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

Exercise 3: CRQA on Categorical Data

In this exercise you will perform cross-recurrence quantification analysis (CRQA) on categorical data. Note that for the following specific assignments you will need a function from the CRP-toolbox again, as well as some special-purpose Matlab functions.

Start Matlab and select the folder where the M-functions and data file are located. That is, make Matlab's active folder equal to the folder to which you downloaded this (e.g. 'C:\...\My Documents'). After this you can call the functions in Matlab on the command line.

Specific assignments

1. First run the following code:

   load('workshop_data.mat');

Hint: Either copy-paste to an empty Matlab script file and then run it, or copy-paste the lines in each individual assignment to the command line followed by 'enter'.

You have just loaded two time series, 'PP1' and 'PP2', into the Workspace. These time series contain categorical data having integer value from 0 to 5. The time series come from a dyadic interaction study, where the behavior of each of the two participants was coded at 1 Hz by using the same six specific behavioral categories.

2. Plot these time series to see what they look like. (Remember that the command 'hold on' allows you to plot two curves in one figure window.) Run:

   figure(1); plot(PP1,'-b'); hold on; plot(PP2,'-r');

3. Next step is to create the cross-recurrence matrix, 'rec', by running:

   rec = CatCRMatrix(PP1,PP2);

   Have a look at the M-function 'CatCRMatrix' and try to understand what it does. Also, have a look at the recurrence matrix 'rec' consisting of 1650×1650 points. The analysis distinguishes between two types of matches (recurrences), which represent different combinations of behaviors of the interaction partners. Each combination corresponds to a number (-1 or +1) in the recurrence matrix 'rec'. All other combinations are considered to be non-matching (non-recurrent) and obtained the value 0.

Note: As explained in the lecture, for categorical data the phase-space reconstruction (like you did in the previous exercise with continuous data) is not necessary. You can directly

build-up the cross-recurrence matrix by comparing the values in the two time series. In the cross-recurrence plot (CRP) a colored dot (i.e. recurrent point) is plotted whenever these values match in a pre-specified way. This first creates the main diagonal (Line-of-Synchrony) of the CRP, containing the equal-time behavioral matches. But by shifting the time series with respect to each other in both directions, lines parallel to the Line-of-Synchrony on both sides are created. Each of these lines reflects the behavioral matches with a specific (increasing) delay between the occurrence of those behaviors in the two time series.

4. Now let's plot the CRP to study its structure, by running:

PlotCRP(rec);

Note: This is a typical checkerboard pattern you would expect in categorical CRPs. There are three colors in this CRP representing the three different types of states of the dyadic system, based on the numerical values in 'rec': red for the value -1, blue for the value +1, and white for the non-matching (i.e. non-recurrent) states with value 0. All together, the CRP nicely displays the rich coordinative structure of the dyadic interaction across all possible timescales. The color-coded recurrence analysis performed here is called *Chromatic CRQA*.

5. Finally, calculate some recurrence measures to quantify this structure. For now we will ignore the different types of matching behaviors (colors) and treat all recurrences equal (although some recurrences are more equal than others ;-)). Run the following function:

   output = CRQA_demo(rec);

   This function performs *Anisotropic CRQA* by quantifying both the vertical and horizontal line structures. It produces the following measures:

   LAM = Laminarity (Proportion of recurrent points on vertical/horizontal lines)
   TT = Trapping Time (Average vertical/horizontal line length)
   MaxL = Length of the longest vertical/horizontal line
   ENT_L = Entropy of vertical/horizontal line lengths

   You can have a look at the results by opening the file 'output' from the Workspace. In the file you'll find two rows. The upper row gives the values for the vertical line structures, the lower row those for the horizontal line structures.

Note: By calculating both the vertical and horizontal line measures and comparing them, Anisotropic CRQA enables you to study asymmetries in the dynamics. Differences between these measures reflect differences in relative strength and dominance between the interaction partners. For more information see:

Cox, R.F.A., Van der Steen, S., De Jonge-Hoekstra, L., Guevara, M., & Van Dijk, M. (2016). Chromatic and anisotropic cross-recurrence quantification analysis of interpersonal behaviour. In C. Webber, C. Ioana, & N. Marwan (Eds). *Recurrence Plots and Their Quantifications: Expanding Horizons* (pp. 209-225). Springer Proceedings in Physics. (link)