ICIS workshop 'Finding Structure in Time' (June 30, 2018)

Exercise 2: CRQA on Continuous Data

The aim of this exercise is to practice cross-recurrence quantification analysis (CRQA) on continuous data, using a Matlab-based CRP-toolbox. Note that the following specific assignments only work with the functions in this toolbox. The toolbox and an online manual are available at http://tocsy.pik-potsdam.de/CRPtoolbox. Another option is to use the files and follow the instructions in the email that has been sent to all participants.

Specific assignments

1. Run the following code:

```
y1=sin([1:900]*2*pi/67)';
y2=sin(.01*([1:900]*2*pi/67).^2)';
```

Hint: Either copy-paste to an empty Matlab script file and then run it, or copy-paste each line individually to the command line and press 'enter' each time.

You have just created two different wavy time series, *y1* and *y2*, which are now in the 'Workspace'. In this assignment you will examine whether and how these time series are coupled by reconstructing a shared phase space.

2. Let's plot them first. By using the command 'hold on' you can plot two curves in one figure window. Run the following code:

```
plot(y1,'-b');
hold on;
plot(y2,'-r');
```

3. An embedding delay (using 'mi') and embedding dimension (using 'fnn') is necessary for the phase-space reconstruction. The embedding delay is based on the *mutual information* between two signals. Run:

```
mi(y1,y2);
```

Hint: Pick initial 'max. Lag' that is not too small (you might have to play with this a bit), and then click 'Apply'. The first local minimum of the curve as the appropriate value.

The embedding dimension is based on the *false nearest neighbors* analysis, and has to be calculated for each signal separately. Run:

```
fnn(y1);
fnn(y2);
```

Hint: You'll need to fill in the delay found above, select the Euclidean norm, and then click 'Apply'. Pick the first local minimum of the curve again. As a rule of thumb you can use the highest embedding dimension you found for further analyses.

4. We can now create the cross-recurrence plot (CRP) by running *crp(y1,y2)*. Fill in the parameter values you found in step 3. Select '*unthresholded neighbourhood*' to get an idea of the threshold you need and click '*Apply*'. Select an appropriate threshold (somewhere in the white region of the color-bar close to the red; usually the first tick mark in the white region of the color-bar is a good start) and create the CRP.

Note: Do not rescale the data. The sine waves were created in the same range, so that will not be necessary. Also, the CRP-toolbox will normalize the data automatically.

5. Can you understand what is going on? Explain the lack of recurrent points at the beginning of the time series.

6. Calculate the recurrence measures by running *crqa(y1,y2)*. Write down the results.

Note: You can store these results in a variable for further analysis by pressing 'store' or by directly assigning them to a variable: *var = crqa(y1,y2)*. Check the manual if you want to know more. The values represent:

1	Recurrence Rate
2	Determinism (Proportion of recurrent points on diagonal lines)
3	Average diagonal line length
4	Length of the longest diagonal line
5	Entropy of diagonal line lengths
6	Laminarity (Proportion of recurrent points on vertical lines)
7	Trapping Time (Average vertical line length)
8	Length of the longest vertical line

7. Perform the same steps with a shuffled version of the data of time series *y1*. You can use the embedding parameters you found earlier. Compare! (To make sure the RR is the same for both analyses you could select '*Fixed RR*' from the neighborhood menu. In the threshold box type the RR you found in the previous analysis.)