the given dimensions.

transform	transform={⟨*name*⟩}{⟨*transformations*⟩}
transform␣global	transform globally={⟨*name*⟩}{⟨*transformations*⟩}

This applies the transformation to the soft path. The transformation is processed by TikZ so should consist of TikZ-level transformations such as `shift={(2,2)}`.

span	span={⟨*name*⟩}{⟨*start point*⟩}{⟨*end point*⟩}
span␣global	span globally={⟨*name*⟩}{⟨*start point*⟩}{⟨*end point*⟩}

This transforms the named path so that it goes from the start point to the end point. As with the `to` path construction and the `splice` method, this won't work if the path ends very close to where it starts.

splice	splice={⟨*initial path*⟩}{⟨*splice path*⟩}{⟨*final path*⟩}
splice␣global	splice globally={⟨*initial path*⟩}{⟨*splice path*⟩}{⟨*final path*⟩}

This splices the middle path into the gap between the initial and final paths. The middle path is transformed to fit (don't try this with a path whose starting and ending points are close together) and the paths are joined so that the last component of the initial path and the first component of the splice path become a single component, and similarly at the other end.

join␣components␣with	join components with={⟨*path*⟩}{⟨*splice path*⟩}
join␣components␣globally␣with	join components globally with={⟨*path*⟩}{⟨*splice path*⟩}

This inserts the `splice path` in the gaps between components of `path`. A *spot weld* is performed first to join any components where the end of one is the start of the next. The result is a single component path. This does *not* close the resulting path, for that see the key `close with`.

close	close={⟨*path*⟩}
close␣globally	close globally={⟨*path*⟩}
close␣with	close with={⟨*path*⟩}{⟨*splice path*⟩}
close␣globally␣with	close globally with={⟨*path*⟩}{⟨*splice path*⟩}

These all close the last component of the given path. The first two will insert a line segment if the initial and final points of the component are not sufficiently close. The latter two allow you to specify another path to insert.

2.3 Intersection Routines

To use these features you need to use the `intersections` library. Note that there is currently an issue with the intersections routine when trying to intersect two parallel (or near parallel) lines. One workaround is to replace one of the lines by a Bézier curve along the same path. The best such replacement is to put the control points at one third and two thirds between the start and end.

split␣at␣self␣intersections	split at self intersections=⟨*path*⟩
split␣globally␣at␣self␣intersections	split globally at self intersections=⟨*path*⟩

This inserts breaks into the named soft path at the points where it intersects itself. The breaks are not gaps, to achieve that use the shortening routines after this, rather they are a change of component. Think of it as if you took the pen off the page at that point and then put it straight back down again.

split␣at␣intersections␣with — split at intersections with={⟨first⟩}{⟨second⟩}
split␣globally␣at␣intersections␣with — split globally at intersections with={⟨first⟩}{⟨second⟩}

This inserts breaks into the first path where it intersects with the second. The second path is not changed.

split␣at␣intersections — split at intersections={⟨first⟩}{⟨second⟩}
split␣globally␣at␣intersections — split globally at intersections={⟨first⟩}{⟨second⟩}

This inserts breaks into a pair of paths at their mutual intersections.

2.4 Working with Components

get␣components␣of — get components of={⟨path⟩}{⟨macro⟩}
get␣components␣of␣globally — get components of globally={⟨path⟩}{⟨macro⟩}
\getComponentOf — \getComponentOf{⟨macro⟩}{⟨number⟩}

This splits the path into a list of its components, which are stored in the macro. The macro can be used in a \foreach.

The macro consists of a comma separated list of names of the components (the actual names used are of the form anonymous_N). To access an individual component, use the command \getComponentOf. This can be used directly in place of a path name in any other key, such as restore, (it is just the LaTeX3 command \clist_item:Nn).

Note that these are *copies* of the components of the original path. Changing a component doesn't update the original path.

render␣components — render components=⟨path⟩

This renders the components of a given path as separate TikZ commands, so that each can be separately styled. It applies the following styles (in this order):

1. every spath component
2. spath component ⟨number⟩
3. spath component=⟨number⟩
4. every ⟨path⟩ component
5. ⟨path⟩ component ⟨number⟩
6. ⟨path⟩ component=⟨number⟩

insert␣gaps␣after␣components — insert gaps after components={⟨path⟩}{⟨gap⟩}{⟨components⟩}
insert␣gaps␣globally␣after␣components — insert gaps globally after components={⟨path⟩}{⟨gap⟩}{⟨components⟩}

This inserts a gap between components of a path by shortening the end of the specified component and start of the next one. The list of components is passed through a \foreach loop so that syntax like 2,4,...,16 can be used.

join␣components	join components={⟨*path*⟩}{⟨*components*⟩}
join␣components␣globally	join components globally={⟨*path*⟩}{⟨*components*⟩}

This removes the `move` between each of the given components and the previous one. The list of components is processed by `\foreach`. If the component is the first one then it is joined to the last component.

spot␣weld	spot weld=⟨*path*⟩
spot␣weld␣globally	spot weld globally=⟨*path*⟩

This removes the `move` between any two components of the path where the end point of one component is the same as the initial point of the next (the tolerance on error here is 0.01pt).

remove␣empty␣components	remove empty components=⟨*path*⟩
remove␣empty␣components␣globally	remove empty components globally=⟨*path*⟩

This removes empty components of the path (which consist of simply a move).

remove␣components	remove components={⟨*path*⟩}{⟨*list*⟩}
remove␣components␣globally	remove components globally={⟨*path*⟩}{⟨*list*⟩}

This removes the listed components of the path. As with other list routines, the list is parsed via `foreach` first.

2.5 Shortening Paths

shorten␣at␣end	shorten at start={⟨*path*⟩}{⟨*length*⟩}
shorten␣at␣start	shorten at end={⟨*path*⟩}{⟨*length*⟩}
shorten␣at␣both␣ends	shorten at both ends={⟨*path*⟩}{⟨*length*⟩}
shorten␣globally␣at␣end	shorten globally at start={⟨*path*⟩}{⟨*length*⟩}
shorten␣globally␣at␣start	shorten globally at end={⟨*path*⟩}{⟨*length*⟩}
shorten␣globally␣at␣both␣ends	shorten globally at both ends={⟨*path*⟩}{⟨*length*⟩}

This shortens a path by the given amount from the specified end. The shortening is done so that it guarantees that it lies along the original path, but therefore the length is not completely guaranteed to be accurate. This is particularly true for Bézier paths and if there is a very short segment at the end.

It uses the derivative at the end to work out how much to shorten by. If wanting to shorten by a large amount it is better to shorten by a small amount a number of times.

2.6 Exporting Paths

There are two keys to export a path.

save␣to␣aux	save to aux=⟨*path*⟩

This will save the path to the auxfile so that it is available again on the next run through.

export␣to␣svg	export to svg=⟨*path*⟩

Saves the path to the file `path.svg` as an SVG document.

2.7 Knots

global␣knot
knot
draft␣mode

`knot=`⟨*path*⟩⟨*gap*⟩⟨*components*⟩
`global knot=`⟨*path*⟩⟨*gap*⟩⟨*components*⟩

This style combines various of the above to make it simpler to draw knots and links. It expands to:

```
knot/.style n args={3}{
  spath/.cd,
  split at self intersections=#1,
  insert gaps after components={#1}{#2}{#3},
  maybe spot weld=#1,
  render components=#1
}
```

(The `global` version makes the path manipulating commands work globally.)

This splits a path at the points where it self-intersects and then inserts gaps between specified components. The key `maybe spot weld` does a `spot weld` depending on whether or not the key `draft mode` is set to `true` or `false`. The point here is that when designing the knot it is useful to not weld together components since that changes the component count. But once the gaps are inserted in the desired places, welding the remaining components produces a nicer diagram.

The components can be styled using the keys as described in `render components`.

2.8 Coordinates

Soft paths are not natural TikZ objects and so when replaced back into a TikZ path construction then they don't fully interact with other TikZ things, like placing nodes at points on the path (though I've done my best to make that work). To make things a little easier there is defined a coordinate system which identifies a point at a certain location along a soft path and keys which apply a transformation.

spath␣cs

`(spath cs:{`⟨*name*⟩`} {`⟨*parameter*⟩`})`

The location specification is a little technical. It is specified as a number from 0 to 1, but the parameter works as follows. Let n be the number of *segments* on the path (these are the individual drawing elements that make up the path). The interval from $\frac{k-1}{n}$ to $\frac{k}{n}$ is assigned to the kth segment of the path. Then for a parameter in that interval, the location uses the natural parametrisation of that segment. For a straight line, it is simply the proportional position along but for a Bézier curve then it uses the Bézier parametrisation.

The space is vital, so if the `name` is contained in a macro then a space has to be inserted somehow. One option is to wrap the macro in braces, as seen in the examples in the next section.

`transform to`	`transform to={⟨path⟩}{⟨parameter⟩}`
`upright transform to`	`upright transform to={⟨path⟩}{⟨parameter⟩}`

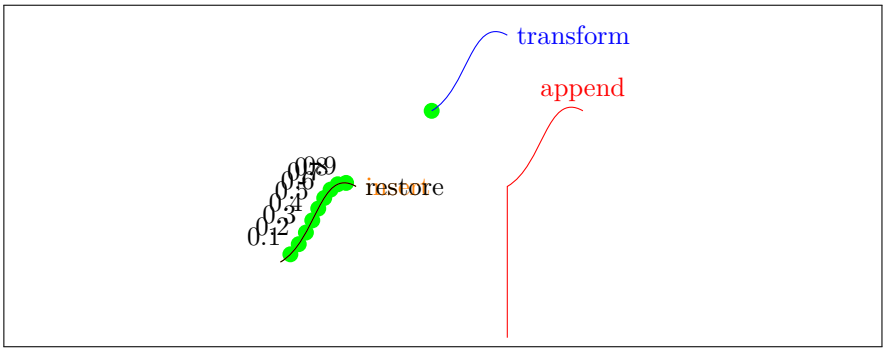
These keys (which are in the `spath` family) set the transformation so that the origin is at the specified point of the curve (as described above) and the x–axis is tangential to the curve. The transformation is *orthogonal* in that it is achieved by a rotation and a translation.

The first key aligns the axes so that the x–axis is in the forward direction of the path as that path was constructed. The second key aligns the axes so that the y–axis points up the page. The intention with the second key is that it is similar to what happens with the `sloped` key when a node is placed on a curve.

3 Examples

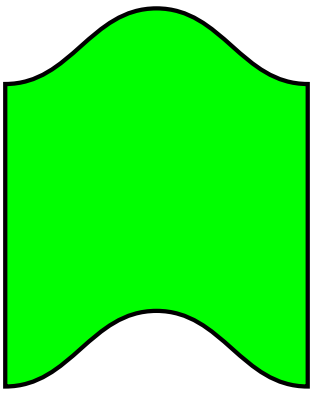
1. Saving, restoring, inserting, and appending.

```
\begin{tikzpicture}
\path[spath/save=rpath] (0,0) to[out=30,in=150] (1,1);
\foreach \k in {1,...,9} {
  \fill[green] (spath cs:rpath 0.\k) circle[radius=3pt];
  \node[above left] at (spath cs:rpath 0.\k) {\(0.\k\)};
}
\fill[green] (2,2) circle[radius=3pt];
\draw[blue, spath/transform={rpath}{shift={(2,2)}},
    spath/restore=rpath] node[right] {transform};
\draw[orange] (3,0) [spath/insert=rpath] node[right] {insert};
\draw[red] (3,-1) -- +(0,2) [spath/append=rpath] node[above]
    {append};
\draw[spath/restore=rpath] node[right] {restore};
\end{tikzpicture}
```



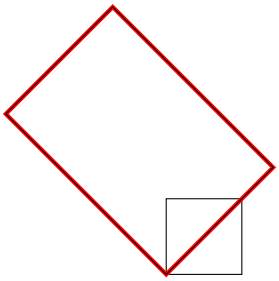
2. Reversing.

```
\begin{tikzpicture}
\path[spath/save=apath] (0,0) to[out=0,in=180] (2,1)
    to[out=0,in=180] (4,0);
\filldraw[
  green,
  draw=black,
  ultra thick,
  spath/restore=apath
] -- ++(0,-4) [spath/append reverse=apath] -- cycle;
\end{tikzpicture}
```

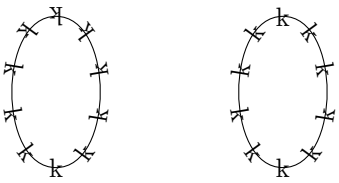


3. Transformations.

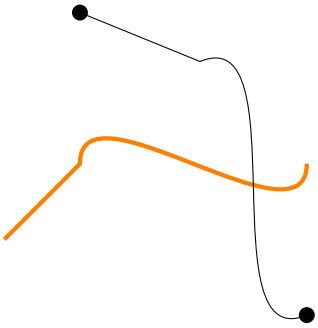
```
\begin{tikzpicture}
\draw[spath/save=tpath] (0,0) rectangle +(1,1);
\draw[rotate=45, xscale=2, yscale=3, ultra thick, red] (0,0)
    rectangle +(1,1);
\draw[
  spath/transform={tpath}{rotate=45, xscale=2, yscale=3},
  spath/restore={tpath}];
\end{tikzpicture}
```



```
\begin{tikzpicture}
\draw[spath/save=oval] (0,0) to[out=0,in=0] (0,2)
    to[out=180,in=180] (0,0);
\foreach \k in {0,...,9} {
  \node[transform shape, spath/transform to={oval}{0.\k}] {k};
}
\begin{scope}[xshift = 3cm]
\draw[spath/save=soval] (0,0) to[out=0,in=0] (0,2)
    to[out=180,in=180] (0,0);
\foreach \k in {0,...,9} {
  \node[transform shape, spath/upright transform to={soval}{0.\k}]
    {k};
}
\end{scope}
\end{tikzpicture}
```

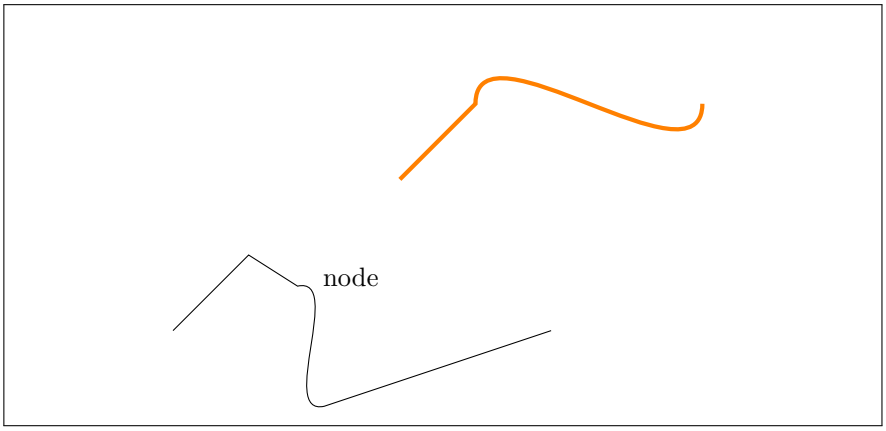



```
\begin{tikzpicture}
\path[draw=orange,ultra thick,spath/save=a] (3,2) -- ++(1,1)
    to[out=90,in=-90] ++(3,0);

\tikzset{
  spath/span={a}{(4,5)}{(7,1)}
}

\fill
(4,5) circle[radius=3pt]
(7,1) circle[radius=3pt]
;

\draw[spath/restore=a];
\end{tikzpicture}
```



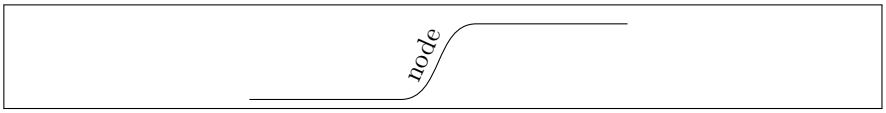
4. To paths.

```
\begin{tikzpicture}
\path[draw=orange,ultra thick,spath/save=a] (3,2) -- ++(1,1)
    to[out=90,in=-90] ++(3,0);

\draw (0,0) -- +(1,1) to[spath/to={a}] node[pos=.6,auto] {node}
    ++(2,-1) -- +(3,1);
\end{tikzpicture}
```



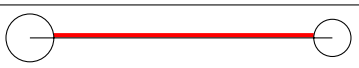
5. Node placement.

```
\begin{tikzpicture}
\path[spath/save=curve] (0,0) to[out=0,in=180] +(1,1);

\draw (0,0) -- (2,0) [spath/append=curve] node[pos=.5,auto,sloped]
    {node} -- +(2,0);

\end{tikzpicture}
```

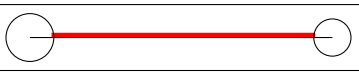


6. Shortening.

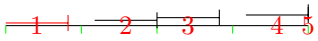
```
\begin{tikzpicture}
\path[spath/save=apath] (0,0) foreach \k in {1,...,4} { -- ++(1,0)
    +(0,0)};
\draw[
  ultra thick,
  red,
  spath/.cd,
  shorten at end={apath}{7pt},
  shorten at start={apath}{9pt},
  translate={apath}{0pt}{1pt},
  restore=apath,
];
\draw (0,0) circle[radius=9pt] [spath/insert=apath]
    circle[radius=7pt];
\end{tikzpicture}
```



```
\begin{tikzpicture}
\path[spath/save=apath] (0,0) foreach \k in {1,...,4} {
    to[out=0,in=180] ++(1,0) +(0,0)};
\draw[
  ultra thick,
  red,
  spath/.cd,
  shorten at end={apath}{7pt},
  shorten at start={apath}{9pt},
  translate={apath}{0pt}{1pt},
  restore=apath,
];
\draw (0,0) circle[radius=9pt] [spath/insert=apath]
    circle[radius=7pt];
\end{tikzpicture}
```



```
\begin{tikzpicture}
\draw[spath/save=npath] (0,0) foreach \k in {1,...,4} { -- ++(1,0)
    +(0,0)};
\draw[green] (0,0) -- +(0,-3pt) foreach \k in {1,...,4} { --
    +(0,-3pt) ++(1,0)} -- +(0,-3pt);

\tikzset{
  spath/.cd,
  insert gaps after components={npath}{10pt}{1,3},
  get components of={npath}\components,
}

\tikzset{
  path 1/.style={
    red,
  },
}

\foreach[count=\k] \cpt in \components {
  \path[
    draw,
    path \k/.try,
    spath/.cd,
    translate=\cpt{0pt}{\k pt},
    restore=\cpt,
  ] +(0,3pt) -- +(0,-3pt);
  \node[text=red] at (spath cs:{\cpt} .5) {\(\k\)};
}
\end{tikzpicture}
```

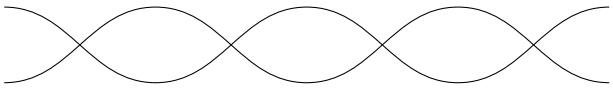


7. Intersections.

   One of the main motivations for implementing the intersection routines was to provide a different way of drawing knots and links and similar diagrams.

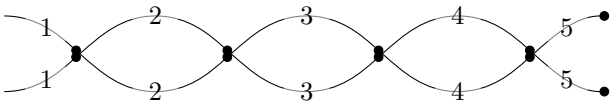
   (a) Define the two paths for the braid (usually these will be defined with `\path`).

```
\begin{tikzpicture}[
  use Hobby shortcut,
]
\draw[spath/save global=pathA] (0,0) to[out=0,in=180] ++(2,1)
    to[out=0,in=180] ++(2,-1)  to[out=0,in=180] ++(2,1)
    to[out=0,in=180] ++(2,-1);
\draw[spath/save global=pathB] (0,1) to[out=0,in=180] ++(2,-1)
    to[out=0,in=180] ++(2,1)  to[out=0,in=180] ++(2,-1)
    to[out=0,in=180] ++(2,1);
\end{tikzpicture}
```



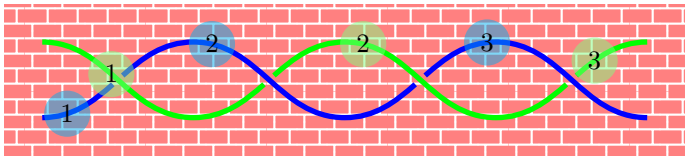
(b) Split the paths at their mutual intersections and render them with a count of the components.

```
\begin{tikzpicture}
\tikzset{
  spath/.cd,
  split at intersections={pathA}{pathB},
  get components of={pathA}\pathAcomponents,
  get components of={pathB}\pathBcomponents,
}

\foreach[count=\k] \cpt in \pathAcomponents {
  \draw[spath/restore=\cpt,-Circle];
  \node[fill=white, fill opacity=.5, circle, text opacity=1] at
    (spath cs:{\cpt} .5) {\(\k\)};
}

\foreach[count=\k] \cpt in \pathBcomponents {
  \draw[spath/restore=\cpt,-Circle];
  \node[fill=white, fill opacity=.5, circle, text opacity=1] at
    (spath cs:{\cpt} .5) {\(\k\)};
}
\end{tikzpicture}
```



(c) Now we insert gaps after certain components in each path and then render the components. To show that the gaps are genuine, we use a patterned background. Although the paths were defined globally, the splitting in the previous example was local so we need to repeat it in this one.

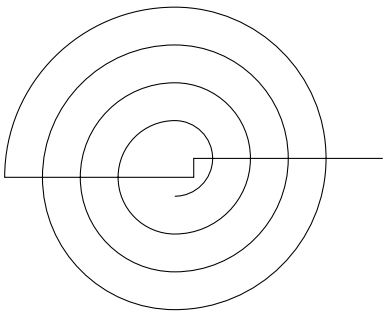
```
\begin{tikzpicture}
\tikzset{
  spath/.cd,
  split at intersections={pathA}{pathB},
  insert gaps after components={pathA}{5pt}{1,3},
  join components={pathA}{3,5},
  get components of={pathA}\pathAcomponents,
  insert gaps after components={pathB}{5pt}{2,4},
  join components={pathB}{2,4},
  get components of={pathB}\pathBcomponents,
}

\fill[red!50!white] (-.5,-.5) rectangle (8.5,1.5);
\fill[pattern=bricks, pattern color=white] (-.5,-.5) rectangle
    (8.5,1.5);

\foreach[count=\k] \cpt in \pathAcomponents {
  \draw[blue, line width=2pt,spath/restore=\cpt];
  \node[fill=cyan, fill opacity=.5, circle, text opacity=1] at
    (spath cs:{\cpt} .3) {\(\k\)};
}

\foreach[count=\k] \cpt in \pathBcomponents {
  \draw[green, line width=2pt,spath/restore=\cpt];
  \node[fill=green!50, fill opacity=.5, circle, text opacity=1]
    at (spath cs:{\cpt} .3) {\(\k\)};
}
\end{tikzpicture}
```



8. This example is notable because many of the intersection points are where segments of the path end, showing that the algorithm works well even in this circumstance.

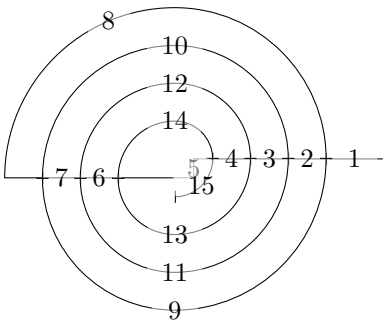
   (a) Here's the original path.

```
\begin{tikzpicture}
\draw[spath/save global=spiral] (5,0) -- (2.5,0) -- ++(0,-.25)
    -- ++(-2.5,0)
arc[radius=2.25cm,start angle=180,end angle=90]
arc[radius=2cm,start angle=90, delta angle=-180]
arc[radius=1.75cm,start angle=-90, delta angle=-180]
arc[radius=1.5cm,start angle=90, delta angle=-180]
arc[radius=1.25cm,start angle=-90, delta angle=-180]
arc[radius=1cm,start angle=90, delta angle=-180]
arc[radius=.75cm,start angle=-90, delta angle=-180]
arc[radius=.5cm,start angle=90, delta angle=-180]
;
\end{tikzpicture}
```



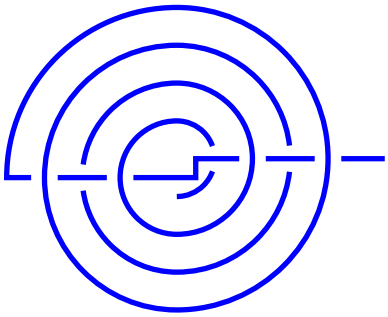
(b) This renders labels on each component after splitting.

```
\begin{tikzpicture}
\tikzset{
  spath/.cd,
  split at self intersections=spiral,
  get components of={spiral}\pathcomponents,
}

\foreach[count=\k] \cpt in \pathcomponents {
  \draw[spath/restore=\cpt,-|];
  \node[fill=white, fill opacity=.5, circle, text opacity=1] at
    (spath cs:{\cpt} .5) {\(\k\)};
}
\end{tikzpicture}
```



(c) Finally, we put the gaps in where we want them.

```
\begin{tikzpicture}
\tikzset{
  spath/.cd,
  split at self intersections=spiral,
  insert gaps after components={spiral}{10pt}{1,3,5,7,10,11,14},
  spot weld=spiral,
  get components of={spiral}\pathcomponents,
}

\foreach[count=\k] \cpt in \pathcomponents {
  \draw[blue, line width=2pt,spath/restore=\cpt];
}
\end{tikzpicture}
```



9. Here's a trefoil knot, demonstrating the `knot` style that simplifies creating knots.

```
\begin{tikzpicture}[
  use Hobby shortcut,
  every trefoil component/.style={ultra thick, draw, red},
  trefoil component 1/.style={blue},
]
\path[spath/save=trefoil] ([closed]90:2) foreach \k in {1,...,3} {
    .. (-30+\k*240:.5) .. (90+\k*240:2) } (90:2);
\tikzset{spath/knot={trefoil}{8pt}{1,3,5}}
\end{tikzpicture}
```