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# **splinar** Documentation

*Release*

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splinar is a package used for a tutorial which explains how to do the Python packaging using

- PyPi
- conda build
- pytest
- Pylint
- Sphinx

And automate the process to distribute this package using github.

The original idea of splinar is found on the great inonvergent website.

If you want to install splinar:

```
pip install splpinart
```

or:

```
conda install -c gouarin splinar
```



## 1.1 Cubic Spline

We consider here a cubic spline passing through the points  $(x_i, y_i)$  with  $a = x_1 < \dots < x_n = b$ , that is, a class function  $\mathcal{C}^2$  on  $[a, b]$  and each restriction at the interval  $[x_{i-1}, x_i]$ ,  $1 \leq i \leq n$ , is a polynomial of degree less than 3. We will note  $S$  such a spline. His equation is given by

$$S_i(x) = Ay_i + By_{i+1} + Cy_i'' + Dy_{i+1}'', \quad x_i \leq x \leq x_{i+1},$$

where

$$A = \frac{x_{i+1} - x}{x_{i+1} - x_i} \quad \text{et} \quad B = \frac{x - x_i}{x_{i+1} - x_i},$$

$$C = \frac{1}{6} (A^3 - A) (x_{i+1} - x_i)^2 \quad \text{et} \quad D = \frac{1}{6} (B^3 - B) (x_{i+1} - x_i)^2.$$

If we derive this equation twice with respect to  $x$ , we get

$$\frac{d^2 S(x)}{dx^2} = Ay_i'' + By_{i+1}''.$$

Since  $A = 1$  in  $x_i$  and  $A = 0$  in  $x_{i+1}$  and conversely for  $B$ , we can see that the second derivative is continuous at the interface of the two intervals  $[x_{i-1}, x_i]$  and  $[x_i, x_{i+1}]$ .

It remains to determine the expression of  $y_i''$ . To do this, we will calculate the first derivative and impose that it is continuous at the interface of two intervals. The first derivative is given by

$$\frac{dy}{dx} = \frac{y_{i+1} - y_i}{x_{i+1} - x_i} - \frac{3A^2 - 1}{6} (x_{i+1} - x_i) y_i'' + \frac{3B^2 - 1}{6} (x_{i+1} - x_i) y_{i+1}''.$$

We therefore want the value of the first derivative in  $x = x_i$  over the interval  $[x_{i-1}, x_i]$  to be equal to the value of the first derivative in  $x = x_i$  over the interval  $[x_i, x_{i+1}]$ ; which gives us for  $i = 2, \dots, n - 1$

$$a_i y_{i-1}'' + b_i y_i'' + c_i y_{i+1}'' = d_i,$$

with

$$\begin{aligned} a_i &= \frac{x_i - x_{i-1}}{x_{i+1} - x_{i-1}} \\ b_i &= 2 \\ c_i &= \frac{x_{i+1} - x_i}{x_{i+1} - x_{i-1}} \\ d_i &= \frac{6}{x_{i+1} - x_{i-1}} \left( \frac{y_{i+1} - y_i}{x_{i+1} - x_i} - \frac{y_i - y_{i-1}}{x_i - x_{i-1}} \right). \end{aligned}$$

So we have  $n - 2$  linear equations to calculate the  $n$  unknowns  $y''_i$  for  $i = 1, \dots, n$ . So we have to make a choice for the first and last values and we will take them equal to zero. We can recognize the resolution of a system with a tridiagonal matrix. It is then easy to solve it by using the algorithm of Thomas which one recalls the principle

$$\begin{aligned} c'_i &= \begin{cases} \frac{c_i}{b_i} & i = 1 \\ \frac{c_i}{b_i - a_i c'_{i-1}} & i = 2, \dots, n. \end{cases} \\ d'_i &= \begin{cases} \frac{d_i}{b_i} & i = 1 \\ \frac{d_i - a_i d'_{i-1}}{b_i - a_i c'_{i-1}} & i = 2, \dots, n. \end{cases} \end{aligned}$$

The solution is then obtained by the formula

$$\begin{aligned} y''_n &= d'_n \\ y''_i &= d'_i - c'_i y''_{i+1} \quad \text{pour } i = n - 1, \dots, 1. \end{aligned}$$



## 2.1 Splinart on a circle

In this tutorial, we will see how to use splinart with a circle.

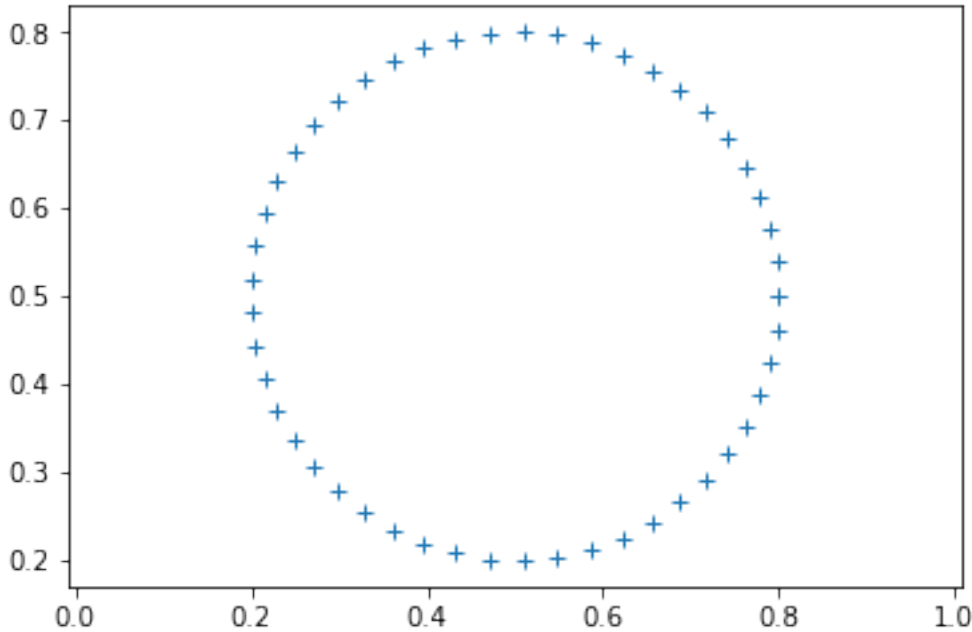
First of all, we have to create a circle.

```
In [34]: import splinart as spl
         center = [.5, .5]
         radius = .3
         theta, path = spl.circle(center, radius)
```

In the previous code, we create a discretization of a circle centered in  $[0.5, 0.5]$  with a radius of 0.3. We don't specify the number of discretization points. The default is 30 points.

We can plot the points using matplotlib.

```
In [2]: %matplotlib inline
In [6]: import matplotlib.pyplot as plt
         plt.axis("equal")
         plt.plot(path[:, 0], path[:, 1], '+')
Out[6]: [<matplotlib.lines.Line2D at 0x7fc91dfe6048>]
```



### 2.1.1 The sample

In order to compute a sample on a given cubic spline equation, we need to provide a Python function that gives us the x coordinates. We can choose for example.

```
In [12]: import numpy as np
         def x_func():
             nsamples = 500
             return (np.random.random() + 2 * np.pi * np.linspace(0, 1, nsamples))%(2*np.pi)
```

We can see that the points are chosen between  $[0, 2\pi]$  in a random fashion.

### 2.1.2 The cubic spline

Given a path, we can apply the spline function in order to compute the second derivative of this cubic spline.

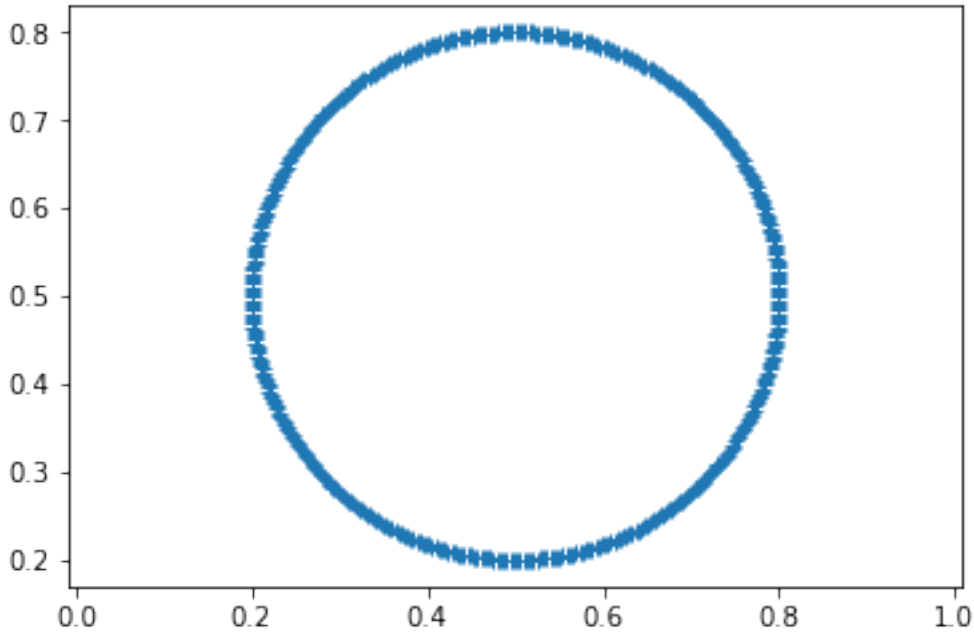
```
In [13]: yder2 = spl.spline.spline(theta, path)
```

And apply the equation to the sample

```
In [14]: xsample = x_func()
         ysample = np.zeros((xsample.size, 2))
         spl.spline.splint(theta, path, yder2, xsample, ysample)
```

which gives

```
In [15]: import matplotlib.pyplot as plt
         plt.axis("equal")
         plt.plot(ysample[:, 0], ysample[:, 1], '+')
Out[15]: [<matplotlib.lines.Line2D at 0x7fc91e05feb8>]
```



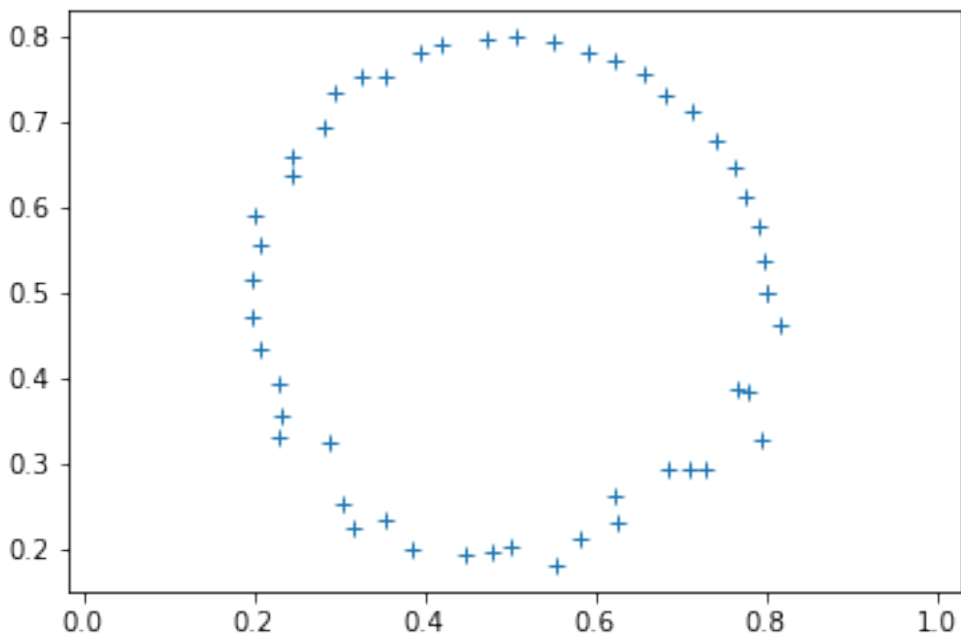
We can see the sample is well defined around the circle that we defined previously.

Now, assume that we move randomly the points of the circle with a small distance.

```
In [35]: spl.compute.update_path(path, scale_value=.001, periodic=True)
```

```
In [36]: import matplotlib.pyplot as plt
plt.axis("equal")
plt.plot(path[:, 0], path[:, 1], '+')
```

```
Out[36]: [matplotlib.lines.Line2D at 0x7fc91da92e10]
```

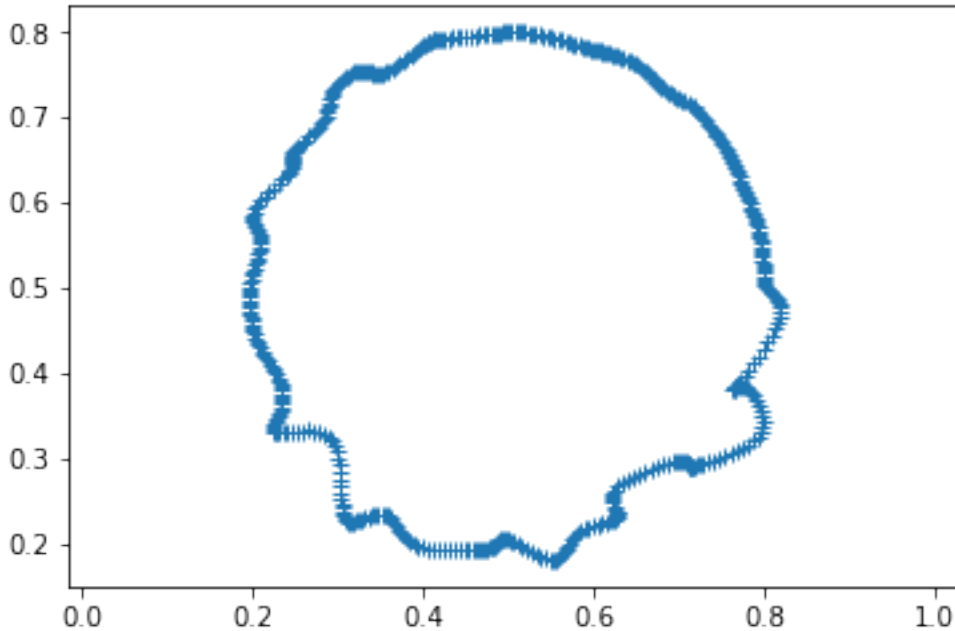


And we compute again the sample of the new cubic spline equation.

```
In [37]: yder2 = spl.spline.spline(theta, path)
spl.spline.splint(theta, path, yder2, xsample, ysample)
spl.compute.update_path(path, scale_value=.001, periodic=True)

In [39]: import matplotlib.pyplot as plt
plt.axis("equal")
plt.plot(ysample[:, 0], ysample[:, 1], '+')

Out [39]: [<matplotlib.lines.Line2D at 0x7fc91d94f748>]
```



The circle is deformed.

This is exactly how works splineart. We give a shape and at each step

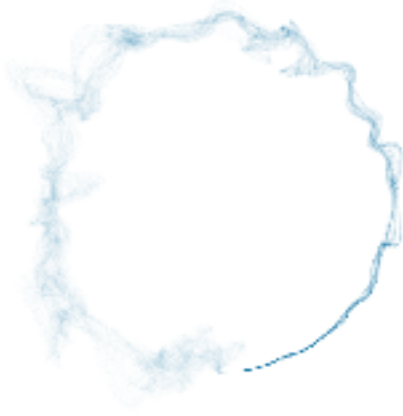
- we perturb the points of this shape
- we compute a sample an this new cubic spline equation
- we add the pixel with a given color on the output image

And we do that several time. We can have the following result

```
In [40]: img_size, channels = 1000, 4
img = np.ones((img_size, img_size, channels), dtype=np.float32)

theta, path = spl.circle(center, radius)
spl.update_img(img, path, x_func, nrep=4000, x=theta, scale_value=.00005)

In [41]: spl.show_img(img)
```





## 3.1 splinart

### 3.1.1 splinart package

#### Subpackages

#### splinart.shapes package

#### Submodules

#### splinart.shapes.base module

Define basic shapes.

`splinart.shapes.base.circle` (*center*, *radius*, *npoints=50*)

Discretization of a circle.

#### Parameters

- **center** (*list* (2)) – 2d coordinates of the center.
- **radius** (*float*) – Radius of the circle.
- **npoints** (*int*) – Number of discretization points (the default value is 50).

#### Returns

- *np.ndarray* – The theta angle.
- *np.ndarray* – The 2d coordinates of the circle.

`splinart.shapes.base.line` (*begin*, *end*, *ypos=0.5*, *npoints=50*)

Discretization of a horizontal line.

#### Parameters

- **begin** (*float*) – The left point of the line.
- **end** (*float*) – The right point of the line.
- **ypos** (*float*) – The position of the y coordinate (the default value is 0.5).
- **npoints** (*int*) – Number of discretization points (the default value is 50).

**Returns** The 2d coordinates of the line.

**Return type** np.ndarray

## Module contents

Shape package

## splinar.spline package

### Submodules

#### splinar.spline.spline module

Cubic spline

`splinar.spline.spline.spline` (*xs, ys*)

Return the second derivative of a cubic spline.

#### Parameters

- **xs** (*np.ndarray*) – The x coordinate of the cubic spline.
- **ys** (*np.ndarray*) – The y coordinate of the cubic spline.

**Returns** The second derivative of the cubic spline.

**Return type** np.ndarray

#### splinar.spline.splint module

Integration of a cubic spline.

`splinar.spline.splint.splint` (*xs, ys, y2s, x, y*)

Evaluate a sample on a cubic spline.

#### Parameters

- **xs** – The x coordinates of the cubic spline.
- **ys** – The y coordinates of the cubic spline.
- **y2s** – The second derivative of the cubic spline.
- **x** – The sample where to evaluate the cubic spline.
- **y** – The y coordinates of the sample.

**See also:**

`splinar.spline.spline()`



## Module contents

Spline package

## Submodules

### splinart.color module

Define the default color of the output.

### splinart.compute module

Material to update the output image using a cubic spline equation.

```
splinart.compute.update_img(img, path, xs_func, x=None, nrep=300, periodic=True,
                             scale_color=0.005, color=(0.0, 0.41568627450980394,
                             0.6196078431372549, 1.0), scale_value=1e-05)
```

Update the image using a cubic spline on a shape.

#### Parameters

- **img** (*np.ndarray*) – The output image.
- **path** (*np.ndarray*) – The y coordinate of the cubic spline if x is not None, the coordinates of the cubic spline if x is None.
- **x** (*np.ndarray*) – The x coordinates of the cubic spline if given. (the default value is None)
- **xs\_func** (*function*) – The function that return the x coordinate of the sampling points where to compute the y coordinates given the spline equation.
- **nrep** (*int*) – Number of iteration (default is 300).
- **periodic** (*bool*) – Define if the first and last points of the path must be equal (default is True).
- **scale\_color** (*float*) – Scale the given color (default is 0.005).
- **color** (*list(4)*) – Define the RGBA color to plot the spline.
- **scale\_value** (*float*) – Rescale the random radius (default value is 0.00001).

#### See also:

`update_path()`

```
splinart.compute.update_path(path, periodic=False, scale_value=1e-05)
```

Update the path of the spline.

We move each point of the path by a random vector defined inside a circle where

- the center is the point of the path
- the radius is a random number between [-1, 1]

#### Parameters

- **path** (*np.ndarray*) – The y coordinate of the cubic spline.
- **periodic** (*bool*) – If True, the first and the last points of the path are the same (the default value is False).

- **scale\_value** (*float*) – Rescale the random radius (default value is 0.00001).

### splinar.draw module

Material to update the image with given points and save or plot this image.

```
splinar.draw.draw_pixel (img, xs, ys, scale_color=0.0005, color=(0.0, 0.41568627450980394,  
0.6196078431372549, 1.0))
```

Add pixels on the image.

#### Parameters

- **img** (*np.ndarray*) – The image where we add pixels.
- **xs** (*np.ndarray*) – The x coordinate of the pixels to add.
- **ys** (*np.ndarray*) – The y coordinate of the pixels to add.
- **scale\_color** (*float*) – Scale the given color (default is 0.0005).
- **color** (*list(4)*) – Define the RGBA color of the pixels.

```
splinar.draw.save_img (img, path, filename)
```

Save the image in a png file.

#### Parameters

- **img** (*np.ndarray*) – The image to save.
- **path** (*str*) – The save directory.
- **filename** (*str*) – The file name with the png extension.

```
splinar.draw.show_img (img)
```

Plot the image using matplotlib.

**Parameters** **img** (*np.ndarray*) – The image to save.

### splinar.version module

#### Module contents

Splinar package

## CHAPTER 4

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### Indices and tables

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