Neuro-Integrative Connectivity (NIC) Workflow Component II: Data Analysis and Functional Connectivity Computation

Version 1.0

Section 0 — Licensing

Section 1 — Uses

The software is intended to be used for the computation of pairwise measures of correlation among electrode readings obtained from electroencephalography (EEG). The current measures computed by the software are nonlinear correlation coefficient developed by Pijn et al. (Pijn et al., 1990), phase coherence developed by Mormann et al. (Mormann et al., 2000), and Pearson's linear correlation coefficient. Additional functional connectivity measures will continue to be added to the NIC workflow.

The program reads EEG data stored in files in the Cloudwave Signal Format (CSF), preferably generated by the companion NICConverter tool.

Section 2 — Requirements

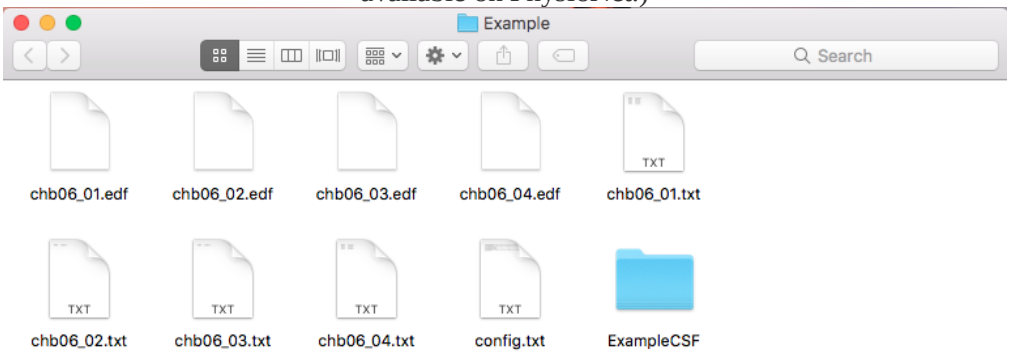
- Java SE 8 or higher is required to run the software; Java SE 10 is available at http://www.oracle.com/technetwork/java/javase/downloads/index.html.

- The software requires Javax JSON and Apache Commons Math JAR files. These should be contained in the JAR file for the converter. However, if there are issues, the required JAR files can be downloaded locally and added to the classpath during execution.

    - **JSON:** JAR files for JSON processing are included in Java EE 7 or higher; Java EE 8 is available at http://www.oracle.com/technetwork/java/javaee/downloads/index.html. Alternatively, specific JAR files may be obtained at http://download.oracle.com/otndocs/jcp/json_p-1_1-final-spec/index.html.

    - **Apache Commons:** The JAR file for Apache Commons Math is available at https://commons.apache.org/proper/commons-math/.

- CSF files should be separated into directories with one directory per patient. CSF files do not need to be located in the same directory as the EDF files; it is simply done here for convenience. (The EDF files used in this example were taken from the CHB-MIT Database that is publicly available on PhysioNet.)



Section 3 — Single Event Processing

Section 3.1: Invocation

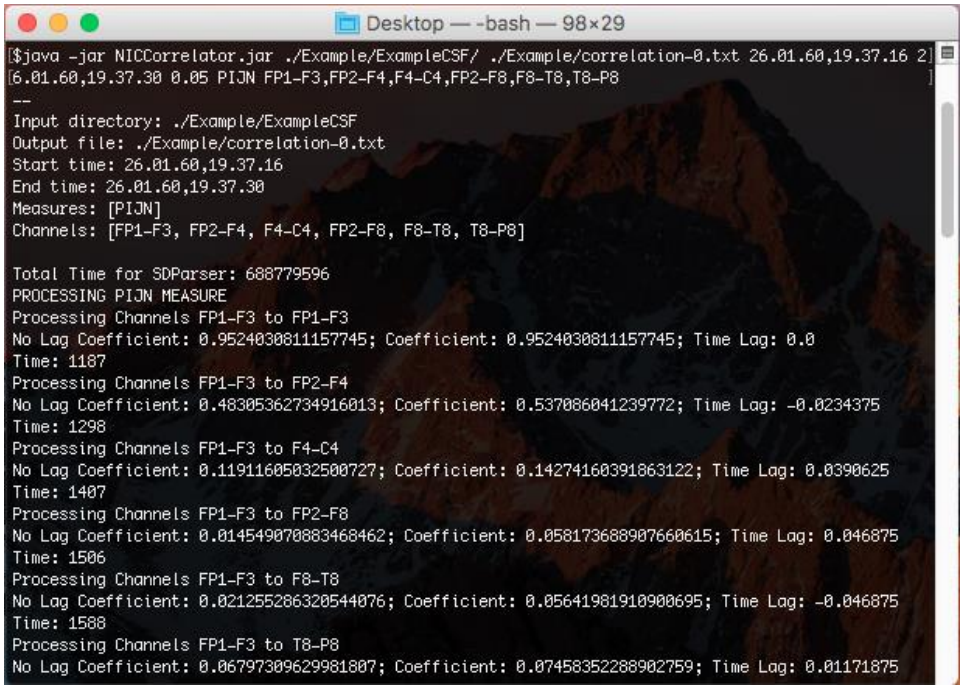
From the command line, navigate to the location of the jar file and enter

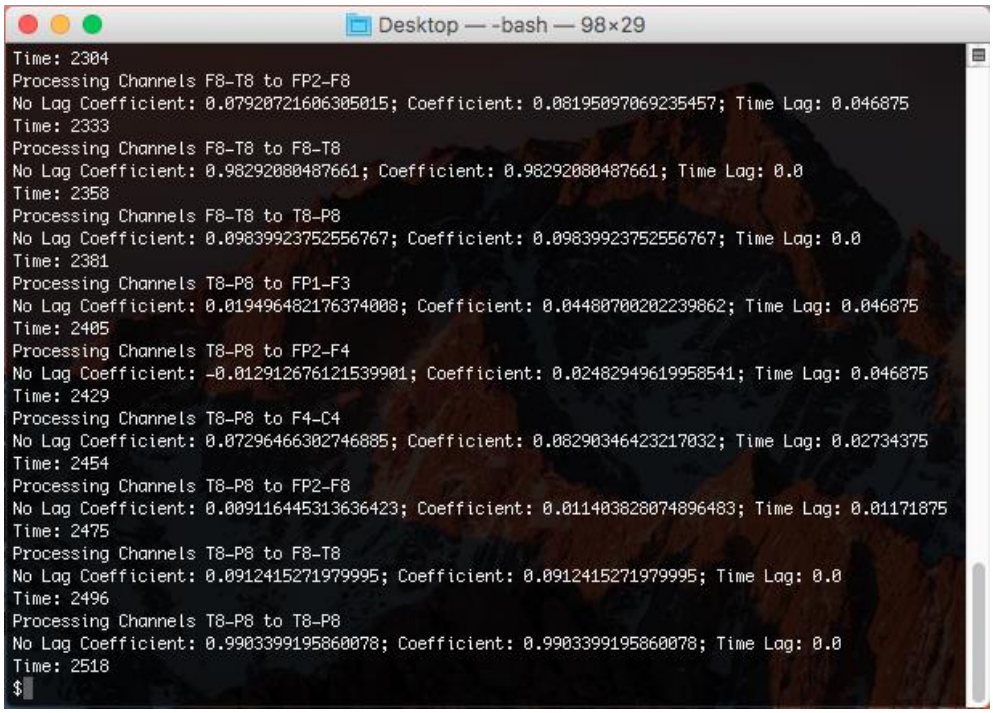
```
java -jar NICCorrelator.jar <CSFDir> <results> <start> <end> <lag>
                    <measureList> <channelList>
```

with the following mandatory arguments:

- `CSFDir`: The String filepath of the directory in which the CSF files to be analyzed are located
- `results`: The String filepath of the output text file
- `start`: The String representing the start time of the event, in the form DD.MM.YY,hh.mm.ss
- `end`: The String representing the end time of the event, in the form DD.MM.YY,hh.mm.ss
- `lag`: The floating point value representing the maximum possible displacement of time (forward and backward) in which to compute correlation
- `measureList`: The String representing the comma-separated list of names of measures to be considered; current options include ALL, PEARSON, PHASE, and PIJN.
- `channelList`: The String representing a comma-separated list of channels that will be analyzed

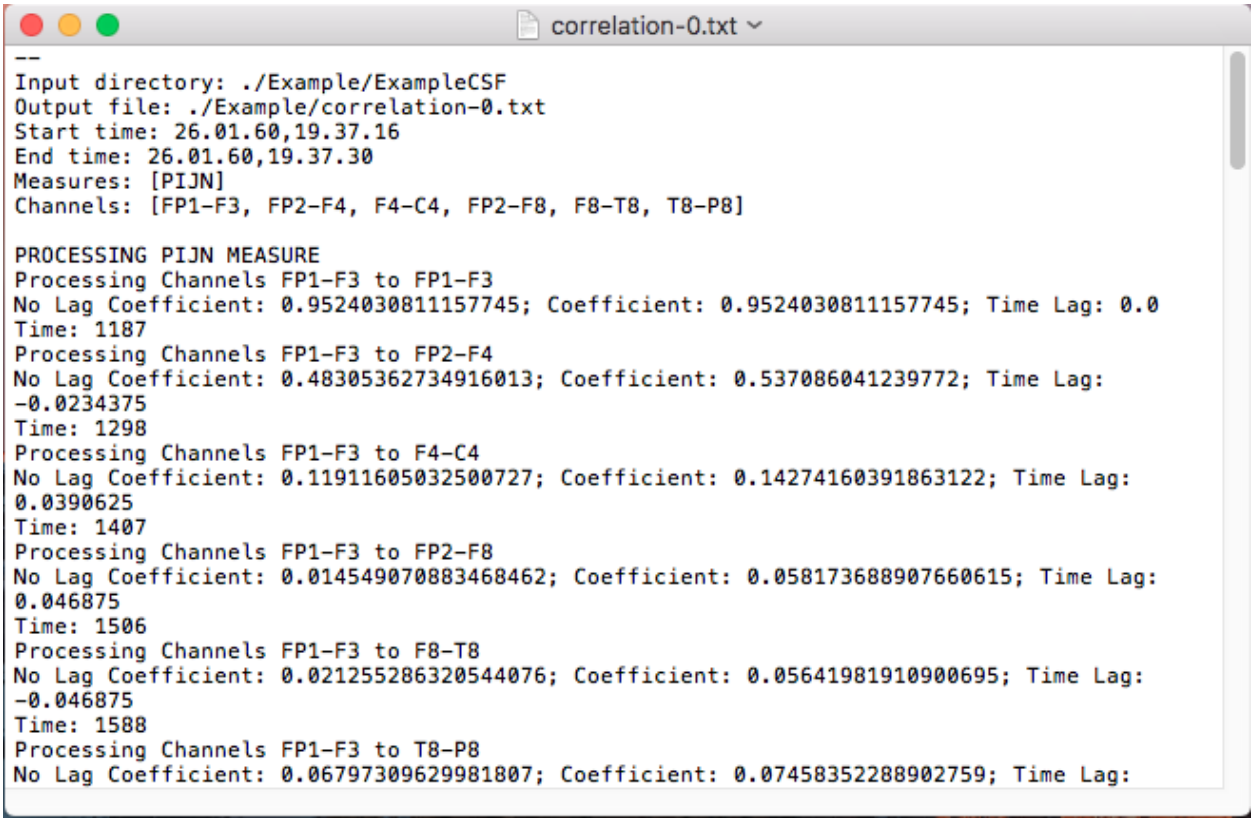
The program will then automatically loop through the coupling measures indicated, in the order PIJN, PHASE, and PEARSON, and print the values to the screen for observational purposes.


Desktop — -bash — 98×29
[$java -jar NICCorrelator.jar ./Example/ExampleCSF/ ./Example/correlation-0.txt 26.01.60,19.37.16 2]
[6.01.60,19.37.30 0.05 PIJN FP1-F3,FP2-F4,F4-C4,FP2-F8,F8-T8,T8-P8]
--
Input directory: ./Example/ExampleCSF
Output file: ./Example/correlation-0.txt
Start time: 26.01.60,19.37.16
End time: 26.01.60,19.37.30
Measures: [PIJN]
Channels: [FP1-F3, FP2-F4, F4-C4, FP2-F8, F8-T8, T8-P8]
Total Time for SDParser: 688779596
PROCESSING PIJN MEASURE
Processing Channels FP1-F3 to FP1-F3
No Lag Coefficient: 0.9524030811157745; Coefficient: 0.9524030811157745; Time Lag: 0.0
Time: 1187
Processing Channels FP1-F3 to FP2-F4
No Lag Coefficient: 0.48305362734916013; Coefficient: 0.537086041239772; Time Lag: -0.0234375
Time: 1298
Processing Channels FP1-F3 to F4-C4
No Lag Coefficient: 0.11911605032500727; Coefficient: 0.14274160391863122; Time Lag: 0.0390625
Time: 1407
Processing Channels FP1-F3 to FP2-F8
No Lag Coefficient: 0.014549070883468462; Coefficient: 0.058173688907660615; Time Lag: 0.046875
Time: 1506
Processing Channels FP1-F3 to F8-T8
No Lag Coefficient: 0.021255286320544076; Coefficient: 0.0564198191090069 5; Time Lag: -0.046875
Time: 1588
Processing Channels FP1-F3 to T8-P8
No Lag Coefficient: 0.06797309629981807; Coefficient: 0.07458352288902759; Time Lag: 0.01171875


Desktop — -bash — 98×29
Time: 2304
Processing Channels F8-T8 to FP2-F8
No Lag Coefficient: 0.07920721606305015; Coefficient: 0.08195097069235457; Time Lag: 0.046875
Time: 2333
Processing Channels F8-T8 to F8-T8
No Lag Coefficient: 0.98292080487661; Coefficient: 0.98292080487661; Time Lag: 0.0
Time: 2358
Processing Channels F8-T8 to T8-P8
No Lag Coefficient: 0.09839923752556767; Coefficient: 0.09839923752556767; Time Lag: 0.0
Time: 2381
Processing Channels T8-P8 to FP1-F3
No Lag Coefficient: 0.019496482176374008; Coefficient: 0.04480700202239862; Time Lag: 0.046875
Time: 2405
Processing Channels T8-P8 to FP2-F4
No Lag Coefficient: -0.012912676121539901; Coefficient: 0.02482949619958541; Time Lag: 0.046875
Time: 2429
Processing Channels T8-P8 to F4-C4
No Lag Coefficient: 0.07296466302746885; Coefficient: 0.08290346423217032; Time Lag: 0.02734375
Time: 2454
Processing Channels T8-P8 to FP2-F8
No Lag Coefficient: 0.009116445313636423; Coefficient: 0.011403828074896483; Time Lag: 0.01171875
Time: 2475
Processing Channels T8-P8 to F8-T8
No Lag Coefficient: 0.09124152719799 95; Coefficient: 0.0912415271979995; Time Lag: 0.0
Time: 2496
Processing Channels T8-P8 to T8-P8
No Lag Coefficient: 0.9903399195860078; Coefficient: 0.9903399195860078; Time Lag: 0.0
Time: 2518
$

Section 3.2: Output

The output of the program will be a text file in the location indicated by the `results` parameter. The text file is prefaced by a labeled list of the input parameters -- this is for verification purpose. The text file contains sections corresponding to the measures indicated in the order PIJN, PHASE, PEARSON. The sections will include the data printed to the screen during runtime, in addition to three comma-separated matrices that contain the maximal correlation values over the window, the times at which the maximal values occur, and the z-scores of the maximal correlation values, normalized over their collective average and standard deviation.



correlation-0.txt

```
Time: 2454
Processing Channels T8-P8 to FP2-F8
No Lag Coefficient: 0.009116445313636423; Coefficient: 0.011403828074896483; Time Lag: 0.01171875
Time: 2475
Processing Channels T8-P8 to F8-T8
No Lag Coefficient: 0.0912415271979995; Coefficient: 0.0912415271979995; Time Lag: 0.0
Time: 2496
Processing Channels T8-P8 to T8-P8
No Lag Coefficient: 0.9903399195860078; Coefficient: 0.9903399195860078; Time Lag: 0.0
Time: 2518
X,FP1-F3, FP2-F4, F4-C4, FP2-F8, F8-T8, T8-P8
FP1-F3,0.9524030811157745, 0.537086041239772, 0.14274160391863122, 0.058173688907660615, 0.05641981910900695,
0.07458352288902759
FP2-F4,0.42134289011071624, 0.9327192378237221, 0.06928170535609024, 0.24565664650274155, 0.08719439205165802,
0.024109890772524456
F4-C4,0.4343232251904755, 0.39884783491822295, 0.9806582338987587, 0.10036119642880381, 0.19949149511796394,
0.07831186574419102
FP2-F8,0.0285325612075793, 0.16930284416337016, 0.023246464971836578, 0.9821425182190429, 0.07659836946495946,
0.03328292714990044
F8-T8,0.026799129012850864, 0.04892104139447939, 0.18037060521636394, 0.08195097069235457, 0.98292080487661,
0.09839923752556767
T8-P8,0.04480700202239862, 0.02482949619958541, 0.08290346423217032, 0.011403828074896483, 0.0912415271979995,
0.9903399195860078

X,FP1-F3, FP2-F4, F4-C4, FP2-F8, F8-T8, T8-P8
FP1-F3,0.0, -0.0234375, 0.0390625, 0.046875, -0.046875, 0.01171875
FP2-F4,-0.015625, 0.0, 0.046875, 0.00390625, -0.046875, 0.03125
F4-C4,-0.046875, -0.046875, 0.0, 0.046875, 0.0, -0.01953125
FP2-F8,0.04296875, 0.0, -0.046875, 0.0, -0.046875, 0.04296875
F8-T8,0.046875, 0.04296875, 0.0, 0.046875, 0.0, 0.0
T8-P8,0.046875, 0.046875, 0.02734375, 0.01171875, 0.0, 0.0

X,FP1-F3, FP2-F4, F4-C4, FP2-F8, F8-T8, T8-P8
FP1-F3,2.022679036881062, 0.7890611438368739, -0.3822617425225265, -0.6334541645000132, -0.6386636910976575,
-0.5847119678703185
FP2-F4,0.44526879119767043, 1.964212037077241, -0.6004599780560784, -0.07657277287883524, -0.5472538518958217,
-0.7346340026715826
F4-C4,0.4838243332887943, 0.37845163725002257, 2.106605432133694, -0.5081444392921176, -0.21369730983585108,
-0.5736376559208106
FP2-F8,-0.7214973266870142, -0.30336678257304284, -0.7371986398397629, 2.111014207888269, -0.578727260889477,
-0.7073872954041545
F8-T8,-0.7266461473865797, -0.6609373410479801, -0.27049216689392913, -0.5628284076894823, 2.113325955913294,
-0.5139720538036051
T8-P8,-0.6731572889306924, -0.7324965557442447, -0.5599992122534451, -0.772374872390328, -0.5352326299069876,
2.135362982515412

Total Time: 2519
```

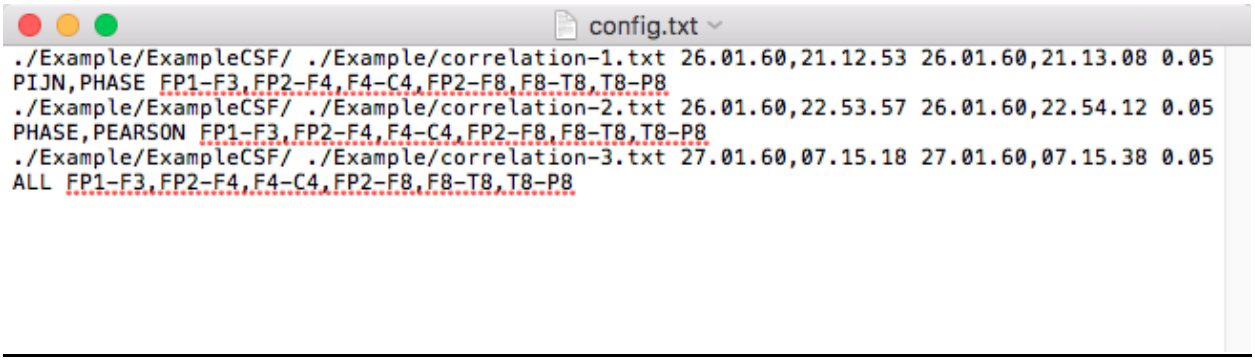
Section 4: Batch Event Processing

Section 4.1: Invocation

From the command line, enter

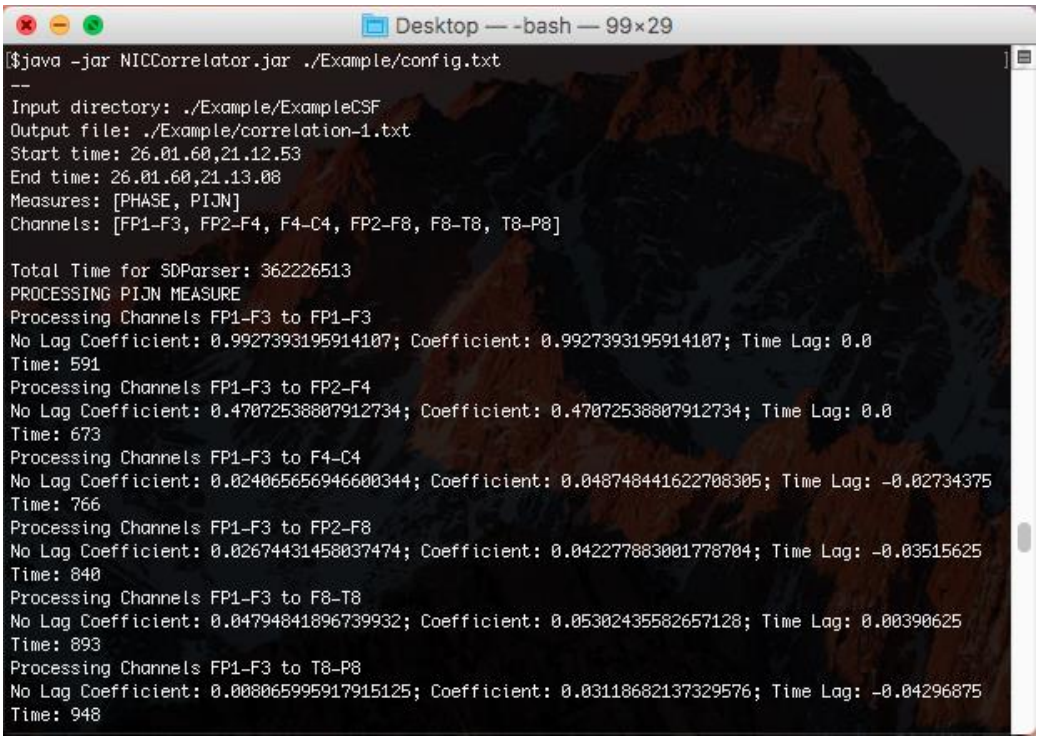
```
java -jar NICCorrelator.jar <config>
```

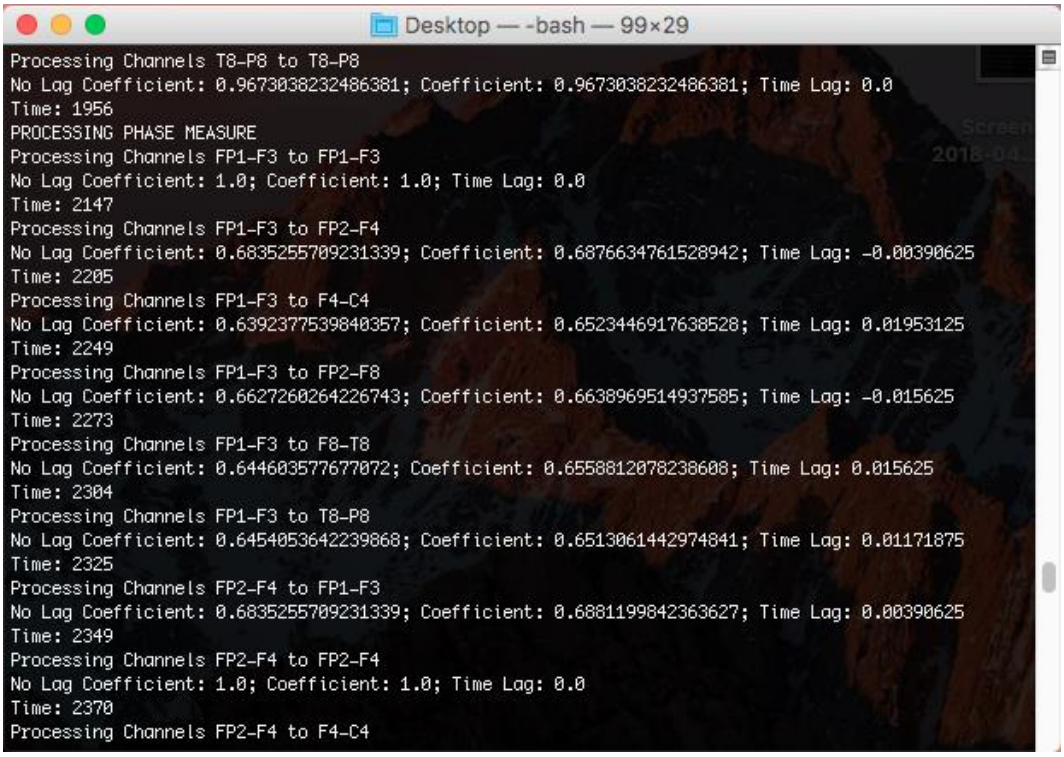
where `config` is a mandatory String argument representing the filepath of a configuration text file where each line is a space-separated string of the parameters listed in the Single Event Processing section in the same order.

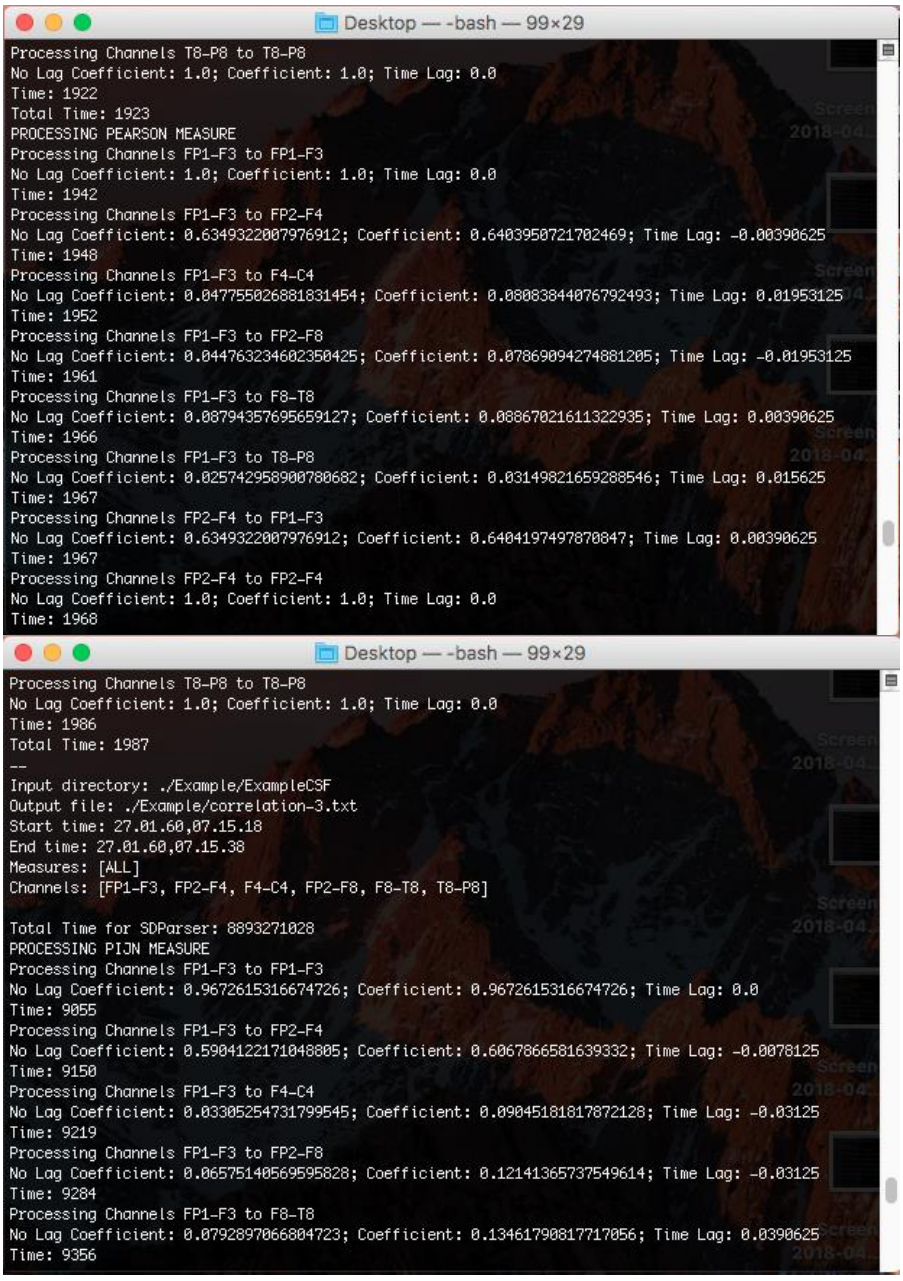


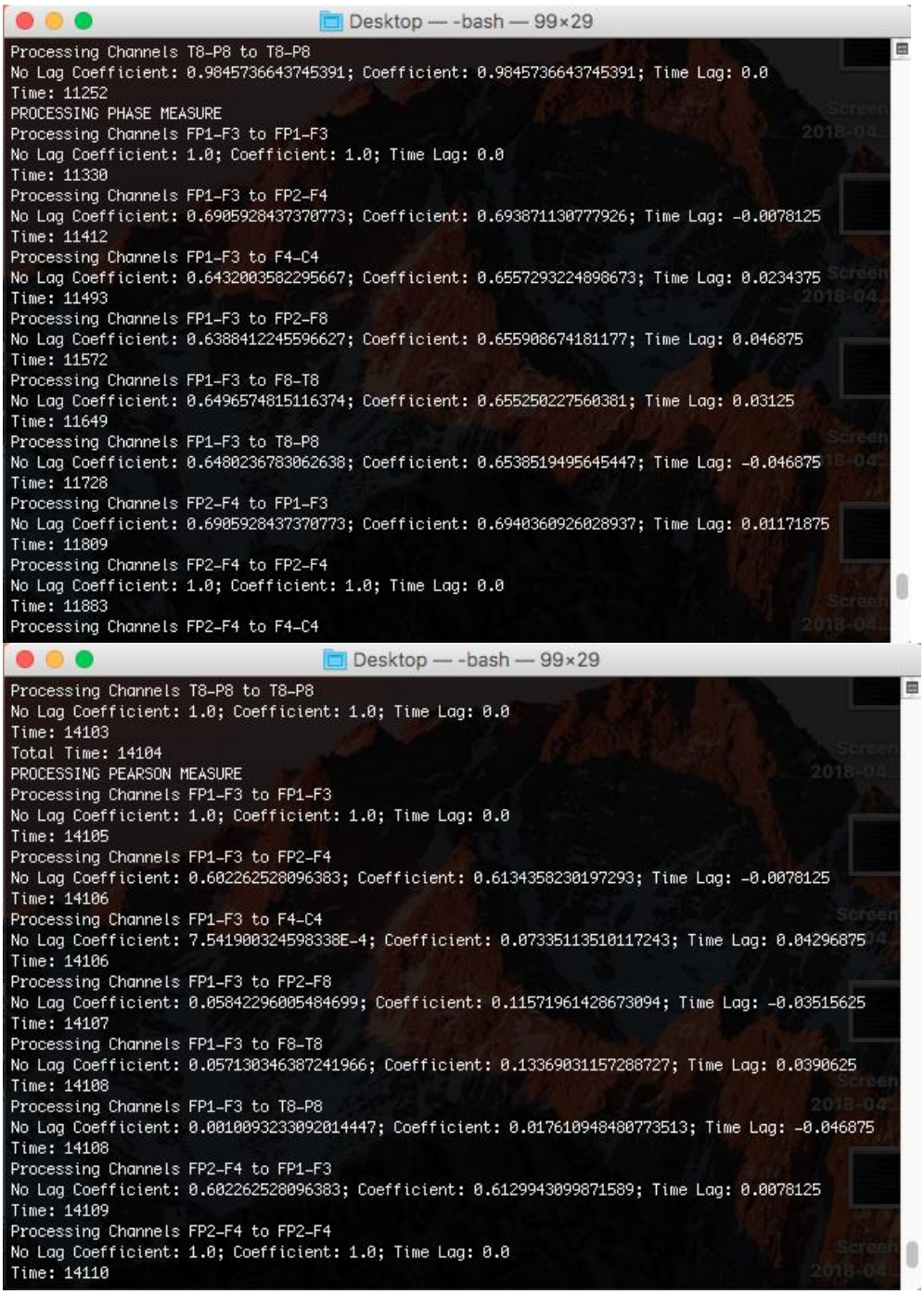
The program will then automatically loop through each line of the configuration file as in Section 3.

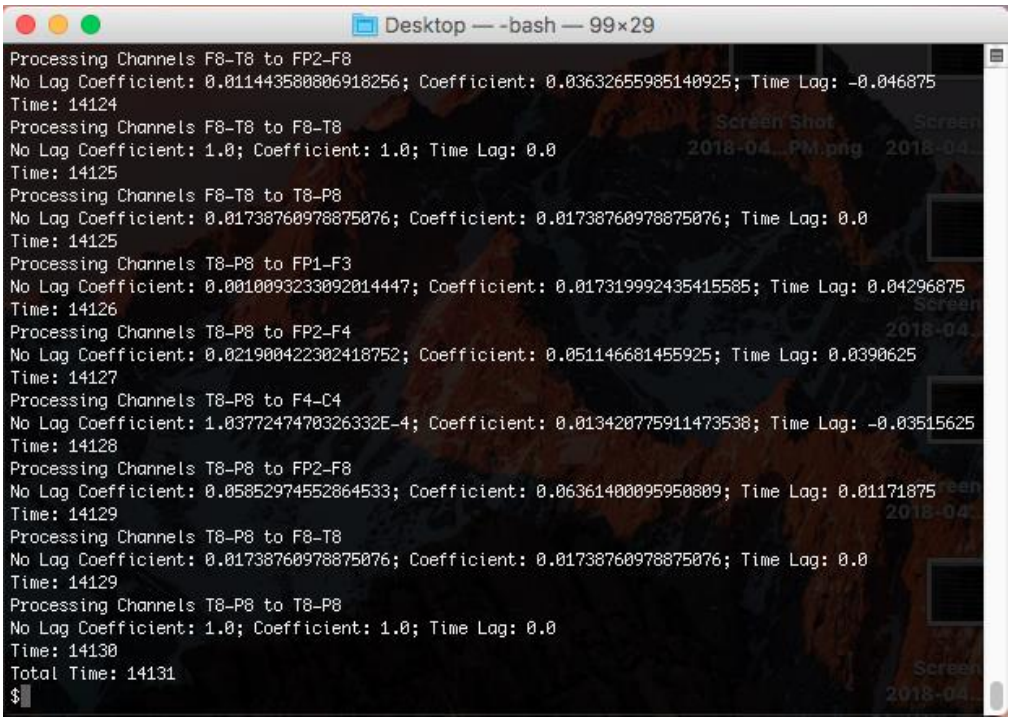
NOTE: Be careful that the names of the text files are distinct in each line. The program WILL overwrite any existing text files at the specified file path.


Desktop — -bash — 99×29
[$java -jar NICCorrelator.jar ./Example/config.txt
--
Input directory: ./Example/ExampleCSF
Output file: ./Example/correlation-1.txt
Start time: 26.01.60,21.12.53
End time: 26.01.60,21.13.08
Measures: [PHASE, PIJN]
Channels: [FP1-F3, FP2-F4, F4-C4, FP2-F8, F8-T8, T8-P8]
Total Time for SDParser: 362226513
PROCESSING PIJN MEASURE
Processing Channels FP1-F3 to FP1-F3
No Lag Coefficient: 0.9927393195914107; Coefficient: 0.9927393195914107; Time Lag: 0.0
Time: 591
Processing Channels FP1-F3 to FP2-F4
No Lag Coefficient: 0.47072538807912734; Coefficient: 0.47072538807912734; Time Lag: 0.0
Time: 673
Processing Channels FP1-F3 to F4-C4
No Lag Coefficient: 0.024065656946600344; Coefficient: 0.048748441622708305; Time Lag: -0.02734375
Time: 766
Processing Channels FP1-F3 to FP2-F8
No Lag Coefficient: 0.02674431458037474; Coefficient: 0.042277883001778704; Time Lag: -0.03515625
Time: 840
Processing Channels FP1-F3 to F8-T8
No Lag Coefficient: 0.04794841896739932; Coefficient: 0.05302435582657128; Time Lag: 0.00390625
Time: 893
Processing Channels FP1-F3 to T8-P8
No Lag Coefficient: 0.008065995917915125; Coefficient: 0.03118682137329576; Time Lag: -0.04296875
Time: 948


Desktop — -bash — 99×29
Processing Channels T8-P8 to T8-P8
No Lag Coefficient: 0.9673038232486381; Coefficient: 0.9673038232486381; Time Lag: 0.0
Time: 1956
PROCESSING PHASE MEASURE
Processing Channels FP1-F3 to FP1-F3
No Lag Coefficient: 1.0; Coefficient: 1.0; Time Lag: 0.0
Time: 2147
Processing Channels FP1-F3 to FP2-F4
No Lag Coefficient: 0.6835255709231339; Coefficient: 0.6876634761528942; Time Lag: -0.00390625
Time: 2205
Processing Channels FP1-F3 to F4-C4
No Lag Coefficient: 0.6392377539840357; Coefficient: 0.6523446917638528; Time Lag: 0.01953125
Time: 2249
Processing Channels FP1-F3 to FP2-F8
No Lag Coefficient: 0.6627260264226743; Coefficient: 0.6638969514937585; Time Lag: -0.015625
Time: 2273
Processing Channels FP1-F3 to F8-T8
No Lag Coefficient: 0.644603577677072; Coefficient: 0.6558812078238608; Time Lag: 0.015625
Time: 2304
Processing Channels FP1-F3 to T8-P8
No Lag Coefficient: 0.6454053642239868; Coefficient: 0.6513061442974841; Time Lag: 0.01171875
Time: 2325
Processing Channels FP2-F4 to FP1-F3
No Lag Coefficient: 0.6835255709231339; Coefficient: 0.6881199842363627; Time Lag: 0.00390625
Time: 2349
Processing Channels FP2-F4 to FP2-F4
No Lag Coefficient: 1.0; Coefficient: 1.0; Time Lag: 0.0
Time: 2370
Processing Channels FP2-F4 to F4-C4

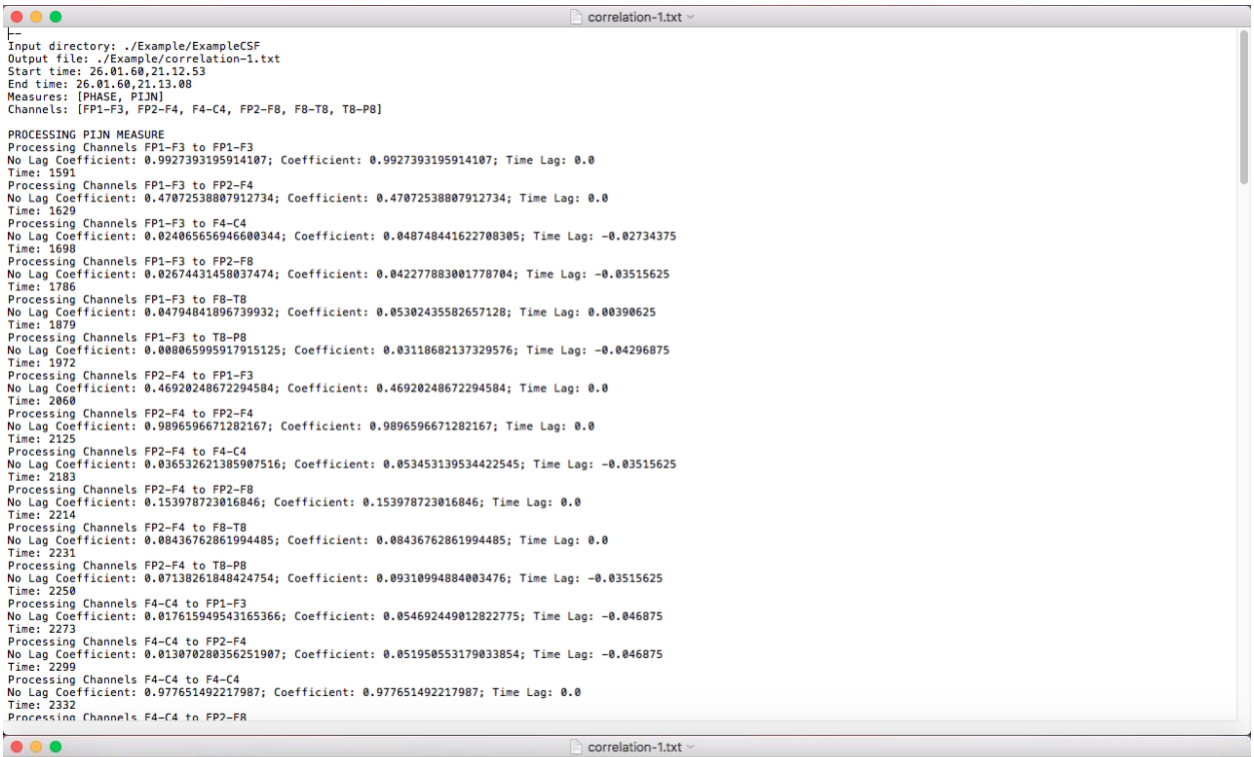

Desktop — -bash — 99×29
Processing Channels T8-P8 to T8-P8
No Lag Coefficient: 1.0; Coefficient: 1.0; Time Lag: 0.0
Time: 1922
Total Time: 1923
PROCESSING PEARSON MEASURE
Processing Channels FP1-F3 to FP1-F3
No Lag Coefficient: 1.0; Coefficient: 1.0; Time Lag: 0.0
Time: 1942
Processing Channels FP1-F3 to FP2-F4
No Lag Coefficient: 0.6349322007976912; Coefficient: 0.6403950721702469; Time Lag: -0.00390625
Time: 1948
Processing Channels FP1-F3 to F4-C4
No Lag Coefficient: 0.047755026881831454; Coefficient: 0.08083844076792493; Time Lag: 0.01953125
Time: 1952
Processing Channels FP1-F3 to FP2-F8
No Lag Coefficient: 0.044763234602350425; Coefficient: 0.07869094274881205; Time Lag: -0.01953125
Time: 1961
Processing Channels FP1-F3 to F8-T8
No Lag Coefficient: 0.08794357695659127; Coefficient: 0.08867021611322935; Time Lag: 0.00390625
Time: 1966
Processing Channels FP1-F3 to T8-P8
No Lag Coefficient: 0.025742958900780682; Coefficient: 0.03149821659288546; Time Lag: 0.015625
Time: 1967
Processing Channels FP2-F4 to FP1-F3
No Lag Coefficient: 0.6349322007976912; Coefficient: 0.6404197497870847; Time Lag: 0.00390625
Time: 1967
Processing Channels FP2-F4 to FP2-F4
No Lag Coefficient: 1.0; Coefficient: 1.0; Time Lag: 0.0
Time: 1968
Desktop — -bash — 99×29
Processing Channels T8-P8 to T8-P8
No Lag Coefficient: 1.0; Coefficient: 1.0; Time Lag: 0.0
Time: 1986
Total Time: 1987
--
Input directory: ./Example/ExampleCSF
Output file: ./Example/correlation-3.txt
Start time: 27.01.60,07.15.18
End time: 27.01.60,07.15.38
Measures: [ALL]
Channels: [FP1-F3, FP2-F4, F4-C4, FP2-F8, F8-T8, T8-P8]
Total Time for SDParser: 8893271028
PROCESSING PIJN MEASURE
Processing Channels FP1-F3 to FP1-F3
No Lag Coefficient: 0.9672615316674726; Coefficient: 0.9672615316674726; Time Lag: 0.0
Time: 9055
Processing Channels FP1-F3 to FP2-F4
No Lag Coefficient: 0.5904122171048805; Coefficient: 0.6067866581639332; Time Lag: -0.0078125
Time: 9150
Processing Channels FP1-F3 to F4-C4
No Lag Coefficient: 0.03305254731799545; Coefficient: 0.09045181817872128; Time Lag: -0.03125
Time: 9219
Processing Channels FP1-F3 to FP2-F8
No Lag Coefficient: 0.06575140569595828; Coefficient: 0.12141365737549614; Time Lag: -0.03125
Time: 9284
Processing Channels FP1-F3 to F8-T8
No Lag Coefficient: 0.0792897066804723; Coefficient: 0.13461790817717056; Time Lag: 0.0390625
Time: 9356


Desktop — -bash — 99×29
Processing Channels T8-P8 to T8-P8
No Lag Coefficient: 0.9845736643745391; Coefficient: 0.9845736643745391; Time Lag: 0.0
Time: 11252
PROCESSING PHASE MEASURE
Processing Channels FP1-F3 to FP1-F3
No Lag Coefficient: 1.0; Coefficient: 1.0; Time Lag: 0.0
Time: 11330
Processing Channels FP1-F3 to FP2-F4
No Lag Coefficient: 0.6905928437370773; Coefficient: 0.693871130777926; Time Lag: -0.0078125
Time: 11412
Processing Channels FP1-F3 to F4-C4
No Lag Coefficient: 0.6432003582295667; Coefficient: 0.6557293224898673; Time Lag: 0.0234375
Time: 11493
Processing Channels FP1-F3 to FP2-F8
No Lag Coefficient: 0.6388412245596627; Coefficient: 0.655908674181177; Time Lag: 0.046875
Time: 11572
Processing Channels FP1-F3 to F8-T8
No Lag Coefficient: 0.6496574815116374; Coefficient: 0.655250227560381; Time Lag: 0.03125
Time: 11649
Processing Channels FP1-F3 to T8-P8
No Lag Coefficient: 0.6480236783062638; Coefficient: 0.6538519495645447; Time Lag: -0.046875
Time: 11728
Processing Channels FP2-F4 to FP1-F3
No Lag Coefficient: 0.6905928437370773; Coefficient: 0.6940360926028937; Time Lag: 0.01171875
Time: 11809
Processing Channels FP2-F4 to FP2-F4
No Lag Coefficient: 1.0; Coefficient: 1.0; Time Lag: 0.0
Time: 11883
Processing Channels FP2-F4 to F4-C4
Desktop — -bash — 99×29
Processing Channels T8-P8 to T8-P8
No Lag Coefficient: 1.0; Coefficient: 1.0; Time Lag: 0.0
Time: 14103
Total Time: 14104
PROCESSING PEARSON MEASURE
Processing Channels FP1-F3 to FP1-F3
No Lag Coefficient: 1.0; Coefficient: 1.0; Time Lag: 0.0
Time: 14105
Processing Channels FP1-F3 to FP2-F4
No Lag Coefficient: 0.602262528096383; Coefficient: 0.6134358230197293; Time Lag: -0.0078125
Time: 14106
Processing Channels FP1-F3 to F4-C4
No Lag Coefficient: 7.541900324598338E-4; Coefficient: 0.07335113510117243; Time Lag: 0.04296875
Time: 14106
Processing Channels FP1-F3 to FP2-F8
No Lag Coefficient: 0.05842296005484699; Coefficient: 0.11571961428673094; Time Lag: -0.03515625
Time: 14107
Processing Channels FP1-F3 to F8-T8
No Lag Coefficient: 0.05713034638724196 6; Coefficient: 0.13369031157288727; Time Lag: 0.0390625
Time: 14108
Processing Channels FP1-F3 to T8-P8
No Lag Coefficient: 0.0010093233092014447; Coefficient: 0.017610948480773513; Time Lag: -0.046875
Time: 14108
Processing Channels FP2-F4 to FP1-F3
No Lag Coefficient: 0.602262528096383; Coefficient: 0.6129943099871589; Time Lag: 0.0078125
Time: 14109
Processing Channels FP2-F4 to FP2-F4
No Lag Coefficient: 1.0; Coefficient: 1.0; Time Lag: 0.0
Time: 14110


Desktop — -bash — 99×29
Processing Channels F8-T8 to FP2-F8
No Lag Coefficient: 0.011443580806918256; Coefficient: 0.03632655985140925; Time Lag: -0.046875
Time: 14124
Processing Channels F8-T8 to F8-T8
No Lag Coefficient: 1.0; Coefficient: 1.0; Time Lag: 0.0
Time: 14125
Processing Channels F8-T8 to T8-P8
No Lag Coefficient: 0.01738760978875076; Coefficient: 0.01738760978875076; Time Lag: 0.0
Time: 14125
Processing Channels T8-P8 to FP1-F3
No Lag Coefficient: 0.0010093233092014447; Coefficient: 0.017319992435415585; Time Lag: 0.04296875
Time: 14126
Processing Channels T8-P8 to FP2-F4
No Lag Coefficient: 0.021900422302418752; Coefficient: 0.051146681455925; Time Lag: 0.0390625
Time: 14127
Processing Channels T8-P8 to F4-C4
No Lag Coefficient: 1.0377247470326332E-4; Coefficient: 0.013420775911473538; Time Lag: -0.03515625
Time: 14128
Processing Channels T8-P8 to FP2-F8
No Lag Coefficient: 0.05852974552864533; Coefficient: 0.06361400095950809; Time Lag: 0.01171875
Time: 14129
Processing Channels T8-P8 to F8-T8
No Lag Coefficient: 0.01738760978875076; Coefficient: 0.01738760978875076; Time Lag: 0.0
Time: 14129
Processing Channels T8-P8 to T8-P8
No Lag Coefficient: 1.0; Coefficient: 1.0; Time Lag: 0.0
Time: 14130
Total Time: 14131
$

Section 4.2: Output

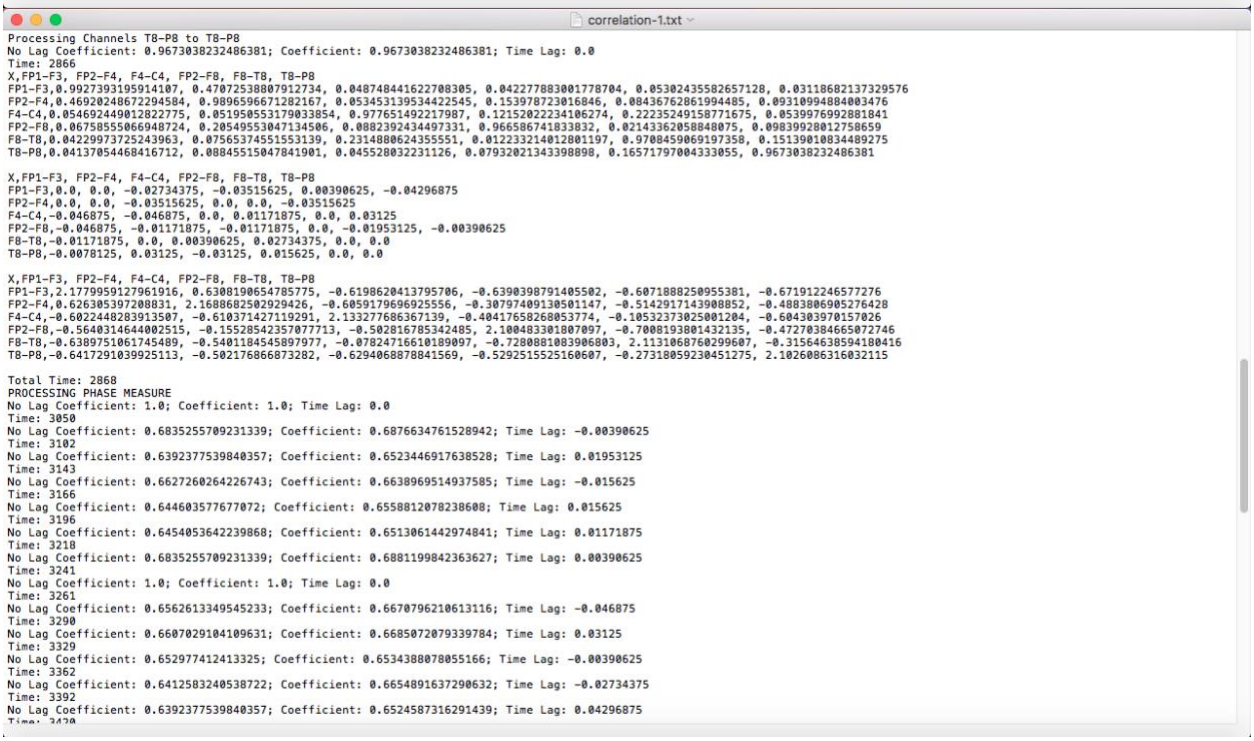
As in the Single Event Processing case, a text file will be generated for each line of the config file.



correlation-1.txt

```
Input directory: ./Example/ExampleCSF
Output file: ./Example/correlation-1.txt
Start time: 26.01.60,21.12.53
End time: 26.01.60,21.13.08
Measures: [PHASE, PIJN]
Channels: [FP1-F3, FP2-F4, F4-C4, FP2-F8, F8-T8, T8-P8]

PROCESSING PIJN MEASURE
Processing Channels FP1-F3 to FP1-F3
No Lag Coefficient: 0.9927393195914107; Coefficient: 0.9927393195914107; Time Lag: 0.0
Time: 1591
Processing Channels FP1-F3 to FP2-F4
No Lag Coefficient: 0.47072538807912734; Coefficient: 0.47072538807912734; Time Lag: 0.0
Time: 1629
Processing Channels FP1-F3 to F4-C4
No Lag Coefficient: 0.024065656946600344; Coefficient: 0.048748441622708305; Time Lag: -0.02734375
Time: 1698
Processing Channels FP1-F3 to FP2-F8
No Lag Coefficient: 0.02674431458037474; Coefficient: 0.042277883001778704; Time Lag: -0.03515625
Time: 1786
Processing Channels FP1-F3 to F8-T8
No Lag Coefficient: 0.04794841896739932; Coefficient: 0.05302435582657128; Time Lag: 0.00390625
Time: 1879
Processing Channels FP1-F3 to T8-P8
No Lag Coefficient: 0.008065995917915125; Coefficient: 0.03118682137329576; Time Lag: -0.04296875
Time: 1972
Processing Channels FP2-F4 to FP1-F3
No Lag Coefficient: 0.46920248672294584; Coefficient: 0.46920248672294584; Time Lag: 0.0
Time: 2060
Processing Channels FP2-F4 to FP2-F4
No Lag Coefficient: 0.9896596671282167; Coefficient: 0.9896596671282167; Time Lag: 0.0
Time: 2125
Processing Channels FP2-F4 to F4-C4
No Lag Coefficient: 0.036532621385907516; Coefficient: 0.053453139534422545; Time Lag: -0.03515625
Time: 2183
Processing Channels FP2-F4 to FP2-F8
No Lag Coefficient: 0.153978723016846; Coefficient: 0.153978723016846; Time Lag: 0.0
Time: 2214
Processing Channels FP2-F4 to F8-T8
No Lag Coefficient: 0.08436762861994485; Coefficient: 0.08436762861994485; Time Lag: 0.0
Time: 2231
Processing Channels FP2-F4 to T8-P8
No Lag Coefficient: 0.07138261848424754; Coefficient: 0.09310994884003476; Time Lag: -0.03515625
Time: 2250
Processing Channels F4-C4 to FP1-F3
No Lag Coefficient: 0.017615949543165366; Coefficient: 0.054692449012822775; Time Lag: -0.046875
Time: 2273
Processing Channels F4-C4 to FP2-F4
No Lag Coefficient: 0.013070280356251907; Coefficient: 0.051950553179033854; Time Lag: -0.046875
Time: 2299
Processing Channels F4-C4 to F4-C4
No Lag Coefficient: 0.977651492217987; Coefficient: 0.977651492217987; Time Lag: 0.0
Time: 2332
Processing Channels F4-C4 to FP2-F8
```



correlation-1.txt

```
Processing Channels T8-P8 to T8-P8
No Lag Coefficient: 0.9673038232486381; Coefficient: 0.9673038232486381; Time Lag: 0.0
Time: 2866
X,FP1-F3, FP2-F4, F4-C4, FP2-F8, F8-T8, T8-P8
FP1-F3,0.9927393195914107, 0.47072538807912734, 0.048748441622708305, 0.042277883001778704, 0.05302435582657128, 0.03118682137329576
FP2-F4,0.46920248672294584, 0.9896596671282167, 0.053453139534422545, 0.153978723016846, 0.08436762861994485, 0.09310994884003476
F4-C4,0.054692449012822775, 0.051950553179033854, 0.977651492217987, 0.12152022234106274, 0.22235249158771675, 0.0539976992881841
FP2-F8,0.06758555066948724, 0.20549553047134506, 0.08823924344973331, 0.9665867418338832, 0.021433620588848075, 0.09839928012758659
F8-T8,0.042299737252439463, 0.07565374551553139, 0.2314880624355551, 0.012233214012801197, 0.9708459069197358, 0.15139010834489275
T8-P8,0.04137054468416712, 0.08845515047841901, 0.045528032231126, 0.07932021343398898, 0.16571797004333055, 0.9673038232486381

X,FP1-F3, FP2-F4, F4-C4, FP2-F8, F8-T8, T8-P8
FP1-F3,0.0, 0.0, -0.02734375, -0.03515625, 0.00390625, -0.04296875
FP2-F4,0.0, 0.0, -0.03515625, 0.0, 0.0, -0.03515625
F4-C4,-0.046875, -0.046875, 0.0, 0.01171875, 0.0, 0.03125
FP2-F8,-0.046875, -0.01171875, -0.01171875, 0.0, -0.01953125, -0.00390625
F8-T8,-0.01171875, 0.0, 0.00390625, 0.02734375, 0.0, 0.0
T8-P8,-0.0078125, 0.03125, -0.03125, 0.015625, 0.0, 0.0

X,FP1-F3, FP2-F4, F4-C4, FP2-F8, F8-T8, T8-P8
FP1-F3,2.1779959127961916, 0.6308190654785775, -0.6198620413795706, -0.6390398791405502, -0.6071888250955381, -0.671912246577276
FP2-F4,0.6263053972080831, 2.1688682502929426, -0.6059179696925556, -0.30797409130501147, -0.5142917143908852, -0.4883806905276428
F4-C4,-0.6022448283913507, -0.610371427119291, 2.133277686367139, -0.40417658268053774, -0.10532373025001204, -0.604303970157026
FP2-F8,-0.5640314644002515, -0.15528542357077713, -0.502816785342485, 2.100483301807097, -0.7008193801432135, -0.47270384665072746
F8-T8,-0.6389751061745489, -0.5401184545897977, -0.07824716610189097, -0.7280881083906803, 2.1131068760299607, -0.31564638594180416
T8-P8,-0.6417291039925113, -0.502176866873282, -0.6294068878841569, -0.5292515525160607, -0.27318059230451275, 2.1026086316032115

Total Time: 2868
PROCESSING PHASE MEASURE
No Lag Coefficient: 1.0; Coefficient: 1.0; Time Lag: 0.0
Time: 3050
No Lag Coefficient: 0.6835255709231339; Coefficient: 0.6876634761528942; Time Lag: -0.00390625
Time: 3102
No Lag Coefficient: 0.6392377539840357; Coefficient: 0.6523446917638528; Time Lag: 0.01953125
Time: 3143
No Lag Coefficient: 0.6627260264226743; Coefficient: 0.6638969514937585; Time Lag: -0.015625
Time: 3166
No Lag Coefficient: 0.644603577677072; Coefficient: 0.6558812078238608; Time Lag: 0.015625
Time: 3196
No Lag Coefficient: 0.6454053642239868; Coefficient: 0.6513061442974841; Time Lag: 0.01171875
Time: 3218
No Lag Coefficient: 0.6835255709231339; Coefficient: 0.6881199842363627; Time Lag: 0.00390625
Time: 3241
No Lag Coefficient: 1.0; Coefficient: 1.0; Time Lag: 0.0
Time: 3261
No Lag Coefficient: 0.6562613349545233; Coefficient: 0.6670796210613116; Time Lag: -0.046875
Time: 3290
No Lag Coefficient: 0.6607029104109631; Coefficient: 0.6685072079339784; Time Lag: 0.03125
Time: 3329
No Lag Coefficient: 0.652977412413325; Coefficient: 0.6534388078055166; Time Lag: -0.00390625
Time: 3362
No Lag Coefficient: 0.6412583240538722; Coefficient: 0.6654891637290632; Time Lag: -0.02734375
Time: 3392
No Lag Coefficient: 0.6392377539840357; Coefficient: 0.6524587316291439; Time Lag: 0.04296875
Time: 3420
```

correlation-1.txt

```
Time: 3653
No Lag Coefficient: 0.6445331027618458; Coefficient: 0.6556735206090353; Time Lag: 0.015625
Time: 3677
No Lag Coefficient: 0.6579729338715173; Coefficient: 0.6579729338715173; Time Lag: 0.0
Time: 3704
No Lag Coefficient: 0.644603577677072; Coefficient: 0.65672119971267; Time Lag: -0.015625
Time: 3728
No Lag Coefficient: 0.652977412413325; Coefficient: 0.6542237602317785; Time Lag: 0.046875
Time: 3751
No Lag Coefficient: 0.6511298121918037; Coefficient: 0.6744619745573041; Time Lag: 0.015625
Time: 3773
No Lag Coefficient: 0.6445331027618458; Coefficient: 0.6574303911041234; Time Lag: -0.015625
Time: 3795
No Lag Coefficient: 1.0; Coefficient: 1.0; Time Lag: 0.0
Time: 3816
No Lag Coefficient: 0.6649480655653205; Coefficient: 0.6649480655653205; Time Lag: 0.0
Time: 3839
No Lag Coefficient: 0.6454053642239868; Coefficient: 0.6503520246270008; Time Lag: -0.01171875
Time: 3860
No Lag Coefficient: 0.6412583240538722; Coefficient: 0.6674177364158899; Time Lag: -0.04296875
Time: 3882
No Lag Coefficient: 0.656209452853884; Coefficient: 0.656209452853884; Time Lag: 0.0
Time: 3905
No Lag Coefficient: 0.6579729338715173; Coefficient: 0.6579729338715173; Time Lag: 0.0
Time: 3939
No Lag Coefficient: 0.6649480655653205; Coefficient: 0.6649480655653205; Time Lag: 0.0
Time: 3968
No Lag Coefficient: 1.0; Coefficient: 1.0; Time Lag: 0.0
Time: 4001
X,FP1-F3, FP2-F4, F4-C4, FP2-F8, F8-T8, T8-P8
FP1-F3,1.0, 0.6876634761528942, 0.6523446917638528, 0.6638969514937585, 0.6558812078238608, 0.6513061442974841
FP2-F4,0.6881199842363627, 1.0, 0.6670796210613116, 0.668507207933978 4, 0.6534388078055166, 0.6654891637290632
F4-C4,0.6524587316291439, 0.6664768277388 18, 1.0, 0.6563852270621561, 0.6755433451786166, 0.656209452853884
FP2-F8,0.6643304690877868, 0.6687661242790326, 0.6562044627643804, 1.0, 0.6556735206090353, 0.6579729338715173
F8-T8,0.656721199712 67, 0.6542237602317785, 0.6744619745573041, 0.6574303911041234, 1.0, 0.6649480655653205
T8-P8,0.6503520246270008, 0.6674177364158899, 0.656209452853884, 0.6579729338715173, 0.6649480655653205, 1.0

X,FP1-F3, FP2-F4, F4-C4, FP2-F8, F8-T8, T8-P8
FP1-F3,0.0, -0.00390625, 0.01953125, -0.015625, 0.015625, 0.01171875
FP2-F4,0.00390625, 0.0, -0.046875, 0.03125, -0.00390625, -0.02734375
F4-C4,0.04296875, 0.046875, 0.0, 0.01953125, -0.015625, 0.0
FP2-F8,0.015625, -0.03515625, -0.01953125, 0.0, 0.015625, 0.0
F8-T8,-0.015625, 0.046875, 0.015625, -0.015625, 0.0, 0.0
T8-P8,-0.01171875, -0.04296875, 0.0, 0.0, 0.0, 0.0

X,FP1-F3, FP2-F4, F4-C4, FP2-F8, F8-T8, T8-P8
FP1-F3,2.2307192785235 35, -0.24495562460061904, -0.5249031217546998, -0.43333637465950764, -0.49687161283471415, -0.5331349669021174
FP2-F4,-0.241337201780912 86, 2.230719278523535, -0.4881095613612165 7, -0.3967940707834 29, -0.5162308230683685, -0.4207160130609 37
F4-C4,-0.5239992068715492, -0.41288748576751716, 2.230719278523535, -0.49287660205733197, -0.34102349302027635, -0.4942698422415915
FP2-F8,-0.42990018149714776, -0.39474182057085705, -0.49430939521860573, 2.230719278523535, -0.4985178052783974, -0.4802919518440283
F8-T8,-0.4902135799785549, -0.5100090498415061, -0.3495947676031672 7, -0.4845923119061971 7, 2.230719278523535, -0.4250049227523316 5
T8-P8,-0.5406976114935 93, -0.4054295555540823, -0.4942698422415915, -0.4802919518440283, -0.4250049227523316 5, 2.230719278523535

Total Time: 4002
```

correlation-3.txt

```
├─
Input directory: ./Example/ExampleCSF
Output file: ./Example/correlation-3.txt
Start time: 27.01.60,07.15.18
End time: 27.01.60,07.15.38
Measures: [ALL]
Channels: [FP1-F3, FP2-F4, F4-C4, FP2-F8, F8-T8, T8-P8]

PROCESSING PIJN MEASURE
Processing Channels FP1-F3 to FP1-F3
No Lag Coefficient: 0.9672615316674726; Coefficient: 0.9672615316674726; Time Lag: 0.0
Time: 9055
Processing Channels FP1-F3 to FP2-F4
No Lag Coefficient: 0.5904122171048805; Coefficient: 0.6067866581639332; Time Lag: -0.0078125
Time: 9150
Processing Channels FP1-F3 to F4-C4
No Lag Coefficient: 0.03305254731799545; Coefficient: 0.09045181817872128; Time Lag: -0.03125
Time: 9219
Processing Channels FP1-F3 to FP2-F8
No Lag Coefficient: 0.06575140569595828; Coefficient: 0.12141365737549614; Time Lag: -0.03125
Time: 9284
Processing Channels FP1-F3 to F8-T8
No Lag Coefficient: 0.0792897066804723; Coefficient: 0.13461790817717056; Time Lag: 0.0390625
Time: 9356
Processing Channels FP1-F3 to T8-P8
No Lag Coefficient: 0.02876543219334793; Coefficient: 0.07325090250790289; Time Lag: -0.046875
Time: 9421
Processing Channels FP2-F4 to FP1-F3
No Lag Coefficient: 0.5738235515587171; Coefficient: 0.5872656572895065; Time Lag: 0.0078125
Time: 9483
Processing Channels FP2-F4 to FP2-F4
No Lag Coefficient: 0.9489024786975867; Coefficient: 0.9489024786975867; Time Lag: 0.0
Time: 9544
Processing Channels FP2-F4 to F4-C4
No Lag Coefficient: 0.03434725342334388; Coefficient: 0.10256411857959247; Time Lag: -0.02734375
Time: 9600
Processing Channels FP2-F4 to FP2-F8
No Lag Coefficient: 0.2104666095619746; Coefficient: 0.2184008429582749; Time Lag: -0.01171875
Time: 9661
Processing Channels FP2-F4 to F8-T8
No Lag Coefficient: 0.07911547117385831; Coefficient: 0.1464789256794291; Time Lag: 0.046875
Time: 9717
Processing Channels FP2-F4 to T8-P8
No Lag Coefficient: 0.02986289239505835; Coefficient: 0.08594043929813155; Time Lag: -0.046875
Time: 9784
Processing Channels F4-C4 to FP1-F3
No Lag Coefficient: 0.014056168093786736; Coefficient: 0.07481334852240673; Time Lag: -0.046875
Time: 9860
Processing Channels F4-C4 to FP2-F4
No Lag Coefficient: 0.02787260346968034 6; Coefficient: 0.0880702432858359; Time Lag: 0.02734375
Time: 9939
Processing Channels F4-C4 to F4-C4
No Lag Coefficient: 0.9547424070730298; Coefficient: 0.9547424070730298; Time Lag: 0.0
Time: 9996
Processing Channels F4-C4 to FP2-F8
```

correlation-3.txt

```
Processing Channels T8-P8 to T8-P8
No Lag Coefficient: 0.9845736643745391; Coefficient: 0.9845736643745391; Time Lag: 0.0
Time: 11252
X,FP1-F3, FP2-F4, F4-C4, FP2-F8, F8-T8, T8-P8
FP1-F3,0.9672615316674726, 0.6067866581639332, 0.09045181817872128, 0.12141365737549614, 0.1346179081771706, 0.07325090250790289
FP2-F4,0.58726565728950 65, 0.9489024786975867, 0.10256411857959247, 0.2184008429582749, 0.1464789256794291, 0.08594043929813155
F4-C4,0.07481334852240673, 0.0880702432858359, 0.9547424070730298, 0.11430524250712926, 0.2854722929552205, 0.03824330271688914
FP2-F8,0.12398025832935411, 0.23520629655945657, 0.1382502669727158, 0.9705543169831952, 0.04319509579875158, 0.07168585555843165
F8-T8,0.14887245226196077, 0.15382836156067725, 0.3065436201412664 6, 0.03912919621940591 5, 0.9860728069321407, 0.011461254613784555
T8-P8,0.021973998631351854, 0.06658394359987996, 0.04734155888521174, 0.08014708591440656, 0.030648787514458542, 0.9845736643745391

X,FP1-F3, FP2-F4, F4-C4, FP2-F8, F8-T8, T8-P8
FP1-F3,0.0, -0.0078125, -0.03125, -0.03125, 0.0390625, -0.046875
FP2-F4,0.0078125, 0.0, -0.02734375, -0.01171875, 0.046875, -0.046875
F4-C4,-0.046875, 0.02734375, 0.0, 0.00390625, -0.00390625, -0.03125
FP2-F8,0.03515625, 0.015625, -0.00390625, 0.0, 0.046875, -0.015625
F8-T8,-0.0390625, -0.046875, 0.00390625, -0.046875, 0.0, 0.0
T8-P8,0.04296875, 0.0390625, 0.0234375, 0.015625, 0.01171875, 0.0

X,FP1-F3, FP2-F4, F4-C4, FP2-F8, F8-T8, T8-P8
FP1-F3,2.058428226715358, 0.9779329565265699, -0.5697403861820955, -0.47693469217265555, -0.43735598201477366, -0.6212987870342787
FP2-F4,0.9194202815399121, 2.003398399792033, -0.5334347120388503, -0.18622318079158368, -0.4018035087279193, -0.5832628919121903
F4-C4,-0.6166154771763999, -0.5768789708561193, 2.020903128836194, -0.4982416103751934, 0.01481825042398741, -0.7262313323382469
FP2-F8,-0.4692415063365606, -0.13585014659652306, -0.4264682703 1362305, 2.0682980934408968, -0.7113887194484655, -0.6259898929915166
F8-T8,-0.394629099797941, -0.379774148869731, 0.07797790740601437, -0.7235759357774351, 2.1148135546361226, -0.806508429102632
T8-P8,-0.774997300248389, -0.6412824754857043, -0.6989600203011763, -0.6006280160574814, -0.7489952983141516, 2.1103199919445434

Total Time: 11253
PROCESSING PHASE MEASURE
No Lag Coefficient: 1.0; Coefficient: 1.0; Time Lag: 0.0
Time: 11330
No Lag Coefficient: 0.6905928437370773; Coefficient: 0.693871130777926; Time Lag: -0.0078125
Time: 11412
No Lag Coefficient: 0.6432003582295667; Coefficient: 0.6557293224898673; Time Lag: 0.0234375
Time: 11493
No Lag Coefficient: 0.6388412245596627; Coefficient: 0.655908674181177; Time Lag: 0.046875
Time: 11572
No Lag Coefficient: 0.6496574815116374; Coefficient: 0.655250227560381; Time Lag: 0.03125
Time: 11649
No Lag Coefficient: 0.6480236783062638; Coefficient: 0.6538519495645447; Time Lag: -0.046875
Time: 11728
No Lag Coefficient: 0.6905928437370773; Coefficient: 0.6940360926028937; Time Lag: 0.01171875
Time: 11809
No Lag Coefficient: 1.0; Coefficient: 1.0; Time Lag: 0.0
Time: 11883
No Lag Coefficient: 0.6497330930679073; Coefficient: 0.6580083309451483; Time Lag: -0.046875
Time: 11961
No Lag Coefficient: 0.6411248260659415; Coefficient: 0.6501235110210343; Time Lag: -0.0234375
Time: 12042
No Lag Coefficient: 0.6548635753188983; Coefficient: 0.6607091918694529; Time Lag: -0.0078125
Time: 12119
No Lag Coefficient: 0.647651548528769; Coefficient: 0.6526973570356815; Time Lag: 0.0234375
Time: 12197
No Lag Coefficient: 0.6432003582295667; Coefficient: 0.654878617980739; Time Lag: -0.0234375
Time: 12278
```

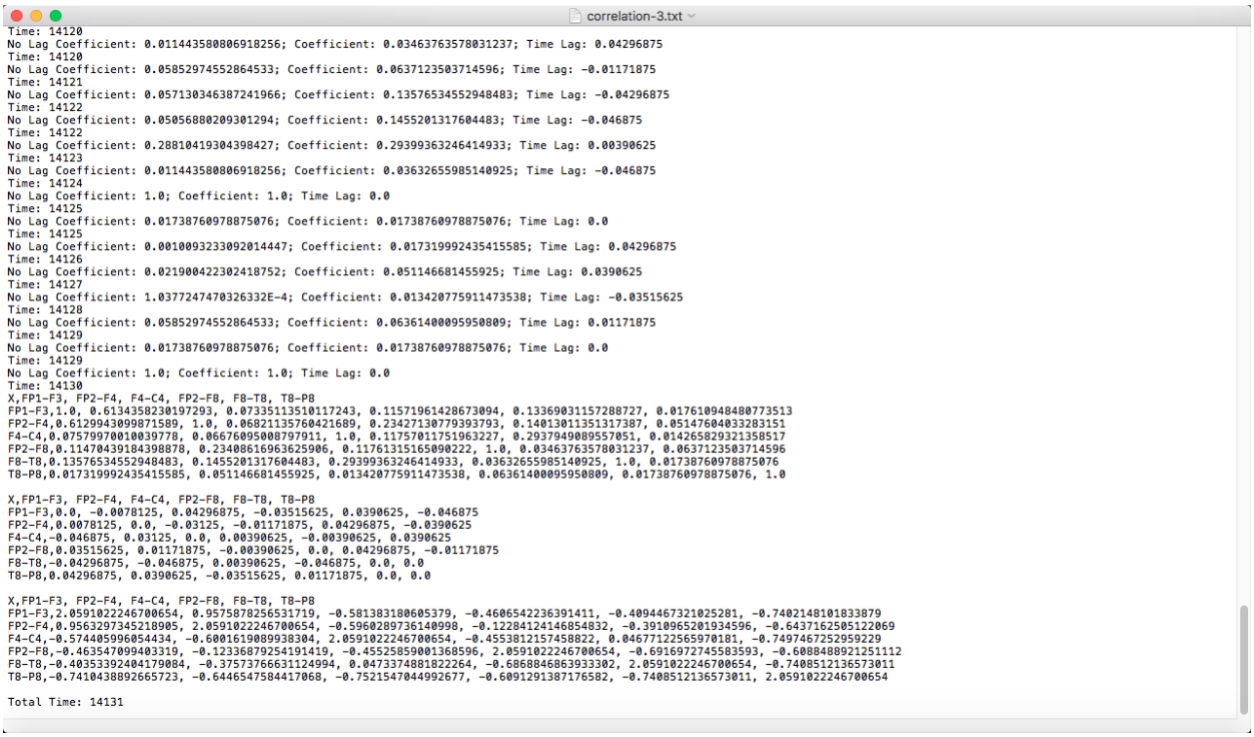
correlation-3.txt

```
No Lag Coefficient: 0.6333081440180406; Coefficient: 0.6505312502179524; Time Lag: -0.0390625
Time: 14028
No Lag Coefficient: 1.0; Coefficient: 1.0; Time Lag: 0.0
Time: 14103
X,FP1-F3, FP2-F4, F4-C4, FP2-F8, F8-T8, T8-P8
FP1-F3,1.0, 0.693871130777926, 0.6557293224898673, 0.655908674181177, 0.655250227560381, 0.6538519495645447
FP2-F4,0.6940360926028937, 1.0, 0.6580083309451483, 0.6501235110210343, 0.6607091918694529, 0.6526973570356815
F4-C4,0.6548786179807 39, 0.6583802437635169, 1.0, 0.6463437221619468, 0.6713345800827649, 0.6504976725047209
FP2-F8,0.6576159932092084, 0.6506046725084478, 0.6465127311843453, 1.0, 0.6520990630191102, 0.6621378725383804
F8-T8,0.6554407640693676, 0.6609896717948707, 0.6713265511896892, 0.6513331111163976, 1.0, 0.6507725518412163
T8-P8,0.6533854130810631, 0.6527065829008073, 0.6506706358586846, 0.6625872808208131, 0.6505312502179524, 1.0

X,FP1-F3, FP2-F4, F4-C4, FP2-F8, F8-T8, T8-P8
FP1-F3,0.0, -0.0078125, 0.0234375, 0.046875, 0.03125, -0.046875
FP2-F4,0.01171875, 0.0, -0.046875, -0.0234375, -0.0078125, 0.0234375
F4-C4,-0.0234375, 0.046875, 0.0, 0.03515625, -0.00390625, -0.015625
FP2-F8,-0.046875, 0.0234375, -0.03515625, 0.0, -0.046875, -0.0234375
F8-T8,-0.03125, 0.0078125, 0.00390625, 0.046875, 0.0, 0.0390625
T8-P8,0.046875, -0.03125, 0.015625, 0.0234375, -0.0390625, 0.0

X,FP1-F3, FP2-F4, F4-C4, FP2-F8, F8-T8, T8-P8
FP1-F3,2.2288278909556536, -0.16531512486137537, -0.463610885583125 63, -0.4622082292436061, -0.46735774481354 62, -0.478293261958365
FP2-F4,-0.16402500739507264, 2.2288278909556536, -0.4457874369483581, -0.5074522730687256, -0.42466480537477047, -0.4873229874008454
F4-C4,-0.4702639930284611, -0.4428788171933751, 2.2288278909556536, -0.5370128797545415, -0.34156673560097 26, -0.504526067169777
FP2-F8,-0.448855793920796, -0.5036892512765307, -0.5356911109841 47, 2.2288278909556536, -0.4919958107461312, -0.4134915179483423
F8-T8,-0.4658676153350438, -0.4224712551348917, -0.3416295897560707, -0.4980064266705242, 2.2288278909556536, -0.5023761747 33985
T8-P8,-0.4819419053103941 6, -0.48725083464827484, -0.5031733721203467, -0.4099768291724334, -0.5042634658417001, 2.2288278909556536

Total Time: 14104
PROCESSING PEARSON MEASURE
No Lag Coefficient: 1.0; Coefficient: 1.0; Time Lag: 0.0
Time: 14105
No Lag Coefficient: 0.602262528096383; Coefficient: 0.6134358230197293; Time Lag: -0.0078125
Time: 14106
No Lag Coefficient: 7.541900324598338E-4; Coefficient: 0.07335113510117243; Time Lag: 0.04296875
Time: 14106
No Lag Coefficient: 0.05842296005484699; Coefficient: 0.11571961428673094; Time Lag: -0.03515625
Time: 14107
No Lag Coefficient: 0.057130346387241966; Coefficient: 0.13369031157288727; Time Lag: 0.0390625
Time: 14108
No Lag Coefficient: 0.0010093223092014447; Coefficient: 0.017610948480773513; Time Lag: -0.046875
Time: 14109
No Lag Coefficient: 0.602262528096383; Coefficient: 0.6129943099871589; Time Lag: 0.0078125
Time: 14109
No Lag Coefficient: 1.0; Coefficient: 1.0; Time Lag: 0.0
Time: 14110
No Lag Coefficient: 0.0073057847489621875; Coefficient: 0.06821135760421689; Time Lag: -0.03125
Time: 14111
No Lag Coefficient: 0.21967863338715365; Coefficient: 0.23427130779393793; Time Lag: -0.01171875
Time: 14111
No Lag Coefficient: 0.05056880209301294; Coefficient: 0.14013011351317387; Time Lag: 0.04296875
Time: 14112
No Lag Coefficient: 0.021900422302418752; Coefficient: 0.05147604033283151; Time Lag: -0.0390625
Time: 14113
No Lag Coefficient: 7.541900324598338E-4; Coefficient: 0.07579970010039778; Time Lag: -0.046875
```



Credits

This software has been developed at Case Western Reserve University as part of a research project and includes contributions by Arthur Gershons and Satya Sahoo (Project PI).