CCME: Code for simulation benchmarking and real data analysis ("Lite" version)

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1 Introduction

This file contains instructions for reproducing the analyses done in [3]. We call this version the "Lite" version since we do not describe fully how to customize and create different simulations than the ones found in the publication. We are working on a more extensive description of the simulation framework and how to use it. The purpose of this document is simply to allow a user to create, on his or her home computer, the results found in [3].

Note well that the folder (see http://stats.johnpalowitch.com/ccme) comes with **all** results from **all** methods from **all** analyses in [3]. Thus if you do not wish to recreate the all simulated data sets (which will probably take about half a week and $\approx$ 30 gigabytes of space) there are instructions in this document you can skip. If you want to examine a particular simulation, or a particular run on a real data set, all the seeds have been saved, so it's a matter of 1) deciding which simulation you want to inspect, 2) finding the associated seed, and 3) understanding well enough how the simulations were created (requires a careful reading of this document) to go to the specific point in the appropriate script and re-create the network.

Throughout, we assume the reader has downloaded the project folder from url. This folder should contain the directories airports, enron, methodFiles and sims, along with a number of .R scripts. When running R scripts (for any part of this document), be sure that your working directory is set to the project folder at all times.

2 Simulations (Section 5)

Within the folder sims are all scripts and subfolders to recreate the analyses from Section 5. The general approach to both our code and the simulation framework is the following. As the simulation framework has many parameters, we run many "experiments" in which one parameter is moved along a grid of values, and the performance of each method is tested many times at each value. The rough outline of the steps needed to accomplish this is as follows:

1. Set up a parameter script to store the parameter settings for each experiment. In principle all experiments are fully customizable with these scripts, but this takes thorough knowledge of the functions used to simulate the networks, which we do not discuss in this document. We recommend the user leave these scripts as they were when they were downloaded, as this is the only way to ensure exact reproducability of the results in [3].

2. Set up a simulation script to call the parameter scripts and simulate/store the networks

3. Set up a method run script to run the methods

4. Set up an analysis script to record, store, and plot the performance of each method

As some methods we analyzed are coded in languages other than R, some of these scripts have lines to save batch files for the other methods. Along the way we will introduce auxiliary scripts to obtain, store, and process results from non-R methods.

2.1 Null Simulations (Section 5.8)

We begin with the "null" simulations presented in Section 5.8. This will serve as practice for re-creating the rest of the simulated networks.

2.1.1 Making the networks

We performed only one experiment involving null networks, which makes this example slightly simpler than others. The parameter script is sims/null_sims/make_par_lists.R, but as mentioned previously, we do not discuss its use in this document. With the parameter settings in hand, the next step is to make the simulated networks. This can be done on a home computer with the latest version of R and at least 500mB of RAM. The script to make the file is sims/null_sims/make_null_sims.R. Run this script with no options changed to make and save the simulated networks.

2.1.2 Running the methods

For all simulations (including those described in the next section) we need to run R methods (which include CCME), OSLOM [2] (which is coded in C++), and SLPAw [4] (which is coded in Java). The analyses in [3] were completed on a Windows desktop computer but the batch files for the latter methods will run with any working implementation of those methods. We leave it to the user to have (and henceforth assume that they have) installed the most recent versions of these methods (the applications/sources are in /methodFiles, but you can also get them yourself from the internet).

Running R methods. The script to run all the R methods on the null network experiment is sims/sbm_sims/null_runs.R. In this script we separate CCME from the other R methods by user options at the top of the script. The user may run just CCME, all other R methods, or both at the same time. These choices will not affect the results (providing no other options have been changed).

Running OSLOM and SLPAw. These methods can be run by their batch files:

- OSLOM: sims/null_sims/experiment1/OSLOM2/run_script.txt. To run this script with the OSLOM software you must set the directory to the folder in which the batch file is stored.

- SLPAw: sims/null_sims/experiment1/slpa_run_script.bat. This script can be run from a Windows command line (providing SLPA is set up appropriately) or with another system as lines of input to the SLPA software.

The construction of the batch files ensures that the results will be saved in the appropriate locations.

2.1.3 Plotting results from the methods

Extracting results from non-R methods. Before any analysis or plotting is to be done, we must gather and store the results from non-R methods. This can be done with the script sims/extract_all_nonCCME.R. **Important**: this script is shared between the null and non-null sims. When extracting null results (as in this section), set the variable sbm to FALSE. Set run_expers to the integer 1. The script can then be run as-is.

The results from all methods may be collected and plotted with the script sims/null_sims/null_performancePlots.R. The scripts can be run as-is. The figures used in [3] will appear in sims/null_sims.

2.2 Community Simulations (Section 5 but not 5.8)

The simulation and analysis of community-structured networks proceeds similarly to the steps outlined in the previous section, but there are some important additions. For starters, there are 9 experiments instead of 1. To follow the instructions in this section, you will need to download the associated experiment folders and place them in the project folder. The 9 experiment folders are split into two sets, available at the following urls:

```
http://stats.johnpalowitch.com/experiments1thru5.zip
http://stats.johnpalowitch.com/experiments6thru9.zip
```

Download and unzip these files. Place their contents in the directory sims/sbm_sims. In what follows we discuss how to reproduce the simulation results presented in all of Section 5 save for 5.8.

2.2.1 Why are the experiment folders so big, and already file-laden?

For starters, you need the seeds that I used to generate the simulated data. Secondly, it's a bit of a tricky business getting the OSLOM directories set up properly, and I didn't want to explain that (or make you do it). Finally, I decided to leave a number of "starting" files in case you want to skip some steps below. If you don't want to actually make all the simulation data (which takes about 2 days if you run the experiments back-to-back, and makes the project folder >30GB), you can start reading at Section 2.2.4.

2.2.2 Making the networks

For the community-structured networks, the files are created in two stages. First, we create the .RData files that house the simulated data. Then we save the data in formats amenable to OSLOM and SLPAw. (For the null simulations these two stages were performed in one go.)

We performed 9 experiments involving community structured networks. As before, there is a parameter script (sims/sbm_sims/make_par_lists.R) but we do not discuss its use; its products are already stored in the downloaded project folder. With the parameter settings in hand, the next step is to make the simulated networks. This can be done on a home computer with the latest version of R with the script sims/sbm_sims/make_sbm_sims.R. The default behavior of the script (no user changes) is to make the experiment files one-at-a-time. This will take multiple days. Depending on your computer's RAM capacity you may be able to run multiple windows of R at once. In doing so you can modify the variable run_expers to set which experiments to create in the window. **Important**: for this run of the script you **must** set the variables writeOSLOM and writeScripts to FALSE. These are the defaults for the variables as downloaded. No other options should be changed if you wish to reproduce the results from [3] exactly.

Next, you must create the data files in formats amenable to OSLOM and SLPAw. This involves another run of the script sims/sbm_sims/make_sbm_sims.R but with some changes in the user variables:

1. Set runSBM to FALSE
2. Set writeOSLOM to TRUE
3. Set writeScripts toTRUE

This also creates the batch files for OSLOM and SLPAw.

2.2.3 Running the methods

For all simulations we need to run R methods (which include CCME), OSLOM [2] (which is coded in C++), and SLPAw [4] (which is coded in Java). The analyses in [3] were completed on a Windows desktop computer but the batch files for the latter methods will run with any working implementation of those methods (the applications/sources are in /methodFiles, but you can also get them yourself from the internet).

Running R methods. The script to run all the R methods on the community network experiments is sims/sbm_sims/run_R_methods.R. As before you may choose to run only igraph methods, only CCME, or both. You may also choose to run just a portion of the experiments. This is helpful if you want to run multiple windows of R at once. Running all experiments back-to-back will take a few days (mostly due to CCME, as it takes longer than the igraph methods).

Running OSLOM and SLPAw. These methods can be run by their batch files:

- OSLOM: sims/null_sims/experiment1/OSLOM2/run_script.txt. To run this script with the OSLOM software you must set the directory to the folder in which the batch file is stored.

- SLPAw: sims/null_sims/experiment1/slpa_run_script.bat. This script can be run from a Windows command line (providing SLPA is set up appropriately) or with another system as lines of input to the SLPA software.

The construction of the batch files ensures that the results will be saved in the appropriate locations.

2.2.4 Plotting results from the methods

Saving the community structure in .dat format. In [3] we judged the accuracy of methods with the overlapping NMI metric [1]. This requires saving both the true community structure of each network and the output of each method in a special file format. The script to do this is sims/sbm_sims/make_comm_dats.R. Run the script as downloaded; it will take about 30-60min.

Calculating oNMI. To calculate the overlapping NMI metric for each run of each method, you must use a special program developed by [1]. Both the C++ source code and the application is stored in methodFiles/mutual3. **Important**: do not use the authors' version of the code for oNMI which is downloadable from their website. We have modified the code to allow for more flexible file management (i.e. the original version of the application would not save the score in an arbitrary file location). To calculate and save the oNMI for each method (on each simulation from each experiment), first ensure that a working version of mutual3 (again, compiled from **our** source code) is in /methodFiles in the project folder. Then run sims/sbm_sims/all_mutual_calcs.txt from a command line capable of running OSLOM (i.e. GNU or otherwise emulator).

Extracting results from non-R methods. Before any analysis or plotting is to be done, we must gather and store the results from non-R methods. This can be done with the script sims/extract_all_nonCCME.R. **Important**: this script is shared between the null and non-null sims. When extracting community results in this section, set the variable sbm to TRUE. Leave the other variables as they were downloaded. The script can then be run as-is and should take between 30minutes to and hour.

Procuring the tears of a sleeping leprechaun. Finally, before we can calculate, plot, and save the results from the methods on the community-structured network simulations, you must procure the tears of a sleeping leprechaun. This can be difficult as leprechauns rarely have dreams distressing enough to cry about while sleeping. You'll do best by looking for sleeping leprechauns in dark or giant-spider-infested corners of the forest. Better yet, find one with pink-eye: the tears don't have to be from sadness or fear. Once you have the tears, and being sure that they do not, at any time, receive direct sunlight, bring them back to your computer. Smear the tears in the shape of a shamrock on your computer screen, and whisper thrice "bestow ye lucky charms".

Plotting: Once you have completed all tasks described above, the results from all methods may be collected and plotted with the script

sims/null_sims/null_performancePlots.R.

The scripts can be run as-is but will take about half a day. As before you may expedite the process by running multiple windows with separate experiments (altering the user variable plot_expers in each window) but this is not recommended without above-usual RAM capacity. The figures used in [3] will appear in sims/sbm_sims.

3 Real Data

In this section we describe the running of OSLOM, SLPAw, and CCME on the two real data sets analyzed in [3]. The two data sets are the airports data set and the ENRON data set.

3.1 Airports Data

All scripts to run the 3 methods on the aiports data are in the subfolder airports. For maximal reproducibility, and as this is not a very big data set, we describe everything from processing the raw data files to producing and plotting the results from the methods. As in the previous section all major scripts are in written in R and the working directory must be set to the downloaded project folder.

3.1.1 Make the data

To construct usable network data from the raw data files, run the following scripts in order:

1. airports/dataPrep.R
2. airports/rm_nodes_make_years.R
3. airports/save_Rdatas.R

3.1.2 Run the methods

First we'll describe running CCME because the script to do so sets up the runs for SLPAw and OSLOM. The script to run CCME is airports/R_method_run_script.R. First ensure that the user variables about seeds are set to their (default) FALSE, unless you want to see a run of the methods that is different from the ones displayed in [3] (which is a perfectly reasonable thing to desire since each method has a stochastic component). To make the OSLOM files set writeOSLOM to TRUE but if you do not plan to run OSLOM later this is not necessary. Otherwise the script will run as-is.

Next run SLPAw with the batch file airports/SLPA_run_script.txt, and run OSLOM by running (with a GNU window set to the directory airports/oslom/OSLOM2) the script airports/oslom/OSLOM2/aports.txt.

3.1.3 Compile SLPA and OSLOM results

To extract and save the community detection results from SLPA and OSLOM, run the R script airports/nonCCME_airports/extract.R.

3.1.4 Plot results

Originally we were able to plot all results from all airport-data-years with base R graphics. This can be done with the script airports/all_plots.R.

Next we used the ggplot2 package to plot some results. However a specific way to enlarge the size of points on the map caused the script not to be sourcable due most likely to some bug. Hence we included a script called airports/all_plots_script_print.R to print out every run of the loop. This prints out airports/all_plots_full_script.R which must be **copied and pasted** into an R console. The script will **not** run sourced. This script saves results for the data year 2015 only as otherwise the script would be far too long.

3.2 ENRON Data

This analysis was done from the project folder subdirectory /enron. The data is already created and saved, so if you only wish to run the methods, ignore the next section.

3.2.1 Creating the network data

The first step in completely duplicating the ENRON data analysis is to download the data set from this url:

`https://www.cs.cmu.edu/~./enron/enron_mail_20150507.tgz`

If this link doesn't work the following webpage should put you back on track:

`https://www.cs.cmu.edu/~./enron/`

Unzip the data and put the "top" folder with the 150 executive folders in an accessible file location. **Very important**: the first script we run is enron/mine_and_save.R. For this script, you must set your R session working directory to the enron directory, not the overall project folder as we have been doing. For all other scripts associated with this section, set your working directory to the overall project folder. In the script enron/mine_and_save.R set the variable mailDir to a string with the name of the data folder. The script will then run as-is and should take no more than a couple hours. Then run makeDirectedList.R and enron/makeEdgeList.R in that order.

3.2.2 Saving the data for OSLOM and SLPAw

The network must be saved for OSLOM as a .dat and for SLPAw .ipairs. The data comes downloaded with the project folder; the OSLOM data is in enron/OSLOM2/edge_list.dat and the SLPAw data is in enron/edge_list.ipairs. If you want to re-create these files, write the variable in enron/edgeList.RData to files with the aforementioned names, in the format in which they exist (viewable with any text editor).

3.2.3 Running the methods

SLPAw can be run on the ENRON network with the batch file:

enron/SLPAw_edge_list_run1_r0.1_v3_T100.icpm.

OSLOM can be run from a GNU command line. Study the ReadMe in enron/OSLOM2 and run OSLOM with the -fast, -singleton, and -w options. CCME can be run with the script enron/runScript.R.

3.2.4 Obtaining results

To read in, analyze, and output tables/plots for the methods' results, run the script enron/postAnalysis.R.

References

[1] A. Lancichinetti and S. Fortunato. Benchmarks for testing community detection algorithms on directed and weighted graphs with overlapping communities. *Physical Review E*, 80(1):016118, 2009.

[2] A. Lancichinetti, F. Radicchi, J. J. Ramasco, S. Fortunato, et al. Finding statistically significant communities in networks. *PloS one*, 6(4):e18961, 2011.

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[4] J. Xie, B. K. Szymanski, and X. Liu. Slpa: Uncovering overlapping communities in social networks via a speaker-listener interaction dynamic process. In *Data Mining Workshops (ICDMW), 2011 IEEE 11th International Conference on*, pages 344–349. IEEE, 2011.