Dynamic Functional Connectivity

A tutorial

Lucas G. S. França* Sunniva Fenn-Moltu† Dafnis Batalle‡

Contents

Introduction

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*King's College London, lucas.franca@kcl.ac.uk
†King's College London, sunniva.fenn-moltu@kcl.ac.uk
‡King's College London, dafnis.batalle@kcl.ac.uk

Fig 1

Fig 2

Adapted from: https://en.wikipedia.org/wiki/Voxel#/media/File:Voxels.svg

Fig 3

Fig 4

Fig 5

Fig 6

Fig 7

Sliding windows

```
import sys
sys.path.insert(1, 'libs/')

import dynfc as dyn
import numpy as np
from numpy.random import seed, rand
import scipy as sc
from scipy import io
import seaborn as sns
import matplotlib.pyplot as plt
import matplotlib.cbook as cbook
import matplotlib.cm as cm
import matplotlib.patches as patches

font = {'weight' : 'regular',
        'size'   : 24}
plt.rc('font', **font)

ts = sc.io.loadmat('data/ts.mat')['ts']
ts = ts.transpose()

corr_mats, idx = dyn.corr_slide(ts,300,50)

idx.shape
```

```
> (24,)
```

```
a = [1,1,1,1,1.6]

fig,ax = plt.subplots(1)
fig.set_figheight(10)
fig.set_figwidth(20)
plt.style.use('tableau-colorblind10')
for i in range(5):

    plt.plot(2*i*a[i] + ts[i,]/1.4)
```

```
> [<matplotlib.lines.Line2D object at 0x7f808b0cdf98>]
> [<matplotlib.lines.Line2D object at 0x7f7fbc991470>]
> [<matplotlib.lines.Line2D object at 0x7f808bd7fbe0>]
> [<matplotlib.lines.Line2D object at 0x7f808bd78278>]
> [<matplotlib.lines.Line2D object at 0x7f7fbc991b70>]
```

```
plt.xlabel('Time [TRs]')
```

```
> Text(0.5, 0, 'Time [TRs]')
```

```
plt.ylabel('BOLD')
```

```
> Text(0, 0.5, 'BOLD')
```

```
ax.tick_params(left=False)
ax.set_yticklabels([])
```

```
> [Text(0, -2.0, ''), Text(0, 0.0, ''), Text(0, 2.0, ''), Text(0, 4.0, ''), Text(0, 6.0, ''), Text(0, 8
```

```
ax.set_ylim(-3,15.4)
```

```
> (-3.0, 15.4)
```

```
ax.set_xlim(0,1200)
```

```
> (0.0, 1200.0)
```

```
rect = patches.Rectangle((idx[0],-2.8),300,18,linewidth=4,edgecolor='#595959',facecolor='none')
ax.add_patch(rect)
```

```
> <matplotlib.patches.Rectangle object at 0x7f7e1b5882b0>
```

```
rect = patches.Rectangle((idx[5],-2.8),300,18,linewidth=4,edgecolor='#A56B6B',facecolor='none')
ax.add_patch(rect)
```

```
> <matplotlib.patches.Rectangle object at 0x7f7e1b588630>
```

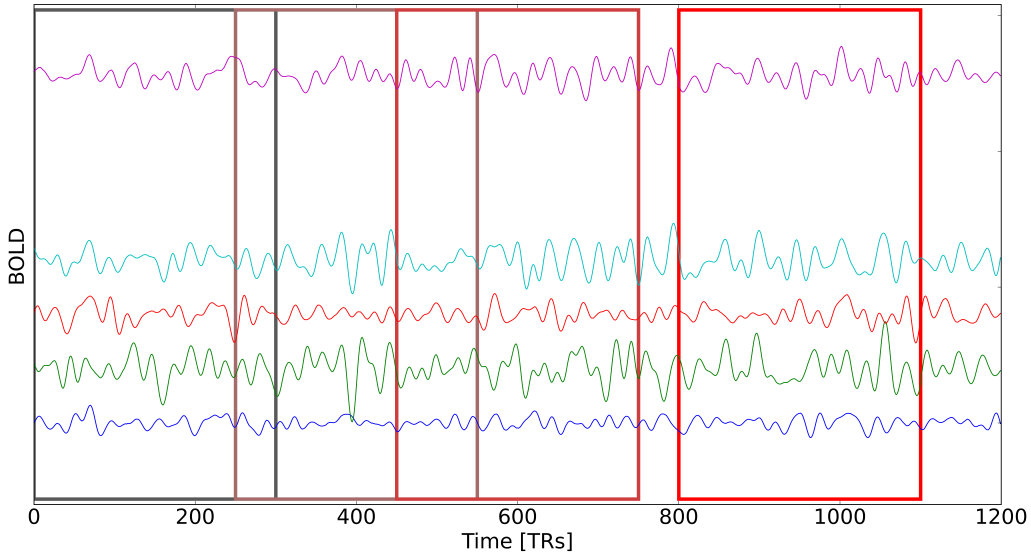
```
rect = patches.Rectangle((idx[9],-2.8),300,18,linewidth=4,edgecolor='#CE3E3E',facecolor='none')
ax.add_patch(rect)
```

```
> <matplotlib.patches.Rectangle object at 0x7f7e1b588940>
```

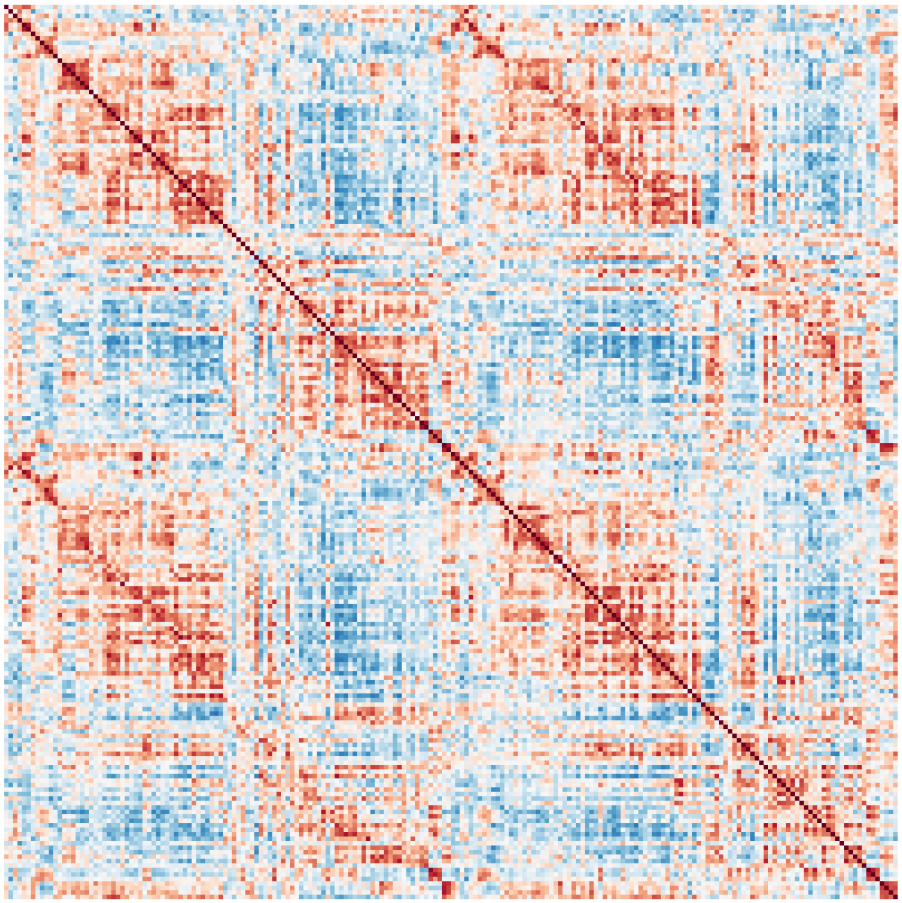
```
rect = patches.Rectangle((idx[16],-2.8),300,18,linewidth=4,edgecolor='#FF0000',facecolor='none')
ax.add_patch(rect)
```

```
> <matplotlib.patches.Rectangle object at 0x7f7e1b588c50>
```

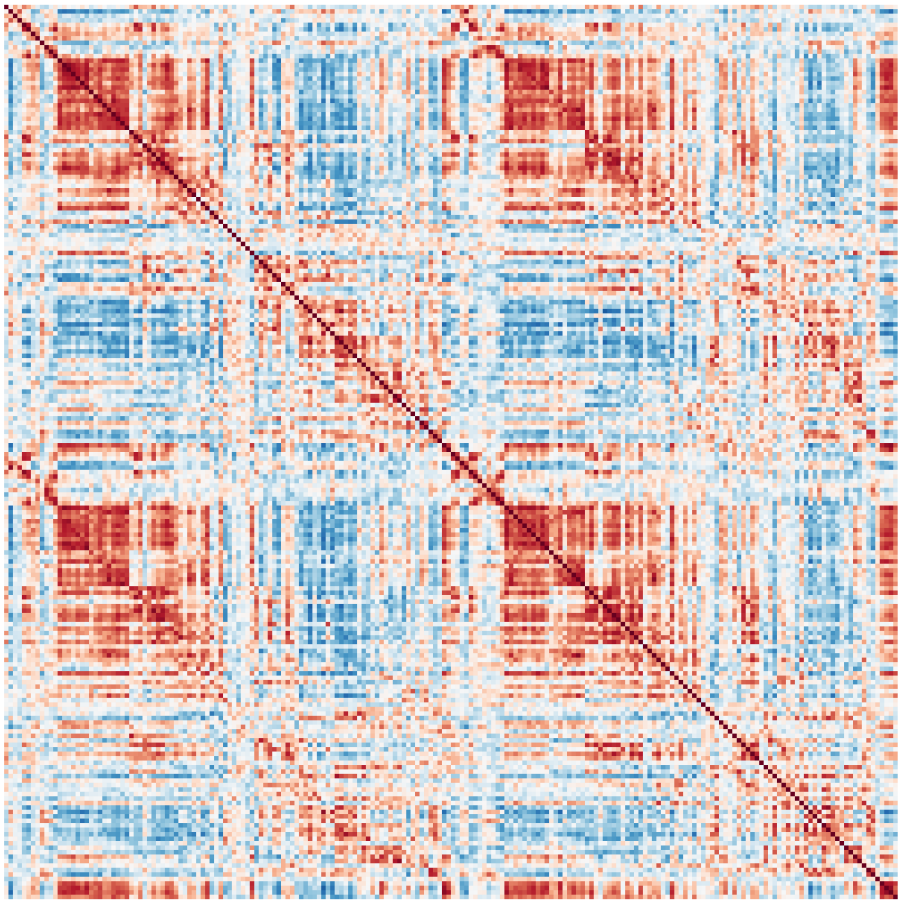
```
plt.show()
```



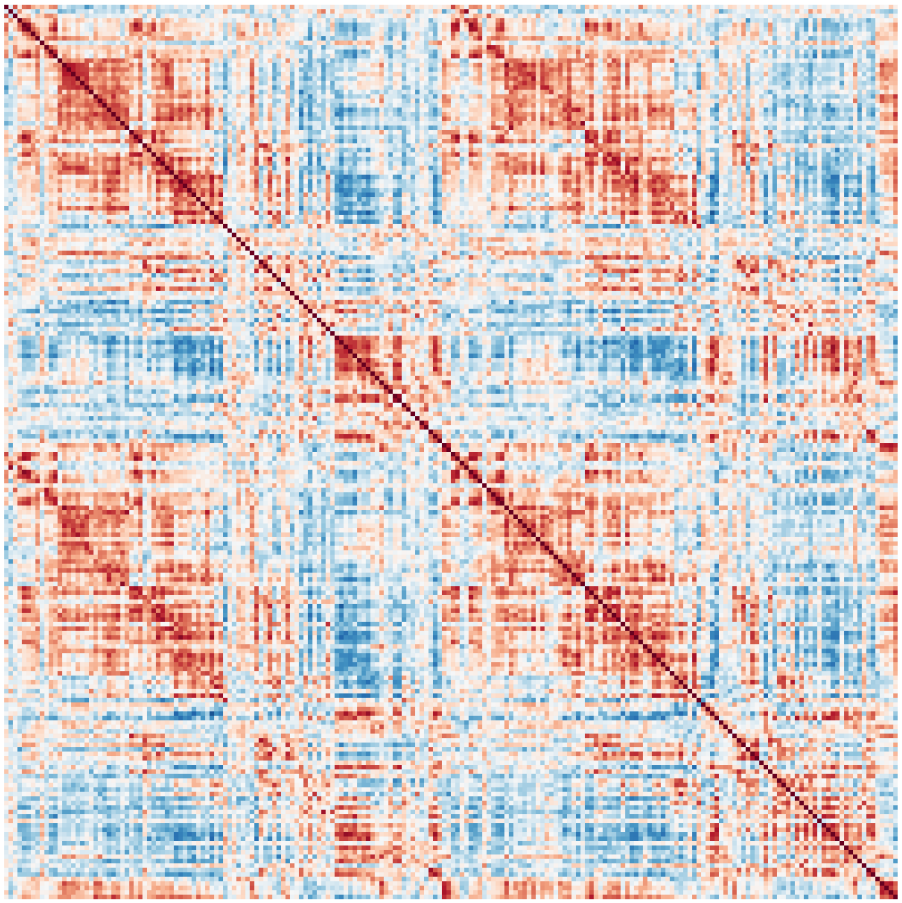

```
> (0.0, 200.0, 200.0, 0.0)
```



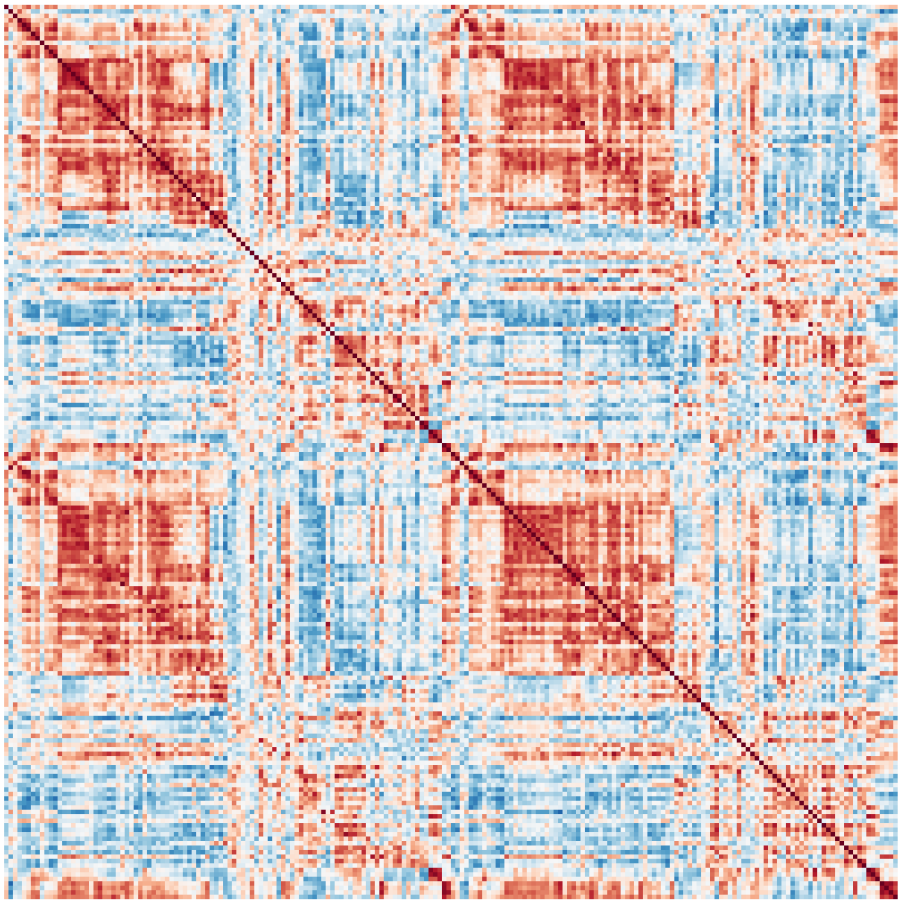
```
> (0.0, 200.0, 200.0, 0.0)
```



```
> (0.0, 200.0, 200.0, 0.0)
```



```
> (0.0, 200.0, 200.0, 0.0)
```



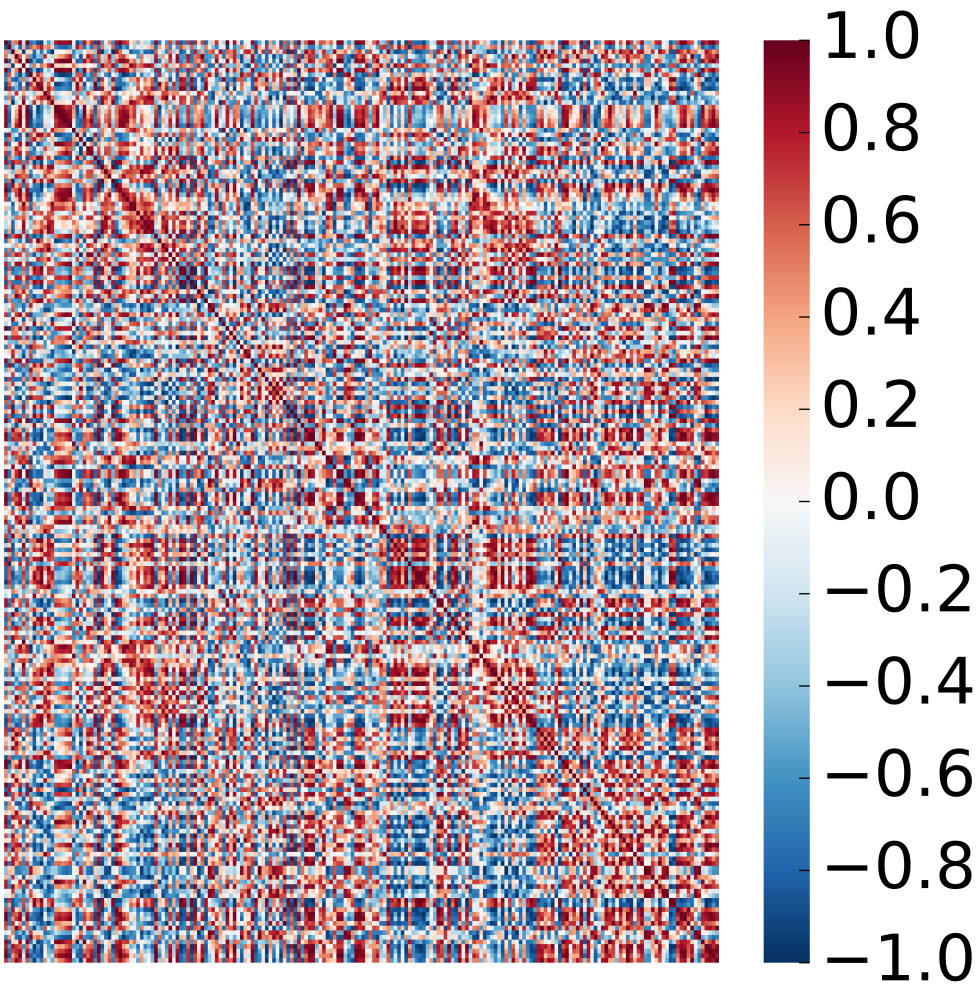
Cofluctuations

```
import sys
sys.path.insert(1, 'libs/')

import numpy as np
import scipy as sc
from scipy import io
import dynfc as dyn
import seaborn as sns
import matplotlib.pyplot as plt

ts = sc.io.loadmat('data/ts.mat')['ts']
ts = ts.transpose()
```

```
mat1, rss = dyn.corr_slide(ts,24)
mat1 = mat1[:,:,0]

aa = plt.figure(figsize = [6,6])
ax = sns.heatmap(mat1,
                 cmap = "RdBu_r",
                 vmin = -1,
                 vmax = 1,
                 square = False,
                 cbar = True)
ax.axis('off')
```

```
> (0.0, 200.0, 200.0, 0.0)
```

```
ax.tick_params(left=False, bottom=False)
plt.show()
```



```
upt = np.triu_indices(mat1.shape[0], k = 1)
vec = (mat1[upt])

toPlot = np.zeros((vec.shape[0],1))
toPlot[:,0] = vec

aa = plt.figure(figsize = (12/50,4))
ax = sns.heatmap(toPlot[:,0:1],
                 cmap = "RdBu_r",
                 vmin = -1,
                 vmax = 1,
                 square = False,
                 cbar = False)
ax.axis('off')
```

```
> (0.0, 1.0, 19900.0, 0.0)
```

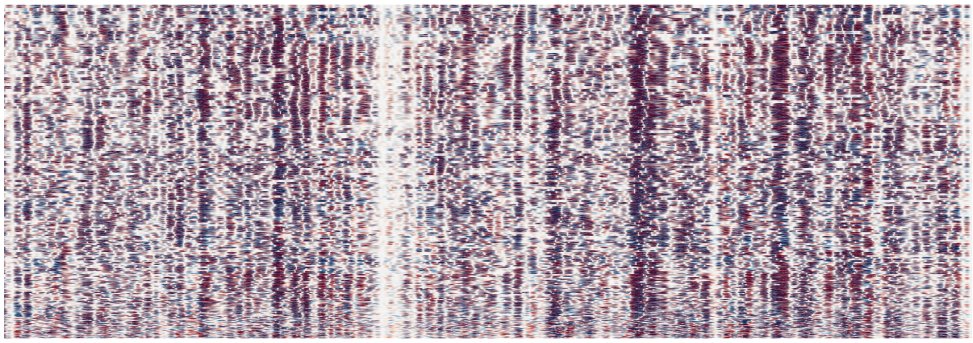
```
plt.show()
```

```
edges_series, corr_mats, rss = dyn.cofluct(ts, 24)

aa = plt.figure(figsize = (12,4))
ax = sns.heatmap(edges_series,
                 cmap = "RdBu_r",
                 vmin = -1,
                 vmax = 1,
                 square = False,
```

```
                  cbar = False)
ax.axis('off')
```

```
> (0.0, 1200.0, 19900.0, 0.0)
```

```
plt.show()
```



#Phase difference

```
import sys
sys.path.insert(1, 'libs/')

import numpy as np
import matplotlib.pyplot as plt
import matplotlib.patches as patches
from mpl_toolkits.mplot3d import Axes3D

theta = np.linspace(0*np.pi, 8*np.pi, 100)
time = np.linspace(0, 8, 100)
y1 = np.sin(theta)
x1 = np.cos(theta)
y2 = np.sin(theta + np.pi/2)
x2 = np.cos(theta + np.pi/2)
r = time/np.max(time)
ones = np.ones(time.shape[0])

fig = plt.figure()
ax = fig.add_subplot(projection='3d')
plt.style.use('classic')

ax.plot(time, x1, y1, color = '#67001f', linewidth=2)
```

```
> [<mpl_toolkits.mplot3d.art3d.Line3D object at 0x7f7f208b4a20>]
```

```
ax.plot(time,ones,y1, linestyle = '--', color = '#0f0f0f')
```

```
> [<mpl_toolkits.mplot3d.art3d.Line3D object at 0x7f7f61ede438>]
```

```
ax.plot(time,x1,-ones, linestyle = '--', color = '#0f0f0f')
```

```
> [<mpl_toolkits.mplot3d.art3d.Line3D object at 0x7f7f61ede518>]
```

```
ax.quiver(time,0,0,0, 0.99*x1, 0.99*y1,
          length = 0.9,
          normalize = False,
          arrow_length_ratio = 0.1,
          alpha = 0.4,
          color = '#053061')
```

```
> <mpl_toolkits.mplot3d.art3d.Line3DCollection object at 0x7f7e1b5a5978>
```

```
ax.text(0.5, 1, 0.5, r'$\sin(\theta)$', fontsize = 20)
```

```
> Text(0.5, 1, '$\\sin(\\theta)$')
```

```
ax.text(0.5, -1, -1, r'$\cos(\theta)$', fontsize = 20)
```

```
> Text(0.5, -1, '$\\cos(\\theta)$')
```

```
ax.set_xlabel('Time')
```

```
> Text(0.5, 0, 'Time')
```

```
ax.set_ylabel('Re')
```

```
> Text(0.5, 0, 'Re')
```

```
ax.set_zlabel('Im')
```

```
> Text(0.5, 0, 'Im')
```

```
ax.set_xlim(0,8)
```

```
> (0.0, 8.0)
```

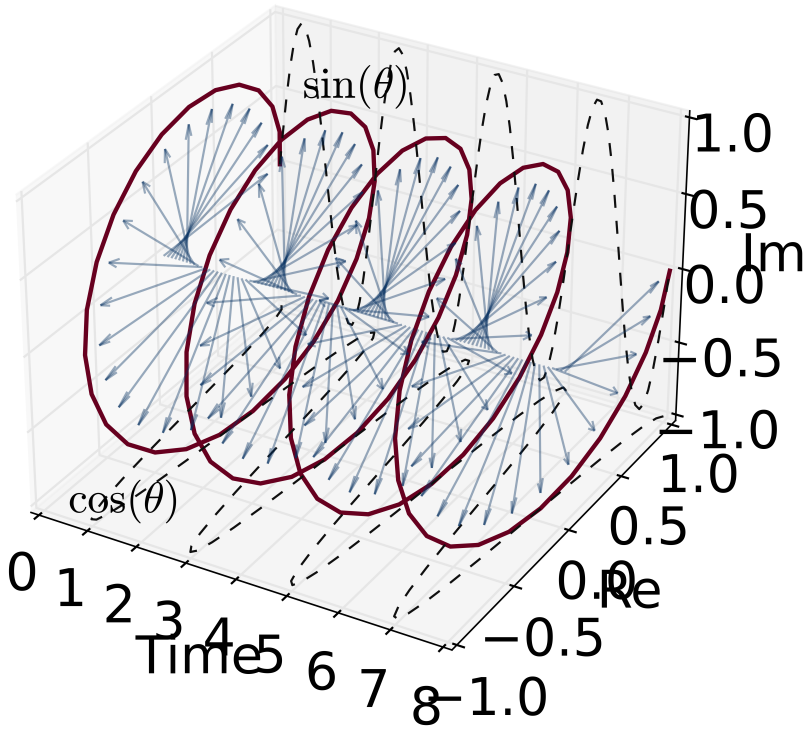
```
ax.set_ylim(-1,1)
```

```
> (-1.0, 1.0)
```

```
ax.set_zlim(-1,1)
```

```
> (-1.0, 1.0)
```

```
plt.show()
```




```
colors1 = plt.cm.Reds(np.arange(0,1,0.01))
colors1[:,-1] = np.arange(0,1,0.01)

colors2 = plt.cm.Blues(np.arange(0,1,0.01))
colors2[:,-1] = np.arange(0,1,0.01)

fig = plt.figure(figsize = (12,8))
ax = fig.add_subplot(projection='3d')
plt.style.use('classic')

ax.scatter(time,ones,r*y1, color = colors1, marker = ",", s = 3)
```

```
> <mpl_toolkits.mplot3d.art3d.Path3DCollection object at 0x7f7f9b327ba8>
```

```
ax.scatter(time,r*x1,-ones, color = colors1, marker = ",", s = 3)
```

```
> <mpl_toolkits.mplot3d.art3d.Path3DCollection object at 0x7f7f2b7fc5c0>
```

```
ax.scatter(time,ones,r*y2, color = colors2, marker = ",", s = 3)
```

```
> <mpl_toolkits.mplot3d.art3d.Path3DCollection object at 0x7f7f2b7fc668>
```

```
ax.scatter(time,r*x2,-ones, color = colors2, marker = ",", s = 3)
#ax.plot(time,r*x2,-ones, linestyle = '--', color = colors2[-10,:])
```

```
> <mpl_toolkits.mplot3d.art3d.Path3DCollection object at 0x7f7f2b7fc080>
```

```
ax.quiver(time,0,0,0, 0.99*r*x1, 0.99*r*y1,
          length = 0.9,
          normalize = False,
          arrow_length_ratio = 0.1,
          alpha = 1,
          color = colors1)
```

```
> <mpl_toolkits.mplot3d.art3d.Line3DCollection object at 0x7f7f2b7fc2e8>
```

```
ax.quiver(time,0,0,0, 0.99*r*x2, 0.99*r*y2,
          length = 0.9,
          normalize = False,
          arrow_length_ratio = 0.1,
          alpha = 1,
          color = colors2)
```

```
> <mpl_toolkits.mplot3d.art3d.Line3DCollection object at 0x7f7f2b7fc860>
```

```
ax.text(0.5, 1, 0.4, r'$A(t)$ $\sin(\theta)$', fontsize = 20)
```

```
> Text(0.5, 1, '$A(t)$ $\\sin(\\theta)$')
```

```
ax.text(0.5, -0.9, -1, r'$A(t)$ $\cos(\theta)$', fontsize = 20)
```

```
> Text(0.5, -0.9, '$A(t)$ $\\cos(\\theta)$')
```

```
ax.set_xlabel('Time')
```

```
> Text(0.5, 0, 'Time')
```

```
ax.set_ylabel('Re')
```

```
> Text(0.5, 0, 'Re')
```

```
ax.set_zlabel('Im')
```

```
> Text(0.5, 0, 'Im')
```

```
ax.set_xlim(0,8)
```

```
> (0.0, 8.0)
```

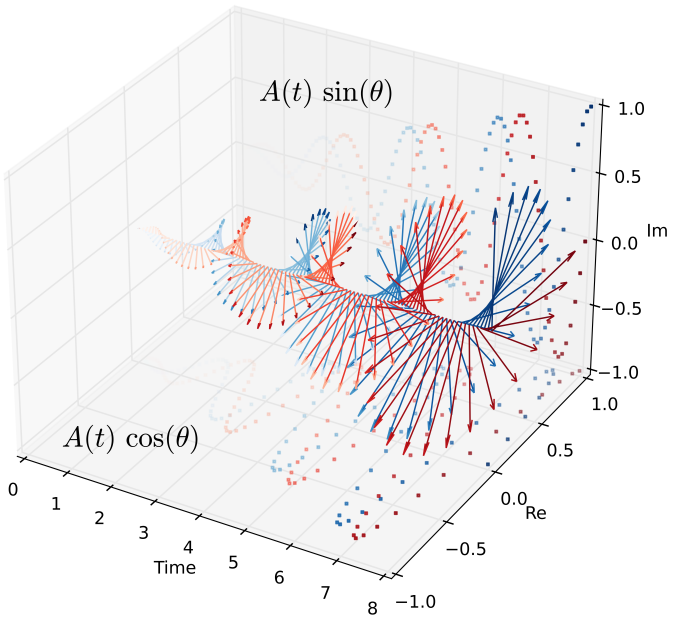
```
ax.set_ylim(-1,1)
```

```
> (-1.0, 1.0)
```

```
ax.set_zlim(-1,1)
```

```
> (-1.0, 1.0)
```

```
plt.show()
```




```
x1_vec = x1
x1_vec = x1_vec[99]
y1_vec = y1
y1_vec = y1_vec[99]

x2_vec = x2
x2_vec = x2_vec[99]
y2_vec = y2
y2_vec = y2_vec[99]
```

```
x, y = 0.0, 0.0

fig,ax = plt.subplots(1)
fig.set_figheight(6)
fig.set_figwidth(7)
ax.scatter(r*x1,r*y1, color = colors1, marker = ".", s = 100)
```

```
> <matplotlib.collections.PathCollection object at 0x7f7ffae50a58>
```

```
ax.scatter(r*x2,r*y2, color = colors2, marker = ".", s = 100)
```

```
> <matplotlib.collections.PathCollection object at 0x7f7f9b33cb70>
```

```
ax.arrow(0,0,x1_vec,y1_vec, width = 0.015, color = colors1[-1,:], head_width = 0.1)
```

```
> <matplotlib.patches.FancyArrow object at 0x7f7f9b33ce10>
```

```
ax.arrow(0,0,x2_vec,y2_vec, width = 0.015, color = colors2[-1,:], head_width = 0.1)
```

```
> <matplotlib.patches.FancyArrow object at 0x7f7f9b33c7f0>
```

```
ax.add_patch(patches.Arc((x,y), 2.3, 2.3, theta1=0.0, theta2=90.0, linestyle = '--'))
```

```
> <matplotlib.patches.Arc object at 0x7f7f9b33c978>
```

```
ax.text(0.7,1, r'$\mathcal{\Delta\varphi = \frac{\pi}{2}}$', fontsize = 24)
```

```
> Text(0.7, 1, '$\\mathcal{\\Delta\\varphi = \\frac{\\pi}{2}}$')
```

```
ax.text(1.18*x1_vec,y1_vec, r'$\mathcal{\varphi}_{1}$', fontsize = 20)
```

```
> Text(1.18, -9.797174393178826e-16, '$\\mathcal{\\varphi}_{1}$')
```

```
ax.text(x2_vec,1.22*y2_vec, r'$\mathcal{\varphi}_{2}$', fontsize = 20)
```

```
> Text(-7.354070601250002e-16, 1.22, '$\\mathcal{\\varphi}_{2}$')
```

```
ax.set_xlim(-1.35,1.35)
```

```
> (-1.35, 1.35)
```

```
ax.set_ylim(-1.35,1.35)
```

```
> (-1.35, 1.35)
```

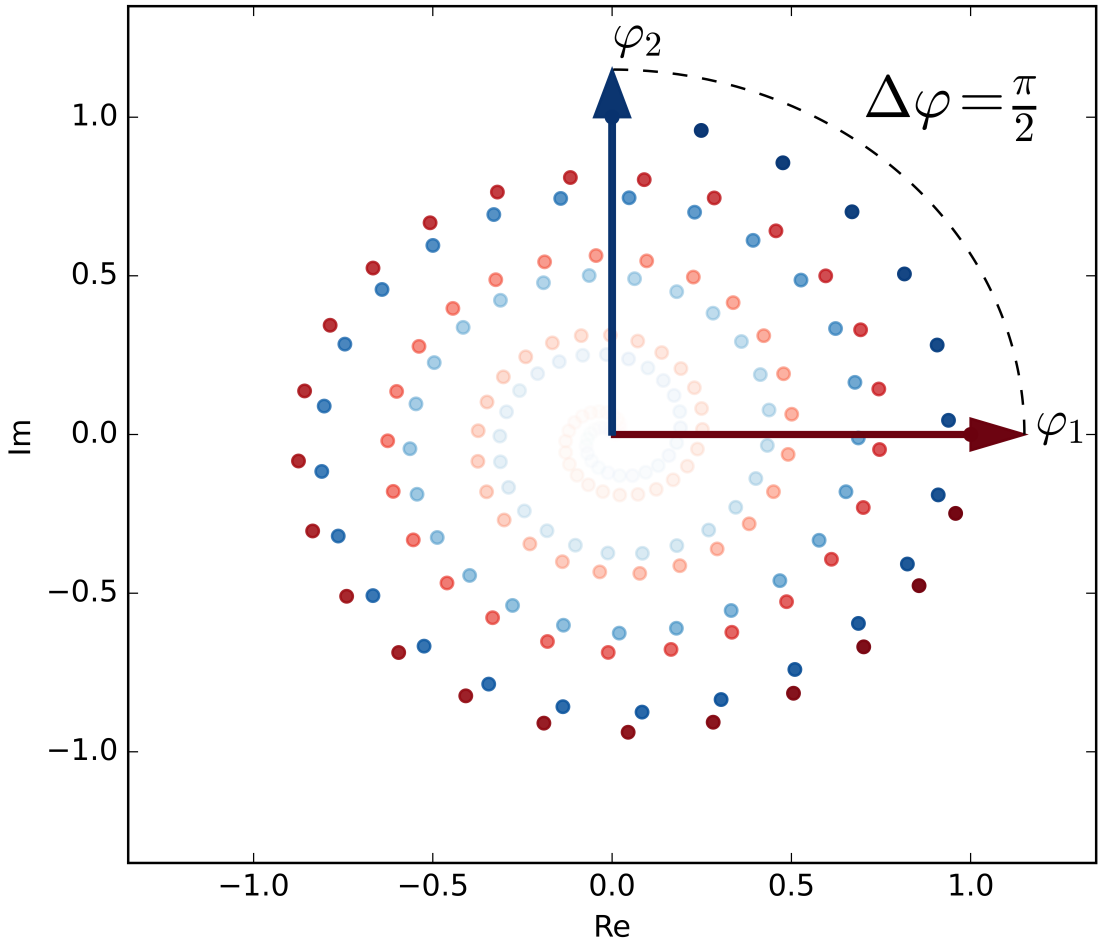
```
ax.set_xlabel('Re')
```

```
> Text(0.5, 0, 'Re')
```

```
ax.set_ylabel('Im')
```

```
> Text(0, 0.5, 'Im')
```

```
plt.show()
```




```
import sys
sys.path.insert(1, 'libs/')

import numpy as np
import scipy as sc
from scipy import io
import dynfc as dyn
```

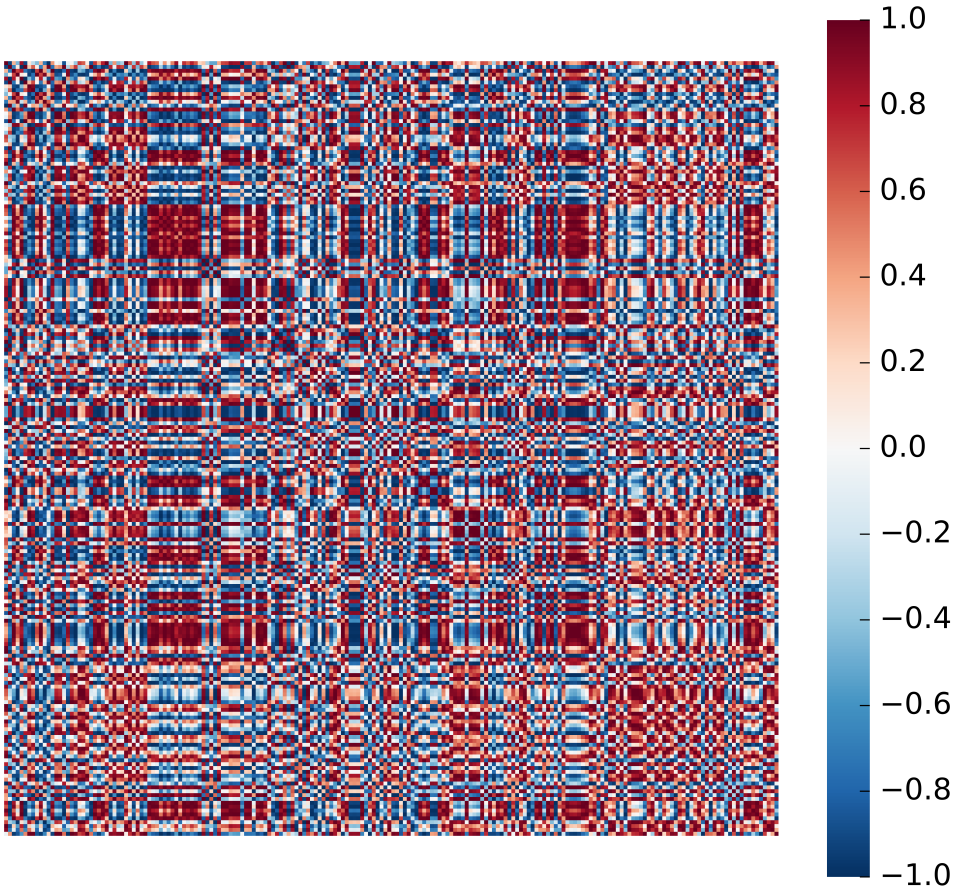
```
import seaborn as sns
import matplotlib.pyplot as plt

ts = sc.io.loadmat('data/ts.mat')['ts']
ts = ts

RSsig = np.zeros((ts.shape[0],ts.shape[1],1))
RSsig[:,:,0] = ts

Phases, syncConn, leidaArray = dyn.run_multiPat(RSsig)
```

```
> Signal filtered.
> Phases obtained.
> Matrices obtained.
> Routine finished for patient no. 1.
```

```
mat1 = syncConn[:,:,0,0]

aa = plt.figure(figsize = [7,6])
ax = sns.heatmap(mat1,
                 cmap = "RdBu_r",
                 vmin = -1,
                 vmax = 1,
                 square = True,
                 cbar = True)
ax.axis('off')
```

```
> (0.0, 200.0, 200.0, 0.0)
```

```
ax.tick_params(left=False, bottom=False)
plt.show()
```




```
aa = plt.figure(figsize = (12/50,4))
ax = sns.heatmap(leidaArray[:,0,]/max(abs(leidaArray[:,0,])),
                 cmap = "RdBu_r",
                 vmin = -1,
                 vmax = 1,
                 square = False,
                 cbar = False)
ax.axis('off')
```

```
> (0.0, 1.0, 1180.0, 0.0)
```

```
plt.show()
```

Package References

```
report::cite_packages(sessionInfo())
```

- JJ Allaire and Yihui Xie and Jonathan McPherson and Javier Luraschi and Kevin Ushey and Aron Atkins and Hadley Wickham and Joe Cheng and Winston Chang and Richard Iannone (2020). rmarkdown: Dynamic Documents for R. R package version 2.6. URL https://rmarkdown.rstudio.com.
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