Manual for SIENA version 3.2

Provisional version

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Abstract

SIENA (for Simulation Investigation for Empirical Network Analysis) is a computer program that carries out the statistical estimation of models for the evolution of social networks according to the dynamic actor-oriented model of Snijders (2001, 2005) and Snijders, Steglich, and Schweinberger (2007). It also carries out MCMC estimation for the exponential random graph model according to the procedures described in Snijders (2002) and Snijders, Pattison, Robins, and Handcock (2006).

Contents

1 General information

SIENA[1], shorthand for Simulation Investigation for Empirical Network Analysis, is a computer program that carries out the statistical estimation of models for repeated measures of social networks according to the dynamic actor-oriented model of Snijders and van Duijn (1997), Snijders (2001), and Snijders, Steglich, and Schweinberger (2007); also see Steglich, Snijders, and Pearson (2010). A tutorial for this method is given in Snijders, van de Bunt and Steglich (2010). Some examples are presented, e.g., in van de Bunt (1999); van de Bunt, van Duijn, and Snijders (1999); and van Duijn, Zeggelink, Stokman, and Wasseur (2003); and Steglich, Snijders, and West (2006). A website for SIENA is maintained at http://stat.gamma.rug.nl/snijders/siena.html . Introductions in French and Spanish are given in de Federico de la Rúa (2004, 2005) and Jariego and de Federico de la Rúa (2006).

The program also carries out MCMC estimation for the exponential random graph model (abbreviated to *ERGM* or *ERG model*), also called p^* model, of Frank and Strauss (1986), Frank (1991), Wasserman and Pattison (1996), and Snijders, Pattison, Robins, and Handcock (2006). The algorithm is described in Snijders (2002). A good introduction is Robins, Snijders, Wang, Handcock, and Pattison (2007).

This is a provisional manual for SIENA version 3.2 (which has not been released yet, but of which beta versions are obtainable from the SIENA website). Changes of this version compared to earlier versions are in Section 20. Official releases of the program and the manual can be downloaded from the web sites, http://stat.gamma.rug.nl/stocnet/ and http://www.stats.ox.ac.uk/siena/. One way to run SIENA is as part of the StOCNET program collection (Boer, Huisman, Snijders, Steglich, Wichers & Zeggelink, 2006), which can be downloaded from the same website. For the operation of StOCNET, the reader is referred to the corresponding manual. If desired, SIENA can be operated also independently of StOCNET, as is explained in Section 17.

This manual consists of two parts: the user's manual and the programmer's manual. It can be viewed and printed with the Adobe Acrobat reader. The manual is updated rather frequently, and it may be worthwhile to check now and then for updates.

The manual focuses on the use of SIENA for analysing the dynamics of directed networks. The case of non-directed networks is very similar, and at various points this case is described more in particular. Sections on data requirements, general operation, etc., apply as well to parameter estimation in the ERGM. Some sections are devoted specifically to this model.

For getting started, there are various options:

1. One excellent option is to read the User's Manual from start to finish (leaving aside the Programmer's Manual).

2. A second option is to read the Minimal Introduction contained in Sections 2 3, together with the table of contents to have an idea of what can be looked up later.

3. Another option is first to read the Minimal Introduction and further to focus on Sections 6 for the model specification, 7 to get a basic insight in what happens in the parameter estimation, 7.2 to understand the output file (which is meant to be as self-explanatory as possible), and 13 for the basis of getting started.

[1] This program was first presented at the International Conference for Computer Simulation and the Social Sciences, Cortona (Italy), September 1997, which originally was scheduled to be held in Siena. See Snijders & van Duijn (1997).

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Part I

Minimal Intro

The following is a minimal cookbook-style introduction for getting started with SIENA as operated from within StOCNET.

2 General remarks for StOCNET.

1. Ensure that the directories in Options - Directories are existing, and that these are the directories where your data are stored, and where the output is to be stored.

2. Always keep in mind that, when the green  sign is visible, StOCNET expects you to press this button in order to confirm the most recent commands and to continue.

   (You can choose to Cancel if you do not wish to confirm.)

3. The output file which you see in Results is the file, with extension `.out`, that is stored in the directory specified in Options - Directories as the Directory of session files.

2.1 Operating StOCNET.

1. Start by choosing to enter a new session or open a previous session.

2. You have to go sequentially through the various steps:
   Data – Transformation (optional) – Selection (optional) – Model – Results.

3. When starting a new session, you must select one or more network data sets as dependent variable(s), and optionally one or more network data sets as dyadic covariates (independent variables).
   In addition, you can optionally select one or more files with actor-level covariates ('actor attributes') (as independent variables). If you do this, StOCNETwill determined the number of variables in the data set and it is advisable to edit the names of the variables (which have the not very helpful default names of Attribute1, etc.).

4. After selecting the data files and clicking Apply, you are requested to save the session, and give it a name which serves later to identify this session.

5. If necessary, transform the data and indicate missing data values. This is self-explanatory (consult the StOCNETmanual if you need help). You have to note yourself how you transformed the variables. But it is recorded also in the session-tree on the right hand side of the StOCNETscreen.
   It is also advisable to save the session (Session - Save session) after having transformed the data.

3 Using SIENA

3.1 Steps for estimation: Choosing SIENA in StOCNET.

1. In the Model step, select SIENA.
   Then select Data Specification, where the dependent network variable(s) must go to Digraphs in seq. order and the dyadic covariates (if any) to the box with that name.
   If you specify one file as dependent network variable, then the ERGM ($p*$) model is applied. If you specify more than one file as dependent network variables, then the (longitudinal) actor-oriented model is applied, and the ordering of the files in the Digraphs in seq. order box must be the correct order in time.

2. If you are analyzing only a network as the dependent variable, then the actor covariates (if any) must go to the box Constant covariates or Changing covariates; the 'changing' refers to change over time, and can be used only for the longitudinal option.

3. Next go to the Model specification and select the effects you wish to include in the model. When starting, choose a small number (e.g., 1 to 4) effects.

4. After clicking OK, you can then continue by estimating parameters: the Estimation option must be selected (which contrasts with Simulation), and the estimation algorithm then is started by clicking the Run button.

5. It will depend on the size of the data set and the number of parameters in the model, how long the estimation takes. The output file opens automatically in the Results step.

6. Below you see some points about how to evaluate the reliability of the results. If the convergence of the algorithm is not quite satisfactory but not extremely poor, then you can continue just by Running the estimation algorithm again.

7. If the parameter estimates obtained are very poor (not in a reasonable range), then it usually is best to start again, with a simpler model, and from a standardized starting value. The latter option must be selected in the Model specification – Options screen.

SIENA estimates parameters by the following procedure:

1. Certain statistics are chosen that should reflect the parameter values;
   the finally obtained parameters should be such, that the *expected values* of the statistics are equal to the *observed values*.
   Expected values are approximated as the averages over a lot of simulated networks.
   Observed values are calculated from the data set. These are also called the *target values*.

2. To find these parameter values, an *iterative stochastic simulation algorithm* is applied.
   This works as follows:

   (a) In Phase 1, the sensitivity of the statistics to the parameters is roughly determined.

   (b) In Phase 2, provisional parameter values are updated:
   this is done by simulating a network according to the provisional parameter values, calculating the statistics and the deviations between these simulated statistics and the *target values*, and making a little change (the 'update') in the parameter values that hopefully goes into the right direction.
   (Only a 'hopefully' good update is possible, because the simulated network is only a random draw from the distribution of networks, and not the expected value itself.)

to unit S_Base by means of procedures in unit Eight.) Procedure UtilityComponents calculates (16) and (17) and makes them available directly. Procedures Contrib_n and Contrib_fn compute the change in objective function, which is

$$\sum_k \alpha_k \big\{ s_{ik}\big(x(i \rightsquigarrow j)\big) - s_{ik}(x) \big\} \ . \tag{18}$$

This is calculated for changing tie variables from 0 to 1, using (16) and α_k = `alpa_f[k]`, in procedures Contrib_n and Contrib_n_alpha in unit Digraph; for changing tie variables from 1 to 0 it is calculated, using (17) and α_k = `alpa_f[k] + alpa_g[k]`, in procedures Contrib_fn and Contrib_fn_alpha in unit Digraph. How these procedures are placed in the simulation algorithm is indicated in Section 23.1.

The *statistic* used for estimating the weight α of the evaluation effect is given by

$$\begin{aligned} &\sum_m \sum_i f1i(dg^{m+1}, m, par) \ + \\ &\quad \sum_{i \neq j} x_{ij}^{m+1} \big(c_1 \ + c_2\, x_{ji}^{m+1} \ + c_3\, x_{i+}^{m+1} \ + c_4\, x_{+i}^{m+1} \ + c_5\, x_{j+}^{m+1} \ + c_6\, x_{+j}^{m+1} \ + c_7\, TP_{ij}^{m+1} \\ &\qquad + c_8\, OS_{ij}^{m+1} \ + c_9\, IS_{ij}^{m+1} \ + c_{10}\, TP_{ji}^{m+1} \ + f1ij(dg^{m+1}, i, j, m, par) \big) \ , \end{aligned} \tag{19}$$

where c_h = ConfigWeight[h] and the superscript $^{m+1}$ refers to the observation moment. This statistic is calculated by procedure CalcFunctions_f in unit DIGRAPH.

The *endowment function* is defined only if $f1i = 0$; then IncludeEndowment is true, else it is false. The contribution of the effect to the endowment function (i.e., an extra component of the loss incurred when changing tie variable x_{ij} from 1 to 0) is given by the corresponding statistical parameter multiplied by (17). The *statistic* used for estimating the weight α of the endowment effect is given by

$$\begin{aligned} &\sum_{i \neq j} (1 - x_{ij}^{m+1}) x_{ij}^{m} \big(c_1 \ + c_2\, x_{ji}^{m} \ + c_3\, x_{i+}^{m} \ + c_4\, x_{+i}^{m} \ + c_5\, x_{j+}^{m} \ + c_6\, x_{+j}^{m} \\ &\qquad + c_7\, TP_{ij}^{m} \ + c_8\, OS_{ij}^{m} \ + c_9\, IS_{ij}^{m} \ + c_{10}\, TP_{ji}^{m} \ + f1ij(dg^{m}, i, j, m, par) \big) \ , \end{aligned} \tag{20}$$

where c_h = ConfigWeight[h] and the superscripts ^{m} and $^{m+1}$ refer to the observation moments. Note that the factor $(1 - x_{ij}^{m+1})x_{ij}^{m}$ means that the summation extends only over (i, j) for which there was a tie at observation m which had disappeared at moment $m + 1$, while the subscripts ^{m} between the parentheses imply that the "quantity lost" is calculated by reference to moment m. This statistic is calculated by procedure CalcFunctions_g in unit DIGRAPH.

24.2 Changing or adding definitions of effects

Objective function effects for the network dynamics are defined by the procedure AddEffect* defined in unit DIGRAPH, and called in procedure DefineNetworkEffects in include file S_Effects which is part of unit S_DAT. Procedure AddEffect* defines the name, the arrays ContributionWeight and ConfigWeight, and the functions f1ijc, f1ij, and f1i, all described in Section 24.1. Note that various versions AddEffect1, AddEffect2, etc., are available for procedure AddEffect*, where omitted arguments are 0 or nil. Usually when a new effect is defined, also new functions will have to be defined that are then used in the roles of f1ijc, f1ij, and/or f1i. Many examples can be found in file S_Effects.

If new effects are added to the rate function for the network dynamics, these additions must be made in a coherent way to each of the following procedures.

1. Procedure DefineFunctionNames in unit S_DAT, which contains the names of all the statistics calculated from each simulation;
2. Procedure DefineModel_lnames in unit S_DAT, which contains the names of all effects in the network change rate function;
3. Function NetworkLambda in unit S_BASE, the network change rate function itself;
4. Procedure NetworkStatistics in unit S_BASE, for the statistics used to estimate the parameters by the Method of Moments.

(For the maximum likelihood estimation procedure, non-constant rate functions are not yet implemented.)

If new effects are added to the model for the behavior dynamics, these additions must be made coherently to each of the following procedures.

- For each kind of effect:
  1. Procedure DefineFunctionNames in unit S_DAT, which contains the names of all the statistics potentially calculated from each simulation;
  2. Function MaxFunctions in unit S_DAT, which contains the number of these statistics (more precisely, the functions called by MaxFunctions);
  3. Procedure ActionStatistics in unit S_BASE, which calculates these statistics.
- For effects in the rate function for behavior change, the analogous procedures have to be changed as those for the rate function for network change:
  function ActionEffects_l in unit S_DAT, procedure DefineModel_lnames in unit S_DAT, function ActionLambda in unit S_BASE, and procedure ActionStatistics in unit S_BASE.
- For effects in the evaluation and endowment functions for behavior change, the following procedures have to be changed:
  function ActionEffects_f in unit S_DAT, procedure DefineModel_fnames in unit S_DAT, and functions Contr_fa and Contr_ga in unit S_BASE; the latter functions must be coordinated with procedure CalcComponents_fa in unit EIGHT.

The functions AddNoTies_yn, SubtractTies_yn, Contr_fa, Contr_ga, NetworkLambda, and ActionLambda are evaluated very frequently by the algorithm. Therefore these have been written so that relatively few calculations are needed to evaluate them. Such calculations for a large part are replaced by updating and storing the basic numerical information needed to compute them. These updates are contained in the procedure ChangeTie in unit S_BASE, and the initialisation is contained in the procedure Initialise_Running_Statistics.

25 Statistical Monte Carlo Studies

According to Sir Ronald A. Fisher, there are three main statistical problems, model specification, model estimation, and problems of distribution. The last one concerns the distribution of statistics, such as the distribution of parameter estimates around the true (data-generating) parameter value or the distribution of test statistics, and can be studied by SIENA in various ways. One way is to use Siena05 and Siena07 repeatedly in batch files. It can be useful to know that if Siena05 is called with only one run, then one data set is simulated and also stored in the internal SIENA format under the project name *sisim*. Further, Siena07 gives brief estimation reports in the files *pname*.bof and *pname*.bos, which can be used more easily as summaries of repeated runs than the normal output file.

This can be used, for example, as follows. It is assumed that the reader knows how to run SIENA outside of StOCNET, see Section 17.

1. Make a directory which includes the files Siena01.exe, Siena05.exe, Siena07.exe and all the data files of a basic project that will be emulated in the simulations.
2. Initialise a Siena project; for example, with project name sprj. Do this by constructing the file sprj.in and running a batch file with the contents

   ```
   siena01.exe sprj
   copy sprj.* sisim.*
   ```

3. The second line in the batch file has also copied all files sprj.* to sisim.*.
   This means that now, two identical projects are available. Of these, sprj.* will be used to generate simulated data, and sisim.* to analyse these.
4. Specify the file sprj.mo to have the desired effects and parameter values. Copy this file to sisima.mo.
5. In the file sprj.si, change the last line so that the number of simulation runs specified is 1.
6. Make a batch file which contains many repetitions of the lines

   ```
   start /w siena05 sprj
   copy sisima.mo sisim.mo
   start /w siena07 sisim
   ```

   For example, 1,000 repetitions, for 1,000 simulations.
   The first line makes one simulation run with the specifications included in sprj.mo, and writes the data files in internal SIENA format to files sisim.d*. The second line specifies the correct model specification for the analysis. (If you wish to estimate parameters with a different specification, the file sisima.mo should be defined accordingly.) The third line estimates the model.
7. The directory should at this moment (before running the batch file) not contain a file called sisim.bos or sisim.bof.
   Run the batch file.
8. After the batch file is finished, the file sisim.bos now contains a summary of all the estimates and standard errors produced. It gives first a heading, then for each simulation/estimation

run a line with initial information, the estimates, and the standard errors. The initial information is the estimation method; if the maximum absolute t-value for convergence is larger than 0.1, then a letter t, else the sign $*$; if the maximum standard error is larger than 10.0, then a letter s, else the sign $*$; and the maximum absolute t-value for convergence. The file sisim.bof contains longer summaries of each estimation run, for reference purposes.
Note that the threshold of 0.1 for the t-ratios for convergence is very conservative, and somewhat larger values usually are acceptable.
To understand the contents of the file sisim.bos, it is good to compare some of the first lines following the heading with the corresponding results summarized in sisim.bof.

Another way to do simulation studies using SIENA, if one has access to a Delphi or Lazarus compiler, is as follows. Open the unit Siena_7 and go to the procedure TEstForm.FormActivate. The first statement in the procedure is `simulate := false`. Set the global variable `simulate` to true. SIENA will then simulate data sets according to the probability model specified in the *pname*.MO file.

Then, manipulate the global constant `sequences` declared in unit Siena_7 by setting it to some positive integer value k (the default is 1). The constant `sequences` gives the number of runs (sequences).

The result is that running SIENA will generate k data sets according to the probability model specified *pname*.MO file. From each data set, the parameters are estimated and test statistics are evaluated.

Some Matlab source files are (by default) generated by SIENA. The source code, when interpreted by Matlab, produces histograms of some statistics, in particular histograms of the parameter estimates and the test statistics.

It should be noted that SIENA generates networks with desired properties, but (by default) no covariates. If covariates are desired, suitable code must be added at the beginning of the procedure SimulateData in the unit S_EST. Please note that both internal and external storage (see Section 21.3) of generated covariates is required. Internal storage is difficult unless one knows SIENA -it is advisable to contact the authors in such cases.

26 Constants

The program contains the following constants. Trying to use a basic information file that implies a data set going beyond these constants leads to an error message in the output file and stops the further operation of SIENA.

name	meaning	in unit
$pmax$	maximum number p of included effects	S_Constants
$ccmax$	maximum number of possible statistics	S_Constants
$nzmax$	maximum number nz of individual variables	EIGHT
$nzzmax$	maximum number nzz of dyadic covariates	EIGHT

Reasonable values for these constants are the following:
$pmax = 70$;
$ccmax = 500$; the maximum number of statistics depends on the number of available effects, the number of dependent behavior variables, and the number of observations M, and is given by MaxFunctions in unit S_Dat; this should not be more than $ccmax$;
$nzmax = 30$;
$nzzmax = 20$.

The number M of observations may not be higher than 99. Since the number of observations is dealt with by a dynamic array, this is not reflected by some constant. The only reason for the upper bound of 99 is that the index number of the observation is used in the internal data file extension names and may not have more than two digits. But 99 seems quite a high upper bound for practical data sets.

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