Package 'tergm'

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Title Fit, Simulate and Diagnose Models for Network Evolution Based on Exponential-Family Random Graph Models

Depends ergm (>= 4.7.0), network (>= 1.18.2), networkDynamic (>= 0.11.4)

Imports robustbase (>= 0.95), coda (>= 0.19-4.1), statnet.common (>= 4.10.0), ergm.multi (>= 0.2.1), purrr (>= 1.0.2), methods, utils, nlme, MASS

LinkingTo ergm

Suggests rmarkdown (>= 2.28), knitr (>= 1.48), tibble (>= 3.2.1), testthat (>= 3.2.1.1), covr (>= 3.6.4), networkLite (>= 1.0.5), rlang, lattice, parallel

BugReports https://github.com/statnet/tergm/issues

Description An integrated set of extensions to the 'ergm' package to analyze and simulate network evolution based on exponential-family random graph models (ERGM). 'tergm' is a part of the 'statnet' suite of packages for network analysis. See Krivitsky and Handcock (2014) <doi:10.1111/rssb.12014> and Carnegie, Krivitsky, Hunter, and Goodreau (2015) <doi:10.1080/10618600.2014.903087>.

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URL https://statnet.org

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Contents

`tergm-package` *tergm: Fit, Simulate and Diagnose Models for Network Evolution Based on Exponential-Family Random Graph Models*

Description

An integrated set of extensions to the 'ergm' package to analyze and simulate network evolution based on exponential-family random graph models (ERGM). 'tergm' is a part of the 'statnet' suite of packages for network analysis. See Krivitsky and Handcock (2014) doi:10.1111/rssb.12014 and Carnegie, Krivitsky, Hunter, and Goodreau (2015) doi:10.1080/10618600.2014.903087.

Details

tergm is a collection of extensions to the **ergm** package to fit, diagnose, and simulate models for dynamic networks — networks that evolve over time — based on exponential-family random graph models (ERGMs). For a list of functions type `help(package='tergm')`

When publishing results obtained using this package, please cite the original authors as described in `citation(package="tergm")`.

All programs derived from this package must cite it.

An exponential-family random graph model (ERGM) postulates an exponential family over the sample space of networks of interest, and **ergm** package implements a suite of tools for modeling single networks using ERGMs.

There have been a number of extensions of ERGMs for modeling the evolution of networks, including the temporal ERGM (TERGM) of Hanneke et al. (2010) and the separable termporal ERGM (STERGM) of Krivitsky and Handcock (2014). The latter model allows familiar ERGM terms and statistics to be reused in a dynamic context, interpreted in terms of formation and dissolution (persistence) of ties. Krivitsky (2012) suggested a method for fitting dynamic models when only a cross-sectional network is available, provided some temporal information for it is available as well.

This package aims to implement these and other ERGM-based models for network evolution. At this time, it implements, via the `tergm()` function, a general framework for modeling tie dynamics in temporal networks with flexible model specification (including (S)TERGMs). Estimation options include a conditional MLE (CMLE) approach for fitting to a series of networks and an Equilibrium Generalized Method of Moments Estimation (EGMME) for fitting to a single network with temporal information. For further development, see the referenced papers.

Temporal model specification in tergm

The operator terms implemented by **tergm** are `Form()`, `Persist()`, `Diss()`, `Cross()`, and `Change()`. These are used to specify how the `ergm` terms (`ergmTerm`) in a formula are evaluated across a network time-series. Note, you cannot use one of these operators within another temporal, so

`Cross(~Form(~edges))` is not a valid specification. (Generally, nesting these operators within other operators will often not work; nesting other operators within them will almost always work, however.)

The durational terms are distinguished either by their name, `mean.age`, or their name extensions: `<name>.ages`, `<name>.mean.age`, and `<name>.age.interval`. In contrast to their eponymous terms in **ergm**, these durational terms take into account the elapsed time since each (term-relevant) dyad in the network was last toggled.

As currently implemented, the package does not support use of many durational terms during estimation, though it may work with some. But durational terms may be used as targets, monitors, or summary statistics. The ability to use these terms in the estimation of models is under development.

Compatibility with previous versions

If you previously used the `stergm()` function in this package, please note that `stergm()` has been superceded by the new `tergm()` function, and has been deprecated. The `dissolution` formula in `stergm()` maps to the new `Persist()` operator in the `tergm()` function, **not** the `Diss()` operator.

For detailed information on how to download and install the software, go to the Statnet project website: https://statnet.org. A tutorial, support newsgroup, references and links to further resources are provided there.

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References

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Morris M, Handcock MS, Hunter DR (2008). Specification of Exponential-Family Random Graph Models: Terms and Computational Aspects. *Journal of Statistical Software*, 24(4). doi:10.18637/jss.v024.i04

See Also

Useful links:

- https://statnet.org
- Report bugs at https://github.com/statnet/tergm/issues

`.extract.fd.formulae` *An Internal Function for Extracting (Some) Formation and Dissolution Formulas from a Combined Formula*

Description

This function is used in `tergm.EGMME.initialfit` and also when targets or monitoring formulas are specified by characters. It makes a basic attempt to identify the formation and dissolution formulas within a larger combined formula (which may also include non-separable terms). Instances of `Form` at the top level (which may occur inside `offset`) contribute to the formation formula; instances of `Persist` and `Diss` at the top level (which may also occur inside `offset`) contribute to the dissolution formula. All other terms are regarded as non-separable; this includes instances of `Form`, `Persist`, and `Diss` that occur inside other operator terms, including inside `Offset`, and also

includes all interactions at the top level (for which the top level term is effectively the interaction operator `*` or `:`), whether or not they include `Form`, `Persist`, and/or `Diss`. The formation and dissolution formulas are obtained by adding the contributing terms, replacing `Form` and `Persist` with trivial operators that protect the environments of their formula arguments but have no effect on statistics or coefficient names (meaning the formulas effectively become cross-sectional), and replacing `Diss` by a similar operator that negates statistics. These are included in the return value as the `form` and `pers` elements of the list (the "dissolution" formula really being the persistence formula), which also includes the formula of non-separable terms as `nonsep`, and the formula of all terms after replacing `Form`, `Persist`, and `Diss` as described above as `all`.

If usage proves problematic, one may specify the monitoring and/or targets formulas explicitly (rather than by characters), and one may pass initial coefficient values for the EGMME to avoid running `tergm.EGMME.initialfit`.

Usage

```
.extract.fd.formulae(formula)
```

Arguments

`formula`	a `formula`.

Value

A `list` containing `form`, `pers`, `nonsep`, and `all` formulas as described above.

`Change-ergmTerm` *The Change Operator Term*

Description

The Change Operator Term

Usage

```
# binary: Change(
#           formula,
#           lm = ~1,
#           subset = TRUE,
#           weights = 1,
#           contrasts = NULL,
#           offset = 0,
#           label = NULL
#         )
```

Arguments

`formula`	a one-sided `ergm()`-style formula with the terms to be evaluated
`lm`, `subset`, `weights`, `contrasts`, `offset`, `label`	`NetSeries()` **LHS only** arguments to specify time-varying parameters. See `N()` term operator in the **ergm.multi** for details. `lm` formula may reference `.Time` for the network's time index, `.TimeID` for the its index in the network series (where the initial network is 1 and the first modelled network is 2), and `.TimeDelta` for the time elapsed between the network and the immediately previous network in the series.

Details

This term accepts a model formula and produces the corresponding model for a network constructed by taking the dyads that have changed between time steps.

See Also

`ergmTerm` for index of model terms currently visible to the package.

Keywords: None

`control.simulate.network` *Auxiliary for Controlling Separable Temporal ERGM Simulation*

Description

Auxiliary function as user interface for fine-tuning STERGM simulation.

Usage

```
control.simulate.network(
  MCMC.burnin.min = 1000,
  MCMC.burnin.max = 1e+05,
  MCMC.burnin.pval = 0.5,
  MCMC.burnin.add = 1,
  MCMC.prop.form = ~discord + sparse,
  MCMC.prop.diss = ~discord + sparse,
  MCMC.prop.weights.form = "default",
  MCMC.prop.weights.diss = "default",
  MCMC.prop.args.form = NULL,
  MCMC.prop.args.diss = NULL,
  MCMC.maxedges = Inf,
  MCMC.maxchanges = 1e+06,
  term.options = NULL,
  MCMC.packagenames = c()
)
```

```
control.simulate.stergm(
  MCMC.burnin.min = NULL,
  MCMC.burnin.max = NULL,
  MCMC.burnin.pval = NULL,
  MCMC.burnin.add = NULL,
  MCMC.prop.form = NULL,
  MCMC.prop.diss = NULL,
  MCMC.prop.weights.form = NULL,
  MCMC.prop.weights.diss = NULL,
  MCMC.prop.args.form = NULL,
  MCMC.prop.args.diss = NULL,
  MCMC.maxedges = NULL,
  MCMC.maxchanges = NULL,
  term.options = NULL,
  MCMC.packagenames = NULL
)
```

Arguments

`MCMC.burnin.min`, `MCMC.burnin.max`, `MCMC.burnin.pval`, `MCMC.burnin.add`

Number of Metropolis-Hastings steps per time step used in simulation. By default, this is determined adaptively by keeping track of increments in the Hamming distance between the transitioned-from network and the network being sampled. Once `MCMC.burnin.min` steps have elapsed, the increments are tested against 0, and when their average number becomes statistically indistinguishable from 0 (with the p-value being greater than `MCMC.burnin.pval`), or `MCMC.burnin.max` steps are proposed, whichever comes first, the simulation is stopped after an additional `MCMC.burnin.add` times the number of elapsed steps have been taken. (Stopping immediately would bias the sampling.)

To use a fixed number of steps, set `MCMC.burnin.min` and `MCMC.burnin.max` to the same value.

`MCMC.prop.form` Hints and/or constraints for selecting and initializing the proposal.

`MCMC.prop.weights.form`

Specifies the proposal weighting scheme to be used in the MCMC Metropolis-Hastings algorithm. Possible choices may be determined by calling `ergm_proposal_table()`.

`MCMC.prop.weights.diss`, `MCMC.prop.args.diss`, `MCMC.prop.diss`

Ignored. These are included for backwards compatibility of calls to `control` functions only; they have no effect on `simulate` behavior.

`MCMC.prop.args.form`

An alternative, direct way of specifying additional arguments to proposals.

`MCMC.maxedges` The maximum number of edges that may occur during the MCMC sampling. If this number is exceeded at any time, sampling is stopped immediately.

`MCMC.maxchanges`

Maximum number of changes for which to allocate space.

`term.options` A list of additional arguments to be passed to term initializers. See `? term.options`.

MCMC.packagenames
: Names of packages in which to look for change statistic functions in addition to those autodetected. This argument should not be needed outside of very strange setups.

Details

This function is only used within a call to the simulate() function. See the Usage section in simulate.stergm() for details.

These functions are included for backwards compatibility, and users are encouraged to use control.simulate.tergm or control.simulate.formula.tergm with the simulate.tergm() family of functions instead. When a control.simulate.stergm or control.simulate.network object is passed to one of the simulate.stergm() functions, the corresponding simulate.tergm() function is invoked, and uses the formation proposal control arguments, ignoring the dissolution proposal control arguments.

Note: The old dissolution formula in stergm represents tie persistence. As a result it maps to the new Persist() operator in tergm, NOT the Diss() operator

Value

A list with arguments as components.

See Also

simulate.stergm(), simulate.formula(). control.stergm() performs a similar function for stergm().

---

control.simulate.tergm

Auxiliary for Controlling Temporal ERGM Simulation

Description

Auxiliary function as user interface for fine-tuning TERGM simulation.

Usage

```
control.simulate.tergm(
  MCMC.burnin.min = NULL,
  MCMC.burnin.max = NULL,
  MCMC.burnin.pval = NULL,
  MCMC.burnin.add = NULL,
  MCMC.prop = NULL,
  MCMC.prop.weights = NULL,
  MCMC.prop.args = NULL,
  MCMC.maxedges = NULL,
  MCMC.maxchanges = NULL,
  term.options = NULL,
```

```
  MCMC.packagenames = NULL
)

control.simulate.formula.tergm(
  MCMC.burnin.min = 1000,
  MCMC.burnin.max = 1e+05,
  MCMC.burnin.pval = 0.5,
  MCMC.burnin.add = 1,
  MCMC.prop = ~discord + sparse,
  MCMC.prop.weights = "default",
  MCMC.prop.args = NULL,
  MCMC.maxedges = Inf,
  MCMC.maxchanges = 1e+06,
  term.options = NULL,
  MCMC.packagenames = c()
)
```

Arguments

`MCMC.burnin.min`, `MCMC.burnin.max`, `MCMC.burnin.pval`, `MCMC.burnin.add`

Number of Metropolis-Hastings steps per time step used in simulation. By default, this is determined adaptively by keeping track of increments in the Hamming distance between the transitioned-from network and the network being sampled. Once `MCMC.burnin.min` steps have elapsed, the increments are tested against 0, and when their average number becomes statistically indistinguishable from 0 (with the p-value being greater than `MCMC.burnin.pval`), or `MCMC.burnin.max` steps are proposed, whichever comes first, the simulation is stopped after an additional `MCMC.burnin.add` times the number of elapsed steps have been taken. (Stopping immediately would bias the sampling.)

To use a fixed number of steps, set `MCMC.burnin.min` and `MCMC.burnin.max` to the same value.

`MCMC.prop` Hints and/or constraints for selecting and initializing the proposal.

`MCMC.prop.weights`

Specifies the proposal weighting scheme to be used in the MCMC Metropolis-Hastings algorithm. Possible choices may be determined by calling `ergm_proposal_table()`.

`MCMC.prop.args` An alternative, direct way of specifying additional arguments to the proposal.

`MCMC.maxedges` The maximum number of edges that may occur during the MCMC sampling. If this number is exceeded at any time, sampling is stopped immediately.

`MCMC.maxchanges`

Maximum number of changes for which to allocate space.

`term.options` A list of additional arguments to be passed to term initializers. See `? term.options`.

`MCMC.packagenames`

Names of packages in which to look for change statistic functions in addition to those autodetected. This argument should not be needed outside of very strange setups.

Details

This function is only used within a call to the simulate() function. See the Usage section in simulate.tergm() for details.

Value

A list with arguments as components.

See Also

simulate.tergm(), simulate.formula(). control.tergm() performs a similar function for tergm().

---

control.stergm *Auxiliary for Controlling Separable Temporal ERGM Fitting*

Description

Auxiliary function as user interface for fine-tuning 'stergm' fitting.

Usage

```
control.stergm(
  init.form = NULL,
  init.diss = NULL,
  init.method = NULL,
  force.main = FALSE,
  MCMC.prop.form = ~discord + sparse,
  MCMC.prop.diss = ~discord + sparse,
  MCMC.prop.weights.form = "default",
  MCMC.prop.args.form = NULL,
  MCMC.prop.weights.diss = "default",
  MCMC.prop.args.diss = NULL,
  MCMC.maxedges = Inf,
  MCMC.maxchanges = 1e+06,
  MCMC.packagenames = c(),
  CMLE.MCMC.burnin = 1024 * 16,
  CMLE.MCMC.interval = 1024,
  CMLE.ergm = NULL,
 CMLE.form.ergm = control.ergm(init = init.form, MCMC.burnin = CMLE.MCMC.burnin,
  MCMC.interval = CMLE.MCMC.interval, MCMC.prop = MCMC.prop.form, MCMC.prop.weights =
   MCMC.prop.weights.form, MCMC.prop.args = MCMC.prop.args.form, MCMC.maxedges =
    MCMC.maxedges, MCMC.packagenames = MCMC.packagenames, parallel = parallel,
  parallel.type = parallel.type, parallel.version.check = parallel.version.check,
    parallel.inherit.MT = parallel.inherit.MT, force.main = force.main),
 CMLE.diss.ergm = control.ergm(init = init.diss, MCMC.burnin = CMLE.MCMC.burnin,
  MCMC.interval = CMLE.MCMC.interval, MCMC.prop = MCMC.prop.diss, MCMC.prop.weights =
```

```
  MCMC.prop.weights.diss, MCMC.prop.args = MCMC.prop.args.diss, MCMC.maxedges =
    MCMC.maxedges, MCMC.packagenames = MCMC.packagenames, parallel = parallel,
  parallel.type = parallel.type, parallel.version.check = parallel.version.check,
    parallel.inherit.MT = parallel.inherit.MT, force.main = force.main),
 CMLE.NA.impute = c(),
 CMLE.term.check.override = FALSE,
 EGMME.main.method = c("Gradient-Descent"),
 EGMME.initialfit.control = control.ergm(),
 EGMME.MCMC.burnin.min = 1000,
 EGMME.MCMC.burnin.max = 1e+05,
 EGMME.MCMC.burnin.pval = 0.5,
 EGMME.MCMC.burnin.add = 1,
 MCMC.burnin = NULL,
 MCMC.burnin.mul = NULL,
 SAN.maxit = 4,
 SAN.nsteps.times = 8,
 SAN = control.san(term.options = term.options, SAN.maxit = SAN.maxit, SAN.prop =
    MCMC.prop.form, SAN.prop.weights = MCMC.prop.weights.form, SAN.prop.args =
    MCMC.prop.args.form, SAN.nsteps = round(sqrt(EGMME.MCMC.burnin.min *
  EGMME.MCMC.burnin.max)) * SAN.nsteps.times, SAN.packagenames = MCMC.packagenames,
    parallel = parallel, parallel.type = parallel.type, parallel.version.check =
    parallel.version.check, parallel.inherit.MT = FALSE),
 SA.restarts = 10,
 SA.burnin = 1000,
 SA.plot.progress = FALSE,
 SA.max.plot.points = 400,
 SA.plot.stats = FALSE,
 SA.init.gain = 0.1,
 SA.gain.decay = 0.5,
 SA.runlength = 25,
 SA.interval.mul = 2,
 SA.init.interval = 500,
 SA.min.interval = 20,
 SA.max.interval = 500,
 SA.phase1.minruns = 4,
 SA.phase1.tries = 20,
 SA.phase1.jitter = 0.1,
 SA.phase1.max.q = 0.1,
 SA.phase1.backoff.rat = 1.05,
 SA.phase2.levels.max = 40,
 SA.phase2.levels.min = 4,
 SA.phase2.max.mc.se = 0.001,
 SA.phase2.repeats = 400,
 SA.stepdown.maxn = 200,
 SA.stepdown.p = 0.05,
 SA.stop.p = 0.1,
 SA.stepdown.ct = 5,
 SA.phase2.backoff.rat = 1.1,
```

```
  SA.keep.oh = 0.5,
  SA.keep.min.runs = 8,
  SA.keep.min = 0,
  SA.phase2.jitter.mul = 0.2,
  SA.phase2.maxreljump = 4,
  SA.guard.mul = 4,
  SA.par.eff.pow = 1,
  SA.robust = FALSE,
  SA.oh.memory = 1e+05,
  SA.refine = c("mean", "linear", "none"),
  SA.se = TRUE,
  SA.phase3.samplesize.runs = 10,
  SA.restart.on.err = TRUE,
  term.options = NULL,
  seed = NULL,
  parallel = 0,
  parallel.type = NULL,
  parallel.version.check = TRUE,
  parallel.inherit.MT = FALSE,
  ...
)
```

Arguments

`init.form`, `init.diss`
: numeric or `NA` vector equal in length to the number of parameters in the formation/dissolution model or `NULL` (the default); the initial values for the estimation and coefficient offset terms. If `NULL` is passed, all of the initial values are computed using the method specified by `control$init.method`. If a numeric vector is given, the elements of the vector are interpreted as follows:

  - Elements corresponding to terms enclosed in `offset()` are used as the fixed offset coefficients. These should match the offset values given in `offset.coef.form` and `offset.coef.diss`.
  - Elements that do not correspond to offset terms and are not `NA` are used as starting values in the estimation.
  - Initial values for the elements that are `NA` are fit using the method specified by `control$init.method`.

  Passing coefficients from a previous run can be used to "resume" an uncoverged `stergm()` run.

`init.method`
: Estimation method used to acquire initial values for estimation. If `NULL` (the default), the initial values are computed using the edges dissolution approximation (Carnegie et al.) when appropriate; note that this relies on `.extract.fd.formulae()` to identify the formation and dissolution parts of the formula; the user should be aware of its behavior and limitations. If `init.method` is set to "zeros", the initial values are set to zeros.

`force.main`
: Logical: If TRUE, then force MCMC-based estimation method, even if the exact MLE can be computed via maximum pseudolikelihood estimation.

`MCMC.prop.form` Hints and/or constraints for selecting and initializing the proposal.

`MCMC.prop.weights.form`
: Specifies the proposal weighting to use.

`MCMC.prop.args.form`
: A direct way of specifying arguments to the proposal.

`MCMC.prop.weights.diss`, `MCMC.prop.args.diss`, `MCMC.prop.diss`
: Ignored.

`MCMC.maxedges` The maximum number of edges that may occur during the MCMC sampling. If this number is exceeded at any time, sampling is stopped immediately.

`MCMC.maxchanges`
: Maximum number of changes in dynamic network simulation for which to allocate space.

`MCMC.packagenames`
: Names of packages in which to look for change statistic functions in addition to those autodetected. This argument should not be needed outside of very strange setups.

`CMLE.MCMC.burnin`
: Burnin used in CMLE fitting.

`CMLE.MCMC.interval`
: Number of Metropolis-Hastings steps between successive draws when running MCMC MLE.

`CMLE.ergm` A convenience argument for specifying both `CMLE.form.ergm` and `CMLE.diss.ergm` at once. See `control.ergm()`.

`CMLE.form.ergm` Control parameters used to fit the CMLE. See `control.ergm()`.

`CMLE.diss.ergm` Ignored, with the exception of initial parameter values.

`CMLE.NA.impute` In STERGM CMLE, missing dyads in transitioned-to networks are accommodated using methods of Handcock and Gile (2009), but a similar approach to transitioned-from networks requires much more complex methods that are not, currently, implemented. `CMLE.NA.impute` controls how missing dyads in transitioned-from networks are be imputed. See argument `imputers` of `impute.network.list()` for details.

By default, no imputation is performed, and the fitting stops with an error if any transitioned-from networks have missing dyads.

`CMLE.term.check.override`
: The method `stergm()` uses at this time to fit a series of more than two networks requires certain assumptions to be made about the ERGM terms being used, which are tested before a fit is attempted. This test sometimes fails despite the model being amenable to fitting, so setting this option to `TRUE` overrides the tests.

`EGMME.main.method`
: Estimation method used to find the Equilibrium Generalized Method of Moments estimator. Currently only "Gradient-Descent" is implemented.

`EGMME.initialfit.control`
: Control object for the ergm fit in tergm.EGMME.initialfit

EGMME.MCMC.burnin.min, EGMME.MCMC.burnin.max
: Number of Metropolis-Hastings steps per time step used in EGMME fitting. By default, this is determined adaptively by keeping track of increments in the Hamming distance between the transitioned-from network and the network being sampled. Once EGMME.MCMC.burnin.min steps have elapsed, the increments are tested against 0, and when their average number becomes statistically indistinguishable from 0 (with the p-value being greater than EGMME.MCMC.burnin.pval), or EGMME.MCMC.burnin.max steps are proposed, whichever comes first, the simulation is stopped after an additional EGMME.MCMC.burnin.add times the number of elapsed steps had been taken. (Stopping immediately would bias the sampling.)

  To use a fixed number of steps, set EGMME.MCMC.burnin.min and EGMME.MCMC.burnin.max to the same value.

EGMME.MCMC.burnin.pval, EGMME.MCMC.burnin.add
: Number of Metropolis-Hastings steps per time step used in EGMME fitting. By default, this is determined adaptively by keeping track of increments in the Hamming distance between the transitioned-from network and the network being sampled. Once EGMME.MCMC.burnin.min steps have elapsed, the increments are tested against 0, and when their average number becomes statistically indistinguishable from 0 (with the p-value being greater than EGMME.MCMC.burnin.pval), or EGMME.MCMC.burnin.max steps are proposed, whichever comes first, the simulation is stopped after an additional EGMME.MCMC.burnin.add times the number of elapsed steps had been taken. (Stopping immediately would bias the sampling.)

  To use a fixed number of steps, set EGMME.MCMC.burnin.min and EGMME.MCMC.burnin.max to the same value.

MCMC.burnin, MCMC.burnin.mul
: No longer used. See EGMME.MCMC.burnin.min, EGMME.MCMC.burnin.max, EGMME.MCMC.burnin.pval, EGMME.MCMC.burnin.pval, EGMME.MCMC.burnin.add and CMLE.MCMC.burnin and CMLE.MCMC.interval.

SAN.maxit
: When target.stats argument is passed to ergm(), the maximum number of attempts to use san() to obtain a network with statistics close to those specified.

SAN.nsteps.times
: Multiplier for SAN.nsteps relative to MCMC.burnin. This lets one control the amount of SAN burn-in (arguably, the most important of SAN parameters) without overriding the other SAN defaults.

SAN
: SAN control parameters. See control.san()

SA.restarts
: Maximum number of times to restart a failed optimization process.

SA.burnin
: Number of time steps to advance the starting network before beginning the optimization.

SA.plot.progress, SA.plot.stats
: Logical: Plot information about the fit as it proceeds. If SA.plot.progress==TRUE, plot the trajectories of the parameters and target statistics as the optimization progresses. If SA.plot.stats==TRUE, plot a heatmap representing correlations of target statistics and a heatmap representing the estimated gradient.

  Do NOT use these with non-interactive plotting devices like pdf(). (In fact, it will refuse to do that with a warning.)

`SA.max.plot.points`
: If `SA.plot.progress==TRUE`, the maximum number of time points to be plotted. Defaults to 400. If more iterations elapse, they will be thinned to at most 400 before plotting.

`SA.init.gain`
: Initial gain, the multiplier for the parameter update size. If the process initially goes crazy beyond recovery, lower this value.

`SA.gain.decay`
: Gain decay factor.

`SA.runlength`
: Number of parameter trials and updates per C run.

`SA.interval.mul`
: The number of time steps between updates of the parameters is set to be this times the mean duration of extant ties.

`SA.init.interval`
: Initial number of time steps between updates of the parameters.

`SA.min.interval`, `SA.max.interval`
: Upper and lower bounds on the number of time steps between updates of the parameters.

`SA.phase1.minruns`
: Number of runs during Phase 1 for estimating the gradient, before every gradient update.

`SA.phase1.tries`
: Number of runs trying to find a reasonable parameter and network configuration.

`SA.phase1.jitter`
: Initial jitter standard deviation of each parameter.

`SA.phase1.max.q`
: Q-value (false discovery rate) that a gradient estimate must obtain before it is accepted (since sign is what is important).

`SA.phase1.backoff.rat`, `SA.phase2.backoff.rat`
: If the run produces this relative increase in the approximate objective function, it will be backed off.

`SA.phase2.levels.min`, `SA.phase2.levels.max`
: Range of gain levels (subphases) to go through.

`SA.phase2.max.mc.se`
: Approximate precision of the estimates that must be attained before stopping.

`SA.phase2.repeats`, `SA.stepdown.maxn`
: A gain level may be repeated multiple times (up to `SA.phase2.repeats`) if the optimizer detects that the objective function is improving or the estimating equations are not centered around 0, so slowing down the parameters at that point is counterproductive. To detect this it looks at the the window controlled by `SA.keep.oh`, thinning objective function values to get `SA.stepdown.maxn`, and 1) fitting a GLS model for a linear trend, with AR(2) autocorrelation and 2) conductiong an approximate Hotelling's T^2 test for equality of estimating equation values to 0. If there is no significance for either at `SA.stepdown.p` `SA.stepdown.ct` runs in a row, the gain level (subphase) is allowed to end. Otherwise, the process continues at the same gain level.

`SA.stepdown.p`, `SA.stepdown.ct`
: A gain level may be repeated multiple times (up to `SA.phase2.repeats`) if the optimizer detects that the objective function is improving or the estimating equations are not centered around 0, so slowing down the parameters at that point is counterproductive. To detect this it looks at the the window controlled by `SA.keep.oh`, thinning objective function values to get `SA.stepdown.maxn`, and 1) fitting a GLS model for a linear trend, with AR(2) autocorrelation and 2) conductiong an approximate Hotelling's T^2 test for equality of estimating equation values to 0. If there is no significance for either at `SA.stepdown.p` `SA.stepdown.ct` runs in a row, the gain level (subphase) is allowed to end. Otherwise, the process continues at the same gain level.

`SA.stop.p`
: At the end of each gain level after the minimum, if the precision is sufficiently high, the relationship between the parameters and the targets is tested for evidence of local nonlinearity. This is the p-value used.

  If that test fails to reject, a Phase 3 run is made with the new parameter values, and the estimating equations are tested for difference from 0. If this test fails to reject, the optimization is finished.

  If either of these tests rejects, at `SA.stop.p`, optimization is continued for another gain level.

`SA.keep.oh`, `SA.keep.min`, `SA.keep.min.runs`
: Parameters controlling how much of optimization history to keep for gradient and covariance estimation.

  A history record will be kept if it's at least one of the following:

  - Among the last `SA.keep.oh` (a fraction) of all runs.
  - Among the last `SA.keep.min` (a count) records.
  - From the last `SA.keep.min.runs` (a count) optimization runs.

`SA.phase2.jitter.mul`
: Jitter standard deviation of each parameter is this value times its standard deviation without jitter.

`SA.phase2.maxreljump`
: To keep the optimization from "running away" due to, say, a poor gradient estimate building on itself, if a magnitude of change (Mahalanobis distance) in parameters over the course of a run divided by average magnitude of change for recent runs exceeds this, the change is truncated to this amount times the average for recent runs.

`SA.guard.mul`
: The multiplier for the range of parameter and statistics values to compute the guard width.

`SA.par.eff.pow`
: Because some parameters have much, much greater effects than others, it improves numerical conditioning and makes estimation more stable to rescale the kth estimating function by $s_k = (\sum_{i=1}^{q} G_{i,k}^2/V_{i,i})^{-p/2}$, where $G_{i,k}$ is the estimated gradient of the ith target statistics with respect to kth parameter. This parameter sets the value of p: `0` for no rescaling, `1` (default) for scaling by root-mean-square normalized gradient, and greater values for greater penalty.

`SA.robust`
: Whether to use robust linear regression (for gradients) and covariance estimation.

`SA.oh.memory` Absolute maximum number of data points per thread to store in the full optimization history.

`SA.refine` Method, if any, used to refine the point estimate at the end: "linear" for linear interpolation, "mean" for average, and "none" to use the last value.

`SA.se` Logical: If TRUE (the default), get an MCMC sample of statistics at the final estimate and compute the covariance matrix (and hence standard errors) of the parameters. This sample is stored and can also be used by `mcmc.diagnostics()` to assess convergence.

`SA.phase3.samplesize.runs` This many optimization runs will be used to determine whether the optimization has converged and to estimate the standard errors.

`SA.restart.on.err` Logical: if `TRUE` (the default) an error somewhere in the optimization process will cause it to restart with a smaller gain value. Otherwise, the process will stop. This is mainly used for debugging

`term.options` A list of additional arguments to be passed to term initializers. See `? term.options`.

`seed` Seed value (integer) for the random number generator. See `set.seed()`.

`parallel` Number of threads in which to run the sampling. Defaults to 0 (no parallelism). See `ergm-parallel` for details and troubleshooting.

`parallel.type` API to use for parallel processing. Defaults to using the **parallel** package with PSOCK clusters. See `ergm-parallel`.

`parallel.version.check` Logical: If TRUE, check that the version of **ergm** running on the slave nodes is the same as that running on the master node.

`parallel.inherit.MT` Logical: If TRUE, slave nodes and processes inherit the `set.MT_terms()` setting.

`...` Additional arguments, passed to other functions This argument is helpful because it collects any control parameters that have been deprecated; a warning message is printed in case of deprecated arguments.

Details

This function is only used within a call to the `stergm()` function. See the Usage section in `stergm()` for details. Generally speaking, `control.stergm` is remapped to `control.tergm`, with dissolution controls ignored and formation controls used as controls for the overall `tergm` process. An exception to this rule is the initial parameter values specified via `init.form`, `init.diss`, `CMLE.form.ergm$init`, and `CMLE.diss.ergm$init`, which will be remapped jointly with the `stergm()` arguments `offset.coef.form` and `offset.coef.diss` to determine the initial parameter values passed to `tergm`.

It is recommended that new code make use of `tergm` and `control.tergm` directly; `stergm` wrappers are included only for backwards compatibility.

Value

A list with arguments as components.

References

Boer, P., Huisman, M., Snijders, T.A.B., and Zeggelink, E.P.H. (2003), StOCNET User\'s Manual. Version 1.4.

Firth (1993), Bias Reduction in Maximum Likelihood Estimates. Biometrika, 80: 27-38.

Hunter, D. R. and M. S. Handcock (2006), Inference in curved exponential family models for networks. Journal of Computational and Graphical Statistics, 15: 565-583.

Hummel, R. M., Hunter, D. R., and Handcock, M. S. (2010), A Steplength Algorithm for Fitting ERGMs, Penn State Department of Statistics Technical Report.

See Also

`stergm()`, `tergm()`, `control.tergm()`. The `control.simulate.stergm()` function performs a similar function for `simulate.tergm()`.

`control.tergm` *Auxiliary for Controlling Temporal ERGM Fitting*

Description

Auxiliary function as user interface for fine-tuning 'tergm' fitting.

Usage

```
control.tergm(
  init = NULL,
  init.method = NULL,
  force.main = FALSE,
  MCMC.prop = ~discord + sparse,
  MCMC.prop.weights = "default",
  MCMC.prop.args = NULL,
  MCMC.maxedges = Inf,
  MCMC.maxchanges = 1e+06,
  MCMC.packagenames = c(),
  CMLE.MCMC.burnin = 1024 * 16,
  CMLE.MCMC.interval = 1024,
 CMLE.ergm = control.ergm(init = init, MCMC.burnin = CMLE.MCMC.burnin, MCMC.interval =
  CMLE.MCMC.interval, MCMC.prop = MCMC.prop, MCMC.prop.weights = MCMC.prop.weights,
  MCMC.prop.args = MCMC.prop.args, MCMC.maxedges = MCMC.maxedges, MCMC.packagenames =
    MCMC.packagenames, parallel = parallel, parallel.type = parallel.type,
    parallel.version.check = parallel.version.check, force.main = force.main,
    term.options = term.options),
  CMLE.NA.impute = c(),
  CMLE.term.check.override = FALSE,
  EGMME.main.method = c("Gradient-Descent"),
  EGMME.initialfit.control = control.ergm(),
  EGMME.MCMC.burnin.min = 1000,
```

```
 EGMME.MCMC.burnin.max = 1e+05,
 EGMME.MCMC.burnin.pval = 0.5,
 EGMME.MCMC.burnin.add = 1,
 MCMC.burnin = NULL,
 MCMC.burnin.mul = NULL,
 SAN.maxit = 4,
 SAN.nsteps.times = 8,
SAN = control.san(term.options = term.options, SAN.maxit = SAN.maxit, SAN.prop =
 MCMC.prop, SAN.prop.weights = MCMC.prop.weights, SAN.prop.args = MCMC.prop.args,
   SAN.nsteps = round(sqrt(EGMME.MCMC.burnin.min * EGMME.MCMC.burnin.max)) *
  SAN.nsteps.times, SAN.packagenames = MCMC.packagenames, parallel = parallel,
 parallel.type = parallel.type, parallel.version.check = parallel.version.check,
   parallel.inherit.MT = parallel.inherit.MT),
 SA.restarts = 10,
 SA.burnin = 1000,
 SA.plot.progress = FALSE,
 SA.max.plot.points = 400,
 SA.plot.stats = FALSE,
 SA.init.gain = 0.1,
 SA.gain.decay = 0.5,
 SA.runlength = 25,
 SA.interval.mul = 2,
 SA.init.interval = 500,
 SA.min.interval = 20,
 SA.max.interval = 500,
 SA.phase1.minruns = 4,
 SA.phase1.tries = 20,
 SA.phase1.jitter = 0.1,
 SA.phase1.max.q = 0.1,
 SA.phase1.backoff.rat = 1.05,
 SA.phase2.levels.max = 40,
 SA.phase2.levels.min = 4,
 SA.phase2.max.mc.se = 0.001,
 SA.phase2.repeats = 400,
 SA.stepdown.maxn = 200,
 SA.stepdown.p = 0.05,
 SA.stop.p = 0.1,
 SA.stepdown.ct = 5,
 SA.phase2.backoff.rat = 1.1,
 SA.keep.oh = 0.5,
 SA.keep.min.runs = 8,
 SA.keep.min = 0,
 SA.phase2.jitter.mul = 0.2,
 SA.phase2.maxreljump = 4,
 SA.guard.mul = 4,
 SA.par.eff.pow = 1,
 SA.robust = FALSE,
 SA.oh.memory = 1e+05,
```

```
  SA.refine = c("mean", "linear", "none"),
  SA.se = TRUE,
  SA.phase3.samplesize.runs = 10,
  SA.restart.on.err = TRUE,
  term.options = NULL,
  seed = NULL,
  parallel = 0,
  parallel.type = NULL,
  parallel.version.check = TRUE,
  parallel.inherit.MT = FALSE
)
```

Arguments

`init`	numeric or `NA` vector equal in length to the number of parameters in the model or `NULL` (the default); the initial values for the estimation and coefficient offset terms. If `NULL` is passed, all of the initial values are computed using the method specified by `control$init.method`. If a numeric vector is given, the elements of the vector are interpreted as follows: • Elements corresponding to terms enclosed in `offset()` are used as the fixed offset coefficients. These should match the offset values given in `offset.coef`. • Elements that do not correspond to offset terms and are not `NA` are used as starting values in the estimation. • Initial values for the elements that are `NA` are fit using the method specified by `control$init.method`. Passing coefficients from a previous run can be used to "resume" an uncoverged `tergm()` run.
`init.method`	Estimation method used to acquire initial values for estimation. If `NULL` (the default), the initial values are computed using the edges dissolution approximation (Carnegie et al.) when appropriate; note that this relies on `.extract.fd.formulae()` to identify the formation and dissolution parts of the formula; the user should be aware of its behavior and limitations. If `init.method` is set to "zeros", the initial values are set to zeros.
`force.main`	Logical: If TRUE, then force MCMC-based estimation method, even if the exact MLE can be computed via maximum pseudolikelihood estimation.
`MCMC.prop`	Hints and/or constraints for selecting and initializing the proposal.
`MCMC.prop.weights`	Specifies the proposal weighting to use.
`MCMC.prop.args`	A direct way of specifying arguments to the proposal.
`MCMC.maxedges`	The maximum number of edges that may occur during the MCMC sampling. If this number is exceeded at any time, sampling is stopped immediately.
`MCMC.maxchanges`	Maximum number of changes permitted to occur during the simulation.

`MCMC.packagenames`
: Names of packages in which to look for change statistic functions in addition to those autodetected. This argument should not be needed outside of very strange setups.

`CMLE.MCMC.burnin`
: Burnin used in CMLE fitting.

`CMLE.MCMC.interval`
: Number of Metropolis-Hastings steps between successive draws when running MCMC MLE.

`CMLE.ergm`
: Control parameters used to fit the CMLE. See `control.ergm()`.

`CMLE.NA.impute`
: In TERGM CMLE, missing dyads in transitioned-to networks are accommodated using methods of Handcock and Gile (2009), but a similar approach to transitioned-from networks requires much more complex methods that are not, currently, implemented. `CMLE.NA.impute` controls how missing dyads in transitioned-from networks are be imputed. See argument `imputers` of `impute.network.list()` for details.

  By default, no imputation is performed, and the fitting stops with an error if any transitioned-from networks have missing dyads.

`CMLE.term.check.override`
: The method `tergm()` uses at this time to fit a series of more than two networks requires certain assumptions to be made about the ERGM terms being used, which are tested before a fit is attempted. This test sometimes fails despite the model being amenable to fitting, so setting this option to `TRUE` overrides the tests.

`EGMME.main.method`
: Estimation method used to find the Equilibrium Generalized Method of Moments estimator. Currently only "Gradient-Descent" is implemented.

`EGMME.initialfit.control`
: Control object for the ergm fit in tergm.EGMME.initialfit

`EGMME.MCMC.burnin.min`, `EGMME.MCMC.burnin.max`
: Number of Metropolis-Hastings steps per time step used in EGMME fitting. By default, this is determined adaptively by keeping track of increments in the Hamming distance between the transitioned-from network and the network being sampled. Once `EGMME.MCMC.burnin.min` steps have elapsed, the increments are tested against 0, and when their average number becomes statistically indistinguishable from 0 (with the p-value being greater than `EGMME.MCMC.burnin.pval`), or `EGMME.MCMC.burnin.max` steps are proposed, whichever comes first, the simulation is stopped after an additional `EGMME.MCMC.burnin.add` times the number of elapsed steps had been taken. (Stopping immediately would bias the sampling.)

  To use a fixed number of steps, set `EGMME.MCMC.burnin.min` and `EGMME.MCMC.burnin.max` to the same value.

`EGMME.MCMC.burnin.pval`, `EGMME.MCMC.burnin.add`
: Number of Metropolis-Hastings steps per time step used in EGMME fitting. By default, this is determined adaptively by keeping track of increments in the Hamming distance between the transitioned-from network and the network being sampled. Once `EGMME.MCMC.burnin.min` steps have elapsed, the increments are

tested against 0, and when their average number becomes statistically indistinguishable from 0 (with the p-value being greater than `EGMME.MCMC.burnin.pval`), or `EGMME.MCMC.burnin.max` steps are proposed, whichever comes first, the simulation is stopped after an additional `EGMME.MCMC.burnin.add` times the number of elapsed steps had been taken. (Stopping immediately would bias the sampling.)

To use a fixed number of steps, set `EGMME.MCMC.burnin.min` and `EGMME.MCMC.burnin.max` to the same value.

`MCMC.burnin`, `MCMC.burnin.mul`

No longer used. See `EGMME.MCMC.burnin.min`, `EGMME.MCMC.burnin.max`, `EGMME.MCMC.burnin.pval`, `EGMME.MCMC.burnin.pval`, `EGMME.MCMC.burnin.add` and `CMLE.MCMC.burnin` and `CMLE.MCMC.interval`.

`SAN.maxit` When `target.stats` argument is passed to `ergm()`, the maximum number of attempts to use `san()` to obtain a network with statistics close to those specified.

`SAN.nsteps.times`

Multiplier for `SAN.nsteps` relative to `MCMC.burnin`. This lets one control the amount of SAN burn-in (arguably, the most important of SAN parameters) without overriding the other SAN defaults.

`SAN` SAN control parameters. See `control.san()`

`SA.restarts` Maximum number of times to restart a failed optimization process.

`SA.burnin` Number of time steps to advance the starting network before beginning the optimization.

`SA.plot.progress`, `SA.plot.stats`

Logical: Plot information about the fit as it proceeds. If `SA.plot.progress==TRUE`, plot the trajectories of the parameters and target statistics as the optimization progresses. If `SA.plot.stats==TRUE`, plot a heatmap representing correlations of target statistics and a heatmap representing the estimated gradient.

Do NOT use these with non-interactive plotting devices like `pdf()`. (In fact, it will refuse to do that with a warning.)

`SA.max.plot.points`

If `SA.plot.progress==TRUE`, the maximum number of time points to be plotted. Defaults to 400. If more iterations elapse, they will be thinned to at most 400 before plotting.

`SA.init.gain` Initial gain, the multiplier for the parameter update size. If the process initially goes crazy beyond recovery, lower this value.

`SA.gain.decay` Gain decay factor.

`SA.runlength` Number of parameter trials and updates per C run.

`SA.interval.mul`

The number of time steps between updates of the parameters is set to be this times the mean duration of extant ties.

`SA.init.interval`

Initial number of time steps between updates of the parameters.

`SA.min.interval`, `SA.max.interval`

Upper and lower bounds on the number of time steps between updates of the parameters.

`SA.phase1.minruns`
: Number of runs during Phase 1 for estimating the gradient, before every gradient update.

`SA.phase1.tries`
: Number of runs trying to find a reasonable parameter and network configuration.

`SA.phase1.jitter`
: Initial jitter standard deviation of each parameter.

`SA.phase1.max.q`
: Q-value (false discovery rate) that a gradient estimate must obtain before it is accepted (since sign is what is important).

`SA.phase1.backoff.rat`, `SA.phase2.backoff.rat`
: If the run produces this relative increase in the approximate objective function, it will be backed off.

`SA.phase2.levels.min`, `SA.phase2.levels.max`
: Range of gain levels (subphases) to go through.

`SA.phase2.max.mc.se`
: Approximate precision of the estimates that must be attained before stopping.

`SA.phase2.repeats`, `SA.stepdown.maxn`
: A gain level may be repeated multiple times (up to `SA.phase2.repeats`) if the optimizer detects that the objective function is improving or the estimating equations are not centered around 0, so slowing down the parameters at that point is counterproductive. To detect this it looks at the the window controlled by `SA.keep.oh`, thinning objective function values to get `SA.stepdown.maxn`, and 1) fitting a GLS model for a linear trend, with AR(2) autocorrelation and 2) conductiong an approximate Hotelling's T^2 test for equality of estimating equation values to 0. If there is no significance for either at `SA.stepdown.p` `SA.stepdown.ct` runs in a row, the gain level (subphase) is allowed to end. Otherwise, the process continues at the same gain level.

`SA.stepdown.p`, `SA.stepdown.ct`
: A gain level may be repeated multiple times (up to `SA.phase2.repeats`) if the optimizer detects that the objective function is improving or the estimating equations are not centered around 0, so slowing down the parameters at that point is counterproductive. To detect this it looks at the the window controlled by `SA.keep.oh`, thinning objective function values to get `SA.stepdown.maxn`, and 1) fitting a GLS model for a linear trend, with AR(2) autocorrelation and 2) conductiong an approximate Hotelling's T^2 test for equality of estimating equation values to 0. If there is no significance for either at `SA.stepdown.p` `SA.stepdown.ct` runs in a row, the gain level (subphase) is allowed to end. Otherwise, the process continues at the same gain level.

`SA.stop.p`
: At the end of each gain level after the minimum, if the precision is sufficiently high, the relationship between the parameters and the targets is tested for evidence of local nonlinearity. This is the p-value used.

  If that test fails to reject, a Phase 3 run is made with the new parameter values, and the estimating equations are tested for difference from 0. If this test fails to reject, the optimization is finished.

  If either of these tests rejects, at `SA.stop.p`, optimization is continued for another gain level.

`SA.keep.oh`, `SA.keep.min`, `SA.keep.min.runs`
: Parameters controlling how much of optimization history to keep for gradient and covariance estimation.

  A history record will be kept if it's at least one of the following:

  - Among the last `SA.keep.oh` (a fraction) of all runs.
  - Among the last `SA.keep.min` (a count) records.
  - From the last `SA.keep.min.runs` (a count) optimization runs.

`SA.phase2.jitter.mul`
: Jitter standard deviation of each parameter is this value times its standard deviation without jitter.

`SA.phase2.maxreljump`
: To keep the optimization from "running away" due to, say, a poor gradient estimate building on itself, if a magnitude of change (Mahalanobis distance) in parameters over the course of a run divided by average magnitude of change for recent runs exceeds this, the change is truncated to this amount times the average for recent runs.

`SA.guard.mul`
: The multiplier for the range of parameter and statistics values to compute the guard width.

`SA.par.eff.pow`
: Because some parameters have much, much greater effects than others, it improves numerical conditioning and makes estimation more stable to rescale the kth estimating function by $s_k = (\sum_{i=1}^{q} G_{i,k}^2/V_{i,i})^{-p/2}$, where $G_{i,k}$ is the estimated gradient of the ith target statistics with respect to kth parameter. This parameter sets the value of p: `0` for no rescaling, `1` (default) for scaling by root-mean-square normalized gradient, and greater values for greater penalty.

`SA.robust`
: Whether to use robust linear regression (for gradients) and covariance estimation.

`SA.oh.memory`
: Absolute maximum number of data points per thread to store in the full optimization history.

`SA.refine`
: Method, if any, used to refine the point estimate at the end: "linear" for linear interpolation, "mean" for average, and "none" to use the last value.

`SA.se`
: Logical: If TRUE (the default), get an MCMC sample of statistics at the final estimate and compute the covariance matrix (and hence standard errors) of the parameters. This sample is stored and can also be used by `mcmc.diagnostics()` to assess convergence.

`SA.phase3.samplesize.runs`
: This many optimization runs will be used to determine whether the optimization has converged and to estimate the standard errors.

`SA.restart.on.err`
: Logical: if `TRUE` (the default) an error somewhere in the optimization process will cause it to restart with a smaller gain value. Otherwise, the process will stop. This is mainly used for debugging

`term.options`
: A list of additional arguments to be passed to term initializers. See `? term.options`.

`seed`
: Seed value (integer) for the random number generator. See `set.seed()`.

`parallel`
: Number of threads in which to run the sampling. Defaults to 0 (no parallelism). See `ergm-parallel` for details and troubleshooting.

`parallel.type` API to use for parallel processing. Defaults to using the **parallel** package with PSOCK clusters. See `ergm-parallel`.

`parallel.version.check`
Logical: If TRUE, check that the version of **ergm** running on the slave nodes is the same as that running on the master node.

`parallel.inherit.MT`
Logical: If TRUE, slave nodes and processes inherit the `set.MT_terms()` setting.

Details

This function is only used within a call to the `tergm()` function. See the Usage section in `tergm()` for details.

Value

A list with arguments as components.

References

Boer, P., Huisman, M., Snijders, T.A.B., and Zeggelink, E.P.H. (2003), StOCNET User\'s Manual. Version 1.4.

Firth (1993), Bias Reduction in Maximum Likelihood Estimates. Biometrika, 80: 27-38.

Hunter, D. R. and M. S. Handcock (2006), Inference in curved exponential family models for networks. Journal of Computational and Graphical Statistics, 15: 565-583.

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See Also

`tergm()`. The `control.simulate.tergm()` function performs a similar function for `simulate.tergm()`.

---

control.tergm.godfather

Control parameters for `tergm.godfather()`.

Description

Returns a list of its arguments.

Usage

```
control.tergm.godfather(term.options = NULL)
```

Arguments

`term.options` A list of additional arguments to be passed to term initializers. See `? term.options`.

Cross-ergmTerm *The Crossection Operator Term*

Description

The Crossection Operator Term

Usage

```
# binary: Cross(
#           formula,
#           lm = ~1,
#           subset = TRUE,
#           weights = 1,
#           contrasts = NULL,
#           offset = 0,
#           label = NULL
#         )
```

Arguments

formula	a one-sided ergm()-style formula with the terms to be evaluated
lm, subset, weights, contrasts, offset, label	NetSeries() **LHS only** arguments to specify time-varying parameters. See N() term operator in the **ergm.multi** for details. lm formula may reference .Time for the network's time index, .TimeID for the its index in the network series (where the initial network is 1 and the first modelled network is 2), and .TimeDelta for the time elapsed between the network and the immediately previous network in the series.

Details

This term accepts a model formula and produces the corresponding model for the cross-sectional network. It is mainly useful for CMLE estimation, and has no effect (i.e., Cross(~TERM) == ~TERM) for EGMME and dynamic simulation.

See Also

ergmTerm for index of model terms currently visible to the package.

Keywords: None

`degrange.mean.age-ergmTerm` *Average age of ties incident on nodes having degree in a given range*

Description

Average age of ties incident on nodes having degree in a given range

Usage

```
# binary: degrange.mean.age(from, to=+Inf, byarg=NULL, emptyval=0)
```

Arguments

`from`, `to`	vectors of distinct integers or `+Inf` , for `to` . If one of the vectors has length 1, it is recycled to the length of the other. Otherwise, they must have the same length.
`byarg`	specifies a vertex attribute (see Specifying Vertex attributes and Levels (`?nodal_attributes`) for details.). If specified, then separate degree statistics are calculated for nodes having each separate value of the attribute.
`emptyval`	can be used to specify the value returned if the network does not have any actors with degree in the specified range. This is, technically, an arbitrary value, but it should not have a substantial effect unless a non-negligible fraction of networks at the parameter configuration of interest has no actors with specified degree.

Details

This term adds one network statistic to the model for each element of `from` (or `to`); the i th such statistic equals the average, among all ties incident on nodes with degree greater than or equal to `from[i]` but strictly less than `to[i]` , of the amount of time elapsed since the tie's formation. The optional argument

See Also

`ergmTerm` for index of model terms currently visible to the package.

Keywords: None

`degree.mean.age-ergmTerm` *Average age of ties incident on nodes having a given degree*

Description

Average age of ties incident on nodes having a given degree

Usage

```
# binary: degree.mean.age(d, byarg=NULL, emptyval=0)
```

Arguments

`d`	a vector of distinct integers
`byarg`	specifies a vertex attribute (see Specifying Vertex attributes and Levels (`?nodal_attributes`) for details.). If specified, then separate degree statistics are calculated for nodes having each separate value of the attribute.
`emptyval`	can be used to specify the value returned if the network does not have any actors with degree in the specified range. This is, technically, an arbitrary value, but it should not have a substantial effect unless a non-negligible fraction of networks at the parameter configuration of interest has no actors with specified degree.

Details

This term adds one network statistic to the model for each element in `d` ; the i th such statistic equals the average, among all ties incident on nodes with degree exactly `d[i]` , of the amount of time elapsed since the tie's formation. The optional argument `byarg` specifies a vertex attribute (see Specifying Vertex Attributes and Levels for details). If specified, then separate degree statistics are calculated for nodes having each separate value of the attribute.

See Also

`ergmTerm` for index of model terms currently visible to the package.

Keywords: None

discord-ergmHint *Discordant dyads*

Description

Propose toggling discordant dyads with greater frequency (typically about 50 percent). May be used in dynamic fitting and simulation.

Usage

```
# discord
```

See Also

ergmHint for index of constraints and hints currently visible to the package.

Keywords: None

Diss-ergmTerm *The Dissolution Operator Term*

Description

The Dissolution Operator Term

Usage

```
# binary: Diss(
#           formula,
#           lm = ~1,
#           subset = TRUE,
#           weights = 1,
#           contrasts = NULL,
#           offset = 0,
#           label = NULL
#         )
```

Arguments

formula	a one-sided ergm()-style formula with the terms to be evaluated
lm, subset, weights, contrasts, offset, label	NetSeries() **LHS only** arguments to specify time-varying parameters. See N() term operator in the **ergm.multi** for details. lm formula may reference .Time for the network's time index, .TimeID for the its index in the network series (where the initial network is 1 and the first modelled network is 2), and .TimeDelta for the time elapsed between the network and the immediately previous network in the series.

Details

This term accepts a model formula and produces the corresponding model for the post-dissolution network (same as `Persist()`), but with all statistics negated.

Note: This is not the equivalent of the old style `dissolution` model, because the signs of the coefficients are reversed. So a larger positive coefficient for `Diss()` operator means more dissolution.

See Also

`ergmTerm` for index of model terms currently visible to the package.

Keywords: None

`edge.ages-ergmTerm` *Sum of ages of extant ties*

Description

Sum of ages of extant ties

Usage

```
# binary: edge.ages
```

Details

This term adds one statistic equaling sum, over all ties present in the network, of the amount of time elapsed since formation.

Unlike `mean.age` , this statistic is well-defined on an empty network. However, if used as a target, it appears to produce highly biased dissolution parameter estimates if the goal is to get an intended average duration.

See Also

`ergmTerm` for index of model terms currently visible to the package.

Keywords: None

EdgeAges-ergmTerm *The EdgeAges Operator Term*

Description

The EdgeAges Operator Term

Usage

```
# binary: EdgeAges(formula)
```

Arguments

formula	cross-sectional, dyad-independent model formula

Details

This term accepts a cross-sectional, dyad-independent model formula. The statistics of the EdgeAges term are equal to the sum over all extant ties of the tie age times the on-toggle change statistics for the tie under the given model formula.

See Also

ergmTerm for index of model terms currently visible to the package.

Keywords: None

edgecov.ages-ergmTerm *Weighted sum of ages of extant ties*

Description

Weighted sum of ages of extant ties

Usage

```
# binary: edgecov.ages(x, attrname=NULL)
```

Arguments

x, attrname	a specification for the dyadic covariate: either one of the following, or the name of a network attribute containing one of the following: **a covariate matrix** with dimensions $n \times n$ for unipartite networks and $b \times (n - b)$ for bipartite networks; attrname, if given, is used to construct the term name. **a network object** with the same size and bipartitedness as LHS; attrname, if given, provides the name of the quantitative edge attribute to use for covariate values (in this case, missing edges in x are assigned a covariate value of zero).

Details

This term adds one statistic equaling sum, over all ties present in the network, of the amount of time elapsed since formation, multiplied by a dyadic covariate.

"Weights" can be negative.

Unlike edgecov.mean.age , this statistic is well-defined on an empty network. However, if used as a target, it appears to produce highly biased dissolution parameter estimates if the goal is to get an intended average duration.

See Also

ergmTerm for index of model terms currently visible to the package.

Keywords: None

---

edgecov.mean.age-ergmTerm

Weighted average age of an extant tie

Description

Weighted average age of an extant tie

Usage

```
# binary: edgecov.mean.age(x, attrname=NULL, emptyval=0)
```

Arguments

x, attrname	a specification for the dyadic covariate: either one of the following, or the name of a network attribute containing one of the following: **a covariate matrix** with dimensions $n \times n$ for unipartite networks and $b \times (n - b)$ for bipartite networks; attrname, if given, is used to construct the term name.

a network object with the same size and bipartitedness as LHS; `attrname`, if given, provides the name of the quantitative edge attribute to use for covariate values (in this case, missing edges in `x` are assigned a covariate value of zero).

`emptyval` can be used to specify the value returned if the network is empty (or all extant edges have been weighted 0). This is, technically, an arbitrary value, but it should not have a substantial effect unless a non-negligible fraction of networks at the parameter configuration of interest is empty and/or if only a few dyads have nonzero weights.

Details

This term adds one statistic equaling the average, over all ties present in the network, of the amount of time elapsed since formation, weighted by a (nonnegative) dyadic covariate.

The behavior when there are negative weights is undefined.

See Also

`ergmTerm` for index of model terms currently visible to the package.

Keywords: None

`edges.ageinterval-ergmTerm`
Number of edges with age falling into a specified range

Description

Number of edges with age falling into a specified range

Usage

```
# binary: edges.ageinterval(from, to=+Inf)
```

Arguments

`from`, `to` parameters to specify the lower bound and strict upper bounds. Can be scalars, vectors of the same length, or one of them must have length one, in which case it is recycled.

Details

This term counts the number of edges in the network for which the time elapsed since formation is greater than or equal to `from` but strictly less than `to` . In other words, it is in the semiopen interval `[from, to)` .

See Also

ergmTerm for index of model terms currently visible to the package.

Keywords: None

Form-ergmTerm *The Formation Operator Term*

Description

The Formation Operator Term

Usage

```
# binary: Form(
#           formula,
#           lm = ~1,
#           subset = TRUE,
#           weights = 1,
#           contrasts = NULL,
#           offset = 0,
#           label = NULL
#         )
```

Arguments

formula	a one-sided ergm()-style formula with the terms to be evaluated
lm, subset, weights, contrasts, offset, label	NetSeries() **LHS only** arguments to specify time-varying parameters. See N() term operator in the **ergm.multi** for details. lm formula may reference .Time for the network's time index, .TimeID for the its index in the network series (where the initial network is 1 and the first modelled network is 2), and .TimeDelta for the time elapsed between the network and the immediately previous network in the series.

Details

This term accepts a model formula and produces the corresponding model for the post-formation network: effectively a network containing both previous time step's ties and ties just formed, the union of the previous and current network. This is the equivalent of the old-style formation model.

See Also

ergmTerm for index of model terms currently visible to the package.

Keywords: None

`impute.network.list` *Impute missing dyads in a series of networks*

Description

This function takes a list of networks with missing dyads and returns a list of networks with missing dyads imputed according to a list of imputation directives.

Usage

```
impute.network.list(
  nwl,
  imputers = c(),
  nwl.prepend = list(),
  nwl.append = list()
)
```

Arguments

`nwl`	A list of `network` objects or a `network.list` object.
`imputers`	A character vector giving one or more methods to impute missing dyads. Currenly implemented methods are as follows: `next` Impute the state of the same dyad in the next network in the list (or later, if that one is also missing). This imputation method is likely to lead to an underestimation of the tie-change rates. The last network in the list cannot be imputed this way. `previous` Impute the state of the same dyad in the previous network in the list (or earlier, if that one is also missing). The first network in the list cannot be imputed this way. `majority` Impute the missing dyad with the value of the majority among the non-missing dyads in that time step's network. A network that has exactly the same number of ties as non-missing non-ties cannot be imputed this way. `0` Assume missing dyads are all non-ties. `1` Assume missing dyads are all ties. If `length(imputers)>1` the specified imputation methods will be applied in succession. For example, `imputers=c("next","previous","majority","0")` would first try to impute a missing dyad with the next time step's value. If it, and all of the later values for that dyad are missing, it will try to impute it with the previous time step's value. If it, and all of the earlier values for that dyad are missing as well, it will try to impute it with the value of the majority of non-missing dyads for that time step. If there is an exact tie, it will impute 0.
`nwl.prepend`	An optional list of networks to treat as preceding those in `nwl`. They will not be imputed or returned, but they can be useful for imputing dyads in the first network in `nwl`, when using `"previous"` imputer.

nwl.append — An optional list of networks to treat as following those in nwl. They will not be imputed or returned, but they can be useful for imputing dyads in the last network in nwl, when using "next" imputer.

Value

A list of networks with missing dyads imputed.

See Also

network, is.na()

---

is.durational *Testing for duration dependent models*

Description

These functions test whether an ERGM is duration dependent or not.

The method for NULL always returns FALSE by convention.

Usage

```
is.durational(object, ...)

## S3 method for class '`NULL`'
is.durational(object, ...)

## S3 method for class 'ergm_model'
is.durational(object, ...)

## S3 method for class 'ergm_state'
is.durational(object, ...)

## S3 method for class 'formula'
is.durational(object, response = NULL, basis = ergm.getnetwork(object), ...)
```

Arguments

object — An ERGM formula, ergm_model object, or ergm_state object.

... — Unused at this time.

response, basis — See ergm().

Value

TRUE if the ERGM terms in the model are duration dependent; FALSE otherwise.

Methods (by class)

- `is.durational(ergm_model)`: Test if the `ergm_model` has duration-dependent terms, which call for `lasttoggle` data structures.
- `is.durational(ergm_state)`: Test if the `ergm_state` has duration-dependent terms, which call for `lasttoggle` data structures.

`lasttoggle` *Lasttoggle*

Description

A data structure used by `tergm` for tracking of limited information about dyad edge histories.

Details

The `tergm` package handles durational information attached to `network` objects by way of the `time` and `lasttoggle` network attributes. The `lasttoggle` data structure is a 3-column matrix; the first two columns are tails and heads (respectively) of dyads, and the third column is the last time at which the dyad was toggled. The default last toggle time is `-INT_MAX/2`. Last toggle times for non-edges are periodically cleared in the C code. The `time` network attribute is simply an integer, and together with the `lasttoggle` data it determines the age of an extant tie as `time + 1` minus the last toggle time for that dyad. The default value for `time` is 0.

`mean.age-ergmTerm` *Average age of an extant tie*

Description

Average age of an extant tie

Usage

```
# binary: mean.age(emptyval=0, log=FALSE)
```

Arguments

`emptyval`	can be used to specify the value returned if the network is empty. This is, technically, an arbitrary value, but it should not have a substantial effect unless a non-negligible fraction of networks at the parameter configuration of interest is empty.
`log`	logical specifying if mean log age should be returned instead of mean age

Details

This term adds one statistic equaling the average, over all ties present in the network, of the amount of time elapsed since formation.

See Also

ergmTerm for index of model terms currently visible to the package.

Keywords: None

NetSeries *A network series specification for conditional modeling.*

Description

A function for specifying the LHS of a temporal network series ERGM.

Usage

```
NetSeries(..., order = 1, NA.impute = NULL)
```

Arguments

...	series specification, in one of three formats: 1. A list of identically- dimensioned and directed networks. 2. Several networks as arguments. 3. A networkDynamic object and a numeric vector of time indices.
order	how many previous networks to store as an accessible covariate of the model.
NA.impute	How missing dyads in transitioned-from networks are be imputed when using conditional estimation. See argument imputers of impute.network.list() for details.

Value

A network object with temporal metadata.

Note

It is not recommended to modify the network returned by NetSeries except by adding and removing edges, and even that must be done with some care, to avoid putting it into an inconsistent state.

It is almost always better to modify the original networks and regenerate the series.

See Also

ergmTerm for specific terms.

Examples

```
data(samplk)

# Method 1: list of networks
monks <- NetSeries(list(samplk1,samplk2,samplk3))
ergm(monks ~ Form(~edges)+Diss(~edges))
ergm(monks ~ Form(~edges)+Persist(~edges))

# Method 2: networks as arguments
monks <- NetSeries(samplk1,samplk2,samplk3)
ergm(monks ~ Form(~edges)+Diss(~edges))
ergm(monks ~ Form(~edges)+Persist(~edges))

# Method 3: networkDynamic and time points:
## TODO
```

---

nodefactor.mean.age-ergmTerm

Average ages of extant half-ties incident on nodes of specified attribute levels

---

Description

Average ages of extant half-ties incident on nodes of specified attribute levels

Usage

```
# binary: nodefactor.mean.age(attr, levels=NULL, emptyval=0, log=FALSE)
```

Arguments

attr	a vertex attribute specification (see Specifying Vertex attributes and Levels (?nodal_attributes) for details.)
levels	controls what levels are included. Note that the default levels value for nodefactor.mean.age retains all levels, unlike the default for nodefactor , which omits the first level.
emptyval	can be used to specify the value returned if the network is empty. A different value may be specified for each level of attr. The length of emptyval should either be 1 (in which case that value is used for every level of attr) or should be equal to the number of retained levels of attr , in which case the i th value in emptyval is used for the i th retained level of attr. This is, technically, an arbitrary value, but it should not have a substantial effect unless a non-negligible fraction of networks at the parameter configuration of interest is empty.
log	logical specifying if mean log age should be returned instead of mean age

Details

This term adds one statistic for each level of `attr` , equaling the average, over all half-ties incident on nodes of that level, of the amount of time elapsed since formation.

See Also

`ergmTerm` for index of model terms currently visible to the package.

Keywords: None

`nodemix.mean.age-ergmTerm`

Average ages of extant ties of specified mixing types

Description

Average ages of extant ties of specified mixing types

Usage

```
# binary: nodemix.mean.age(attr, b1levels=NULL, b2levels=NULL, levels=NULL,
#                          levels2=NULL, emptyval=0, log=FALSE)
```

Arguments

`attr`	a vertex attribute specification (see Specifying Vertex attributes and Levels (`?nodal_attributes`) for details.)
`b1levels`, `b2levels`, `levels`, `level2`	control what statistics are included in the model and the order in which they appear. `levels2` apply to all networks; `levels` applies to unipartite networks; `b1levels` and `b2levels` apply to bipartite networks (see Specifying Vertex attributes and Levels (`?nodal_attributes`) for details)
`emptyval`	can be used to specify the value returned if the network is empty. A different value may be specified for each mixing type of `attr`. The length of `emptyval` should either be 1 (in which case that value is used for every mixing type of `attr`) or should be equal to the number of retained mixing types of `attr` , in which case the `i` th value in `emptyval` is used for the `i` th retained mixing type of `attr`. This is, technically, an arbitrary value, but it should not have a substantial effect unless a non-negligible fraction of networks at the parameter configuration of interest is empty.
`log`	logical specifying if mean log age should be returned instead of mean age

Details

This term adds one statistic for each mixing type of `attr` , equaling the average, over all ties of that mixing type, of the amount of time elapsed since formation.

See Also

ergmTerm for index of model terms currently visible to the package.

Keywords: None

`Persist-ergmTerm` *The Persistence Operator Term*

Description

The Persistence Operator Term

Usage

```
# binary: Persist(
#           formula,
#           lm = ~1,
#           subset = TRUE,
#           weights = 1,
#           contrasts = NULL,
#           offset = 0,
#           label = NULL
#         )
```

Arguments

`formula`	a one-sided `ergm()`-style formula with the terms to be evaluated
`lm`, `subset`, `weights`, `contrasts`, `offset`, `label`	`NetSeries()` **LHS only** arguments to specify time-varying parameters. See `N()` term operator in the **ergm.multi** for details. `lm` formula may reference `.Time` for the network's time index, `.TimeID` for the its index in the network series (where the initial network is 1 and the first modelled network is 2), and `.TimeDelta` for the time elapsed between the network and the immediately previous network in the series.

Details

This term accepts a model formula and produces the corresponding model for the post-dissolution/persistence network: effectively the network containing ties that persisted since the last time step.

This is the equivalent of the old-style `dissolution` model. So a larger positive coefficient for `Persist()` operator means less dissolution. It produces the same results as the new `Diss()` operator, except the signs of the coefficients are negated.

See Also

ergmTerm for index of model terms currently visible to the package.

Keywords: None

simulate.network *STERGM wrappers for TERGM simulation*

Description

The simulate.network and simulate.networkDynamic wrappers are provided for backwards compatibility. It is recommended that new code make use of the simulate_formula.network and simulate_formula.networkDynamic functions instead. See simulate.tergm() for details on these new functions.

Usage

```
## S3 method for class 'network'
simulate(
  object,
  nsim = 1,
  seed = NULL,
  formation,
  dissolution,
  coef.form,
  coef.diss,
  constraints = ~.,
  monitor = NULL,
  time.slices = 1,
  time.start = NULL,
  time.burnin = 0,
  time.interval = 1,
  time.offset = 1,
  control = control.simulate.network(),
  output = c("networkDynamic", "stats", "changes", "final", "ergm_state"),
  stats.form = FALSE,
  stats.diss = FALSE,
  verbose = FALSE,
  ...
)

## S3 method for class 'networkDynamic'
simulate(
  object,
  nsim = 1,
  seed = NULL,
  formation,
  dissolution,
  coef.form = attr(object, "coef.form"),
  coef.diss = attr(object, "coef.diss"),
  constraints = ~.,
  monitor = NULL,
```

```
  time.slices = 1,
  time.start = NULL,
  time.burnin = 0,
  time.interval = 1,
  time.offset = 1,
  control = control.simulate.network(),
  output = c("networkDynamic", "stats", "changes", "final", "ergm_state"),
  stats.form = FALSE,
  stats.diss = FALSE,
  verbose = FALSE,
  ...
)
```

Arguments

object	an object of type network or networkDynamic
nsim	Number of replications (separate chains of networks) of the process to run and return. The networkDynamic method only supports nsim=1.
seed	Seed value (integer) for the random number generator. See set.seed().
formation, dissolution	One-sided ergm()-style formulas for the formation and dissolution models, respectively. The dissolution model is parameterized in terms of tie persistence.
coef.form	Parameters for the formation model.
coef.diss	Parameters for the dissolution (persistence) model.
constraints	A formula specifying one or more constraints on the support of the distribution of the networks being modeled. Multiple constraints may be given, separated by "+" and "-" operators. See ergmConstraint for the detailed explanation of their semantics and also for an indexed list of the constraints visible to the **ergm** package. The default is to have no constraints except those provided through the ergmlhs API. Together with the model terms in the formula and the reference measure, the constraints define the distribution of networks being modeled. It is also possible to specify a proposal function directly either by passing a string with the function's name (in which case, arguments to the proposal should be specified through the MCMC.prop.args argument to the relevant control function, or by giving it on the LHS of the hints formula to MCMC.prop argument to the control function. This will override the one chosen automatically. Note that not all possible combinations of constraints and reference measures are supported. However, for relatively simple constraints (i.e., those that simply permit or forbid specific dyads or sets of dyads from changing), arbitrary combinations should be possible.
monitor	A one-sided formula specifying one or more terms whose value is to be monitored. If monitor is specified as a character (one of "formation", "dissolution", and "all") then the function .extract.fd.formulae() is used to determine the corresponding formula; the user should be aware of its behavior and limitations.

`time.slices` Number of time slices (or statistics) to return from each replication of the dynamic process. See below for return types. Defaults to 1, which, if `time.burnin==0` and `time.interval==1` (the defaults), advances the process one time step.

`time.start` An optional argument specifying the time point at which the simulation is to start. See Details for further information.

`time.burnin` Number of time steps to discard before starting to collect network statistics.

`time.interval` Number of time steps between successive recordings of network statistics.

`time.offset` Argument specifying the offset between the point when the state of the network is sampled (`time.start`) and the the beginning of the spell that should be recorded for the newly simulated network state.

`control` A list of control parameters for algorithm tuning, constructed using `control.simulate.network()`. These are mapped to `control.simulate.formula.tergm()` controls by assigning:

- `MCMC.prop.form` to `MCMC.prop`,
- `MCMC.prop.args.form` to `MCMC.prop.args`, and
- `MCMC.prop.weights.form` to `MCMC.prop.weights`.

`output` A character vector specifying output type: one of `"networkDynamic"` (the default), `"stats"`, `"changes"`, `"final"`, and `"ergm_state"`, with partial matching allowed.

`stats.form`, `stats.diss`
Logical: Whether to return formation/dissolution model statistics. This is not the recommended method: use the `monitor` argument instead. Note that if either `stats.form` or `stats.diss` is `TRUE`, all generative model statistics will be returned.

`verbose` A logical or an integer to control the amount of progress and diagnostic information to be printed. `FALSE/0` produces minimal output, with higher values producing more detail. Note that very high values (5+) may significantly slow down processing.

`...` Further arguments passed to or used by methods.

Details

Note that return values may be structured differently than in past versions.

Remember that in `stergm`, the dissolution formula is parameterized in terms of tie persistence: negative coefficients imply lower rates of persistence and postive coefficients imply higher rates. The dissolution effects are simply the negation of these coefficients.

Because the old `dissolution` formula in `stergm` represents tie persistence, it maps to the new `Persist()` operator in the `tergm` function, NOT the `Diss()` operator

Value

Depends on the `output` argument. See `simulate.tergm()` for details. Note that some formation/dissolution separated information is also attached to the return value for calls made through `simulate.network` and `simulate.networkDynamic` in an attempt to increase backwards compatibility.

Examples

```
logit<-function(p)log(p/(1-p))
coef.form.f<-function(coef.diss,density) -log(((1+exp(coef.diss))/(density/(1-density)))-1)

# Construct a network with 20 nodes and 20 edges
n<-20
target.stats<-edges<-20
g0<-network.initialize(n,dir=TRUE)
g1<-san(g0~edges,target.stats=target.stats,verbose=TRUE)

S<-10

# To get an average duration of 10...
duration<-10
coef.diss<-logit(1-1/duration)

# To get an average of 20 edges...
dyads<-network.dyadcount(g1)
density<-edges/dyads
coef.form<-coef.form.f(coef.diss,density)

# ... coefficients.
print(coef.form)
print(coef.diss)

# Simulate a networkDynamic
dynsim<-simulate(g1,formation=~edges,dissolution=~edges,
                 coef.form=coef.form,coef.diss=coef.diss,
                 time.slices=S,verbose=TRUE)

# "Resume" the simulation.
dynsim2<-simulate(dynsim,formation=~edges,dissolution=~edges,time.slices=S,verbose=TRUE)
```

`simulate.tergm` *Draw from the distribution of a Temporal Exponential Family Random Graph Model*

Description

`simulate()` is used to draw from temporal exponential family random network models in their natural parameterizations. See `tergm()` for more information on these models.

Usage

```
## S3 method for class 'tergm'
simulate(
  object,
  nsim = 1,
```

```
  seed = NULL,
  coef = coefficients(object),
  constraints = object$constraints,
  monitor = object$targets,
  time.slices = 1,
  time.start = NULL,
  time.burnin = 0,
  time.interval = 1,
  control = control.simulate.tergm(),
  output = c("networkDynamic", "stats", "changes", "final", "ergm_state"),
  nw.start = NULL,
  stats = FALSE,
  verbose = FALSE,
  ...
)

## S3 method for class 'network'
simulate_formula(
  object,
  nsim = 1,
  seed = NULL,
  coef = NULL,
  constraints = ~.,
  monitor = NULL,
  time.slices = 1,
  time.start = NULL,
  time.burnin = 0,
  time.interval = 1,
  time.offset = 1,
  control = control.simulate.formula.tergm(),
  output = c("networkDynamic", "stats", "changes", "final", "ergm_state"),
  stats = FALSE,
  verbose = FALSE,
  ...,
  basis = ergm.getnetwork(object),
  dynamic = FALSE
)

## S3 method for class 'networkDynamic'
simulate_formula(
  object,
  nsim = 1,
  seed = NULL,
  coef = attr(basis, "coef"),
  constraints = ~.,
  monitor = NULL,
  time.slices = 1,
  time.start = NULL,
```

```
  time.burnin = 0,
  time.interval = 1,
  time.offset = 1,
  control = control.simulate.formula.tergm(),
  output = c("networkDynamic", "stats", "changes", "final", "ergm_state"),
  stats = FALSE,
  verbose = FALSE,
  ...,
  basis = eval_lhs.formula(object),
  dynamic = FALSE
)
```

Arguments

object	for simulate.tergm, an object of type tergm giving a model fit; for simulate_formula.network and simulate_formula.networkDynamic, a formula specifying the model simulate_formula.network understands the lasttoggle "API".
nsim	Number of replications (separate chains of networks) of the process to run and return. The networkDynamic method only supports nsim=1.
seed	Seed value (integer) for the random number generator. See set.seed().
coef	Parameters for the model.
constraints	A formula specifying one or more constraints on the support of the distribution of the networks being modeled. Multiple constraints may be given, separated by "+" and "-" operators. See ergmConstraint for the detailed explanation of their semantics and also for an indexed list of the constraints visible to the **ergm** package. The default is to have no constraints except those provided through the ergmlhs API. Together with the model terms in the formula and the reference measure, the constraints define the distribution of networks being modeled. It is also possible to specify a proposal function directly either by passing a string with the function's name (in which case, arguments to the proposal should be specified through the MCMC.prop.args argument to the relevant control function, or by giving it on the LHS of the hints formula to MCMC.prop argument to the control function. This will override the one chosen automatically. Note that not all possible combinations of constraints and reference measures are supported. However, for relatively simple constraints (i.e., those that simply permit or forbid specific dyads or sets of dyads from changing), arbitrary combinations should be possible.
monitor	A one-sided formula specifying one or more terms whose value is to be monitored. If monitor is specified as a character (one of "formation", "dissolution", and "all") then the function .extract.fd.formulae() is used to determine the corresponding formula; the user should be aware of its behavior and limitations.
time.slices	Number of time slices (or statistics) to return from each replication of the dynamic process. See below for return types. Defaults to 1, which, if time.burnin==0 and time.interval==1 (the defaults), advances the process one time step.

`time.start` An optional argument specifying the time point at which the simulation is to start. See Details for further information.

`time.burnin` Number of time steps to discard before starting to collect network statistics.

`time.interval` Number of time steps between successive recordings of network statistics.

`control` A list of control parameters for algorithm tuning. Constructed using `control.simulate.tergm()` or `control.simulate.formula.tergm()`. For backwards compatibility, control lists from `control.simulate.stergm()` and `control.simulate.network()` are allowed in calls to `simulate.tergm`; they are mapped to `control.simulate.tergm` by assigning:

- `MCMC.prop.form` to `MCMC.prop`,
- `MCMC.prop.args.form` to `MCMC.prop.args`,
- `MCMC.prop.weights.form` to `MCMC.prop.weights`.

`output` A character vector specifying output type: one of `"networkDynamic"` (the default), `"stats"`, `"changes"`, `"final"`, and `"ergm_state"`, with partial matching allowed. See Value section for details.

`nw.start` A specification for the starting network to be used by `simulate.tergm`, optional for EGMME fits, but required for CMLE and CMPLE fits:

a numeric index `i` use `i`th time-point's network, where the first network in the series used to fit the model is defined to be at the first time point;

`"first"` **or** `"last"` the first or last time point used in fitting the model; or

`network` specify the network directly.

`networkDynamic`s cannot be used as starting networks for `simulate.tergm` at this time. (They can be used as starting networks for `simulate_formula.networkDynamic`, of course.)

`stats` Logical: Whether to return model statistics. This is not the recommended method: use `monitor` argument instead.

`verbose` A logical or an integer to control the amount of progress and diagnostic information to be printed. `FALSE/0` produces minimal output, with higher values producing more detail. Note that very high values (5+) may significantly slow down processing.

`...` Further arguments passed to or used by methods.

`time.offset` Argument specifying the offset between the point when the state of the network is sampled (`time.start`) and the the beginning of the spell that should be recorded for the newly simulated network state.

`basis` For the `network` and `networkDynamic` methods, the network to start the simulation from. (If `basis` is missing, the default is the left hand side of the `object` argument.)

`dynamic` Logical; if `TRUE`, dynamic simulation is performed in `tergm`; if `FALSE` (the default), ordinary `ergm` simulation is performed instead. Note that when `dynamic=FALSE`, default argument values for `ergm`'s `simulate` methods are used.

Details

The dynamic process is run forward and the results are returned. For the method for networkDynamic, the simulation is resumed from the last generated time point of basis (or the left hand side of object if basis is missing), by default with the same model and parameters.

The starting network for the tergm object method (simulate.tergm) is determined by the nw.start argument.

- If time.start is specified, it is used as the initial time index of the simulation.
- If time.start is not specified (is NULL), then if the object carries a time stamp from which to start or resume the simulation, either in the form of a "time" network attribute (for the network method — see the lasttoggle "API") or in the form of an net.obs.period network attribute (for the networkDynamic method), this attribute will be used. (If specified, time.start will override it with a warning.)
- Othewise, the simulation starts at 0.

Value

Depends on the output argument:

"stats" If stats == FALSE, an mcmc matrix with monitored statistics, and if stats == TRUE, a list containing elements stats for statistics specified in the monitor argument, and stats.gen for the model statistics. If stats == FALSE and no monitored statistics are specified, an empty list is returned, with a warning. When nsim>1, an mcmc.list (or list of them) of the statistics is returned instead.

"networkDynamic"
A networkDynamic object representing the simulated process, with ties present in the initial network having onset -Inf and ties present at the end of the simulation having terminus +Inf. The method for networkDynamic returns the initial networkDynamic with simulated changes applied to it. The net.obs.period network attribute is updated (or added if not existing) to reflect the time period that was simulated. If the network does not have any persistent.ids defined for vertices, a vertex.pid will be attached in a vertex attribute named 'tergm_pid' to facilitate 'bookkeeping' between the networkDynamic argument and the simulated network time step. Additionally, attributes (attr(), not network attributes) are attached as follows:

formula, monitor: Model and monitoring formulas used in the simulation, respectively.

stats, stats.gen: Network statistics as above.

coef: Coefficients used in the simulation.

changes: A four-column matrix summarizing the changes in the "changes" output. (This may be removed in the future.)

When nsim>1, a network.list of these networkDynamics is returned.

"changes" An integer matrix with four columns (time, tail, head, and to), giving the time-stamped changes relative to the current network. to is 1 if a tie was formed and 0 if a tie was dissolved. The convention for time is that it gives the time point during which the change is effective. For example, a row c(5,2,3,1)

indicates that between time 4 and 5, a tie from node 2 to node 3 was formed, so that it was absent at time point 4 and present at time point 5; while a row `c(5,2,3,0)` indicates that in that time, that tie was dissolved, so that it is was present at time point 4 and absent at time point 5. Additionally, the same attributes (`attr()`, not network attributes) as with `output=="networkDynamic"` are attached. When `nsim>1`, a list of these change matrices is returned.

`"final"` A `network` object representing the last network in the series generated. `lasttoggle` and `time` attributes are also included. Additionally, the same attributes (`attr()`, not network attributes) as with `output=="networkDynamic"` are attached. When `nsim>1`, a `network.list` of these `network`s is returned.

`"ergm_state"` The `ergm_state` object resulting from the simulation. Attributes are attached as for other output types.

Note that when using `simulate_formula.networkDynamic` with either `"final"` or `"ergm_state"` for `output`, the nodes included in these objects are those produced by `network.collapse` at the start time.

Examples

```
data(samplk)

# Fit a transition from Time 1 to Time 2
samplk12 <- tergm(list(samplk1, samplk2)~
                  Form(~edges+mutual+transitiveties+cyclicalties)+
                  Diss(~edges+mutual+transitiveties+cyclicalties),
                  estimate="CMLE")

# direct simulation from tergm object
sim1 <- simulate(samplk12, nw.start="last")

# equivalent simulation from formula with network LHS;
# must pass dynamic=TRUE for tergm simulation
sim2 <- simulate(samplk2 ~ Form(~edges+mutual+transitiveties+cyclicalties) +
                           Diss(~edges+mutual+transitiveties+cyclicalties),
                           coef = coef(samplk12),
                           dynamic=TRUE)

# the default simulate output is a networkDynamic, and we can simulate
# with a networkDynamic LHS as well
sim3 <- simulate(sim2 ~ Form(~edges+mutual+transitiveties+cyclicalties) +
                        Diss(~edges+mutual+transitiveties+cyclicalties),
                        coef = coef(samplk12),
                        dynamic=TRUE)
```

`snctrl` *Statnet Control*

Description

A utility to facilitate argument completion of control lists, reexported from `statnet.common`.

Currently recognised control parameters

This list is updated as packages are loaded and unloaded.

Package ergm:

`control.ergm` drop, init, init.method, main.method, force.main, main.hessian, checkpoint, resume, MPLE.samplesize, init.MPLE.samplesize, MPLE.type, MPLE.maxit, MPLE.nonvar, MPLE.nonident, MPLE.nonident.tol, MPLE.covariance.samplesize, MPLE.covariance.method, MPLE.covariance.sim.burnin, MPLE.covariance.sim.interval, MPLE.check, MPLE.constraints.ignore, MCMC.prop, MCMC.prop.weights, MCMC.prop.args, MCMC.interval, MCMC.burnin, MCMC.samplesize, MCMC.effectiveSize, MCMC.effectiveSize.damp, MCMC.effectiveSize.maxruns, MCMC.effectiveSize.burr MCMC.effectiveSize.burnin.min, MCMC.effectiveSize.burnin.max, MCMC.effectiveSize.burnin.nmin, MCMC.effectiveSize.burnin.nmax, MCMC.effectiveSize.burnin.PC, MCMC.effectiveSize.burnin.scl, MCMC.effectiveSize.order.max, MCMC.return.stats, MCMC.runtime.traceplot, MCMC.maxedges, MCMC.addto.se, MCMC.packagenames, SAN.maxit, SAN.nsteps.times, SAN, MCMLE.termination, MCMLE.maxit, MCMLE.conv.min.pval, MCMLE.confidence, MCMLE.confidence.boost, MCMLE.confidence.boo MCMLE.confidence.boost.lag, MCMLE.NR.maxit, MCMLE.NR.reltol, obs.MCMC.mul, obs.MCMC.samplesize.m obs.MCMC.samplesize, obs.MCMC.effectiveSize, obs.MCMC.interval.mul, obs.MCMC.interval, obs.MCMC.burnin.mul, obs.MCMC.burnin, obs.MCMC.prop, obs.MCMC.prop.weights, obs.MCMC.prop.args, obs.MCMC.impute.min_informative, obs.MCMC.impute.default_density, MCMLE.min.depfac, MCMLE.sampsize.boost.pow, MCMLE.MCMC.precision, MCMLE.MCMC.max.ESS.frac, MCMLE.metric, MCMLE.method, MCMLE.dampening, MCMLE.dampening.min.ess, MCMLE.dampening.level, MCMLE.steplength.margin, MCMLE.steplength, MCMLE.steplength.parallel, MCMLE.sequential, MCMLE.density.guard.min, MCMLE.density.guard, MCMLE.effectiveSize, obs.MCMLE.effectiveSize, MCMLE.interval, MCMLE.burnin, MCMLE.samplesize.per_theta, MCMLE.samplesize.min, MCMLE.samplesize, obs.MCMLE.samplesize.per_theta, obs.MCMLE.samplesize.min, obs.MCMLE.samplesize, obs.MCMLE.interval, obs.MCMLE.burnin, MCMLE.steplength.solver, MCMLE.last.boost, MCMLE.steplength.esteq, MCMLE.steplength.miss.sample, MCMLE.steplength.min, MCMLE.effectiveSize.interval_drop, MCMLE.save_intermediates, MCMLE.nonvar, MCMLE.nonident, MCMLE.nonident.tol, SA.phase1_n, SA.initial_gain, SA.nsubphases, SA.min_iterations, SA.max_iterations, SA.phase3_n, SA.interval, SA.burnin, SA.samplesize, CD.samplesize.per_theta, obs.CD.samplesize.per_theta, CD.nsteps, CD.multiplicity, CD.nsteps.obs, CD.multiplicity.obs, CD.maxit, CD.conv.min.pval, CD.NR.maxit, CD.NR.reltol, CD.metric, CD.method, CD.dampening, CD.dampening.min.ess, CD.dampening.level, CD.steplength.margin, CD.steplength, CD.adaptive.epsilon, CD.steplength.esteq, CD.steplength.miss.sample, CD.steplength.min, CD.steplength.parallel, CD.steplength.solver, loglik, term.options, seed, parallel, parallel.type, parallel.version.check, parallel.inherit.MT, ...

`control.ergm.bridge` bridge.nsteps, bridge.target.se, bridge.bidirectional, drop, MCMC.burnin, MCMC.burnin.between, MCMC.interval, MCMC.samplesize, obs.MCMC.burnin, obs.MCMC.burnin.between, obs.MCMC.interval, obs.MCMC.samplesize, MCMC.prop, MCMC.prop.weights, MCMC.prop.args, obs.MCMC.prop, obs.MCMC.prop.weights, obs.MCMC.prop.args, MCMC.maxedges, MCMC.packagenames, term.options, seed, parallel, parallel.type, parallel.version.check, parallel.inherit.MT, ...

`control.ergm.godfather` term.options

control.gof.ergm nsim, MCMC.burnin, MCMC.interval, MCMC.batch, MCMC.prop, MCMC.prop.weights, MCMC.prop.args, MCMC.maxedges, MCMC.packagenames, MCMC.runtime.traceplot, network.output, seed, parallel, parallel.type, parallel.version.check, parallel.inherit.MT

control.gof.formula nsim, MCMC.burnin, MCMC.interval, MCMC.batch, MCMC.prop, MCMC.prop.weights, MCMC.prop.args, MCMC.maxedges, MCMC.packagenames, MCMC.runtime.traceplot, network.output, seed, parallel, parallel.type, parallel.version.check, parallel.inherit.MT

control.logLik.ergm bridge.nsteps, bridge.target.se, bridge.bidirectional, drop, MCMC.burnin, MCMC.interval, MCMC.samplesize, obs.MCMC.samplesize, obs.MCMC.interval, obs.MCMC.burnin, MCMC.prop, MCMC.prop.weights, MCMC.prop.args, obs.MCMC.prop, obs.MCMC.prop.weights, obs.MCMC.prop.args, MCMC.maxedges, MCMC.packagenames, term.options, seed, parallel, parallel.type, parallel.version.check, parallel.inherit.MT, ...

control.san SAN.maxit, SAN.tau, SAN.invcov, SAN.invcov.diag, SAN.nsteps.alloc, SAN.nsteps, SAN.samplesize, SAN.prop, SAN.prop.weights, SAN.prop.args, SAN.packagenames, SAN.ignore.finite.offsets, term.options, seed, parallel, parallel.type, parallel.version.check, parallel.inherit.MT

control.simulate MCMC.burnin, MCMC.interval, MCMC.prop, MCMC.prop.weights, MCMC.prop.args, MCMC.batch, MCMC.effectiveSize, MCMC.effectiveSize.damp, MCMC.effectiveSize.maxruns, MCMC.effectiveSize.burnin.pval, MCMC.effectiveSize.burnin.min, MCMC.effectiveSize.burnin.max, MCMC.effectiveSize.burnin.nmin, MCMC.effectiveSize.burnin.nmax, MCMC.effectiveSize.burnin.PC, MCMC.effectiveSize.burnin.scl, MCMC.effectiveSize.order.max, MCMC.maxedges, MCMC.packagenames, MCMC.runtime.traceplot, network.output, term.options, parallel, parallel.type, parallel.version.check, parallel.inherit.MT, ...

control.simulate.ergm MCMC.burnin, MCMC.interval, MCMC.scale, MCMC.prop, MCMC.prop.weights, MCMC.prop.args, MCMC.batch, MCMC.effectiveSize, MCMC.effectiveSize.damp, MCMC.effectiveSize.maxr MCMC.effectiveSize.burnin.pval, MCMC.effectiveSize.burnin.min, MCMC.effectiveSize.burnin.max, MCMC.effectiveSize.burnin.nmin, MCMC.effectiveSize.burnin.nmax, MCMC.effectiveSize.burnin.PC, MCMC.effectiveSize.burnin.scl, MCMC.effectiveSize.order.max, MCMC.maxedges, MCMC.packagenames, MCMC.runtime.traceplot, network.output, term.options, parallel, parallel.type, parallel.version.check, parallel.inherit.MT, ...

control.simulate.formula MCMC.burnin, MCMC.interval, MCMC.prop, MCMC.prop.weights, MCMC.prop.args, MCMC.batch, MCMC.effectiveSize, MCMC.effectiveSize.damp, MCMC.effectiveSize.maxr MCMC.effectiveSize.burnin.pval, MCMC.effectiveSize.burnin.min, MCMC.effectiveSize.burnin.max, MCMC.effectiveSize.burnin.nmin, MCMC.effectiveSize.burnin.nmax, MCMC.effectiveSize.burnin.PC, MCMC.effectiveSize.burnin.scl, MCMC.effectiveSize.order.max, MCMC.maxedges, MCMC.packagenames, MCMC.runtime.traceplot, network.output, term.options, parallel, parallel.type, parallel.version.check, parallel.inherit.MT, ...

control.simulate.formula.ergm MCMC.burnin, MCMC.interval, MCMC.prop, MCMC.prop.weights, MCMC.prop.args, MCMC.batch, MCMC.effectiveSize, MCMC.effectiveSize.damp, MCMC.effectiveSize.maxr MCMC.effectiveSize.burnin.pval, MCMC.effectiveSize.burnin.min, MCMC.effectiveSize.burnin.max, MCMC.effectiveSize.burnin.nmin, MCMC.effectiveSize.burnin.nmax, MCMC.effectiveSize.burnin.PC, MCMC.effectiveSize.burnin.scl, MCMC.effectiveSize.order.max, MCMC.maxedges, MCMC.packagenames, MCMC.runtime.traceplot, network.output, term.options, parallel, parallel.type, parallel.version.check, parallel.inherit.MT, ...

See Also

statnet.common::snctrl()

stergm *Separable Temporal Exponential Family Random Graph Models (Deprecated)*

Description

stergm() fits Separable Temporal ERGMs' (STERGMs) Conditional MLE (CMLE) (Krivitsky and Handcock, 2014) and Equilibrium Generalized Method of Moments Estimator (EGMME) (Krivitsky, 2009). This function is deprecated in favor of tergm(), whose special case it is, and may be removed in a future version.

Usage

```
stergm(
  nw,
  formation,
  dissolution,
  constraints = ~.,
  estimate,
  times = NULL,
  offset.coef.form = NULL,
  offset.coef.diss = NULL,
  targets = NULL,
  target.stats = NULL,
 eval.loglik = NVL(getOption("tergm.eval.loglik"), getOption("ergm.eval.loglik")),
  control = control.stergm(),
  verbose = FALSE,
  ...,
  SAN.offsets = NULL
)
```

Arguments

nw	A network object (for EGMME); or networkDynamic object, a network.list object, or a list containing networks (for CMLE and CMPLE). stergm understands the lasttoggle "API".
formation, dissolution	One-sided ergm()-style formulas for the formation and dissolution models, respectively. In stergm, the dissolution formula is parameterized in terms of tie persistence: negative coefficients imply lower rates of persistence and postive coefficients imply higher rates. The dissolution effects are simply the negation of these coefficients.
constraints	A formula specifying one or more constraints on the support of the distribution of the networks being modeled. Multiple constraints may be given, separated by "+" and "-" operators. See ergmConstraint for the detailed explanation of their semantics and also for an indexed list of the constraints visible to the **ergm** package.

The default is to have no constraints except those provided through the ergmlhs API.

Together with the model terms in the formula and the reference measure, the constraints define the distribution of networks being modeled.

It is also possible to specify a proposal function directly either by passing a string with the function's name (in which case, arguments to the proposal should be specified through the MCMC.prop.args argument to the relevant control function, or by giving it on the LHS of the hints formula to MCMC.prop argument to the control function. This will override the one chosen automatically.

Note that not all possible combinations of constraints and reference measures are supported. However, for relatively simple constraints (i.e., those that simply permit or forbid specific dyads or sets of dyads from changing), arbitrary combinations should be possible.

estimate — One of "EGMME" for Equilibrium Generalized Method of Moments Estimation, based on a single network with some temporal information and making an assumption that it is a product of a STERGM process running to its stationary (equilibrium) distribution; "CMLE" for Conditional Maximum Likelihood Estimation, modeling a transition between two networks, or "CMPLE" for Conditional Maximum PseudoLikelihood Estimation, using MPLE instead of MLE. CMPLE is extremely inaccurate at this time.

times — For CMLE and CMPLE estimation, times or indexes at which the networks whose transition is to be modeled are observed. Default to c(0,1) if nw is a networkDynamic and to 1:length(nw) (all transitions) if nw is a network.list or a list. Unused for EGMME. Note that at this time, the selected time points will be treated as temporally adjacent. Irregularly spaced time series are not supported at this time.

offset.coef.form — Numeric vector to specify offset formation parameters.

offset.coef.diss — Numeric vector to specify offset dissolution parameters.

targets — One-sided ergm()-style formula specifying statistics whose moments are used for the EGMME. Unused for CMLE and CMPLE. Targets is required for EGMME estimation. It may contain any valid ergm terms. Any offset terms are used only during the preliminary SAN run; they are removed automatically for the EGMME proper. If targets is specified as a character (one of "formation" and "dissolution") then the function .extract.fd.formulae() is used to determine the corresponding formula; the user should be aware of its behavior and limitations.

target.stats — A vector specifying the values of the targets statistics that EGMME will try to match. Defaults to the statistics of nw. Unused for CMLE and CMPLE.

eval.loglik — Whether or not to calculate the log-likelihood of a CMLE STERGM fit. See ergm() for details. Can be set globally via option(tergm.eval.loglik=...), falling back to getOption("ergm.eval.loglik") if not set.

control — A list of control parameters for algorithm tuning. Constructed using control.stergm(). Remapped to control.tergm().

verbose	A logical or an integer to control the amount of progress and diagnostic information to be printed. FALSE/0 produces minimal output, with higher values producing more detail. Note that very high values (5+) may significantly slow down processing.
...	Additional arguments, to be passed to lower-level functions.
SAN.offsets	Offset coefficients (if any) to use during the SAN run.

Details

The stergm function uses a pair of formulas, formation and dissolution to model tie-dynamics. The dissolution formula, however, is parameterized in terms of tie persistence: negative coefficients imply lower rates of persistence and postive coefficients imply higher rates. The dissolution effects are simply the negation of these coefficients, but the discrepancy between the terminology and interpretation has always been unfortunate, and we have fixed this in the new tergm function.

If you are making the transition from old stergm to new tergm, note that the dissolution formula in stergm maps to the new Persist() operator in the tergm function, NOT the Diss() operator.

Value

stergm() returns an object of class tergm; see tergm() for details and methods.

References

Krivitsky P.N. and Handcock M.S. (2014) A Separable Model for Dynamic Networks. *Journal of the Royal Statistical Society, Series B*, 76(1): 29-46. doi:10.1111/rssb.12014

Krivitsky, P.N. (2012). Modeling of Dynamic Networks based on Egocentric Data with Durational Information. *Pennsylvania State University Department of Statistics Technical Report*, 2012(2012-01). https://web.archive.org/web/20170830053722/https://stat.psu.edu/research/technical-report-files-2012-technical-reports/TR1201A.pdf

See Also

ergm(), network, %v%, %n%, ergmTerm

---

summary_formula.networkDynamic

Calculation of networkDynamic statistics.

Description

A method for summary_formula() to calculate the specified statistics for an observed networkDynamic at the specified time point(s). See ergmTerm for more information on the statistics that may be specified.

Usage

```
## S3 method for class 'networkDynamic'
summary_formula(object, at, ..., basis = NULL)
```

Arguments

object	An formula object with a networkDynamic as its LHS. (See summary_formula() for more details.)
at	A vector of time points at which to calculate the statistics.
...	Further arguments passed to or used by methods.
basis	An optional networkDynamic object relative to which the statistics should be calculated.

Value

A matrix with length(at) rows, one for each time point in at, and columns for each term of the formula, containing the corresponding statistics measured on the network.

See Also

ergm(), networkDynamic, ergmTerm, summary.formula()

Examples

```
# create a toy dynamic network
my.nD <- network.initialize(100,directed=FALSE)
activate.vertices(my.nD, onset=0, terminus = 10)
add.edges.active(my.nD,tail=1:2,head=2:3,onset=5,terminus=8)

# use a summary formula to display number of isolates and edges
# at discrete time points
summary(my.nD~isolates+edges, at=1:10)
```

---

tergm *Temporal Exponential-Family Random Graph Models*

Description

tergm() fits Temporal ERGMs' (TERGMs) and Separable Temporal ERGMs' (STERGMs) Conditional MLE (CMLE) (Krivitsky and Handcock, 2010) and Equilibrium Generalized Method of Moments Estimator (EGMME) (Krivitsky, 2009).

Usage

```
tergm(
  formula,
  constraints = ~.,
  estimate,
  times = NULL,
  offset.coef = NULL,
  targets = NULL,
  target.stats = NULL,
```

```
  SAN.offsets = NULL,
 eval.loglik = NVL(getOption("tergm.eval.loglik"), getOption("ergm.eval.loglik")),
  control = control.tergm(),
  verbose = FALSE,
  ...,
  basis = eval_lhs.formula(formula)
)
```

Arguments

formula	an ERGM formula.
constraints	A formula specifying one or more constraints on the support of the distribution of the networks being modeled. Multiple constraints may be given, separated by "+" and "-" operators. See ergmConstraint for the detailed explanation of their semantics and also for an indexed list of the constraints visible to the **ergm** package. The default is to have no constraints except those provided through the ergmlhs API. Together with the model terms in the formula and the reference measure, the constraints define the distribution of networks being modeled. It is also possible to specify a proposal function directly either by passing a string with the function's name (in which case, arguments to the proposal should be specified through the MCMC.prop.args argument to the relevant control function, or by giving it on the LHS of the hints formula to MCMC.prop argument to the control function. This will override the one chosen automatically. Note that not all possible combinations of constraints and reference measures are supported. However, for relatively simple constraints (i.e., those that simply permit or forbid specific dyads or sets of dyads from changing), arbitrary combinations should be possible.
estimate	One of "EGMME" for Equilibrium Generalized Method of Moments Estimation, based on a single network with some temporal information and making an assumption that it is a product of a TERGM process running to its stationary (equilibrium) distribution; "CMLE" for Conditional Maximum Likelihood Estimation, modeling a transition between two networks, or "CMPLE" for Conditional Maximum PseudoLikelihood Estimation, using MPLE instead of MLE. CMPLE is extremely inaccurate at this time.
times	For CMLE and CMPLE estimation, times or indexes at which the networks whose transition is to be modeled are observed. This argument is mandatory if nw is a networkDynamic and defaults to 1:length(nw) (all transitions) if nw is a network.list or a list. Ignored when estimating EGMME or if LHS is already a NetSeries. Note that at this time, the selected time points will be treated as temporally adjacent. Irregluarly spaced time series are not supported at this time.
offset.coef	Numeric vector to specify offset parameters.
targets	One-sided ergm()-style formula specifying statistics whose moments are used for the EGMME. Unused for CMLE and CMPLE. Targets is required for EGMME estimation. It may contain any valid ergm terms. Any offset terms are used

only during the preliminary SAN run; they are removed automatically for the EGMME proper. If `targets` is specified as a character (one of `"formation"` and `"dissolution"`) then the function `.extract.fd.formulae()` is used to determine the corresponding formula; the user should be aware of its behavior and limitations.

`target.stats` A vector specifying the values of the `targets` statistics that EGMME will try to match. Defaults to the statistics of `nw`. Unused for CMLE and CMPLE.

`SAN.offsets` Offset coefficients (if any) to use during the SAN run.

`eval.loglik` Whether or not to calculate the log-likelihood of a CMLE TERGM fit. See `ergm()` for details. Can be set globally via `option(tergm.eval.loglik=...)`, falling back to `getOption("ergm.eval.loglik")` if not set.

`control` A list of control parameters for algorithm tuning. Constructed using `control.tergm()`.

`verbose` A logical or an integer to control the amount of progress and diagnostic information to be printed. `FALSE/0` produces minimal output, with higher values producing more detail. Note that very high values (5+) may significantly slow down processing.

`...` Additional arguments, to be passed to lower-level functions.

`basis` optional network data overriding the left hand side of `formula`

Value

`tergm()` returns an object of class `tergm` that inherits from `ergm` and has the usual methods (`coef.ergm()`, `summary.ergm()`, `mcmc.diagnostics()`, etc.) implemented for it. Note that `gof()` only works for the CMLE method.

References

Krackhardt, D and Handcock, MS (2006) Heider vs Simmel: Emergent features in dynamic structures. ICML Workshop on Statistical Network Analysis. Springer, Berlin, Heidelberg, 2006.

Hanneke S, Fu W, and Xing EP (2010). Discrete Temporal Models of Social Networks. *Electronic Journal of Statistics*, 2010, 4, 585-605. doi:10.1214/09EJS548

Krivitsky P.N. and Handcock M.S. (2014) A Separable Model for Dynamic Networks. *Journal of the Royal Statistical Society, Series B*, 76(1): 29-46. doi:10.1111/rssb.12014

Krivitsky, P.N. (2012). Modeling of Dynamic Networks based on Egocentric Data with Durational Information. *Pennsylvania State University Department of Statistics Technical Report*, 2012(2012-01). https://arxiv.org/abs/2203.06866

See Also

`network`, `networkDynamic`, and `NetSeries()` for the data structures, `ergm()` and `ergmTerm` for model specification, package vignette `browseVignettes(package='tergm')` for a short demonstration, the Statnet web site https://statnet.org/workshop-tergm/ for a tutorial

Examples

```
## Not run:
# EGMME Example
par(ask=FALSE)
n<-30
g0<-network.initialize(n,dir=FALSE)

#                     edges, degree(1), mean.age
target.stats<-c(      n*1/2,    n*0.6,        20)

dynfit<-tergm(g0 ~ Form(~edges + degree(1)) + Diss(~edges),
               targets = ~edges+degree(1)+mean.age,
               target.stats=target.stats, estimate="EGMME",
               control=control.tergm(SA.plot.progress=TRUE))

par(ask=TRUE)
mcmc.diagnostics(dynfit)
summary(dynfit)

## End(Not run)

# CMLE Example
data(samplk)

# Fit a transition from Time 1 to Time 2
samplk12 <- tergm(list(samplk1, samplk2)~
                  Form(~edges+mutual+transitiveties+cyclicalties)+
                  Diss(~edges+mutual+transitiveties+cyclicalties),
                  estimate="CMLE")

mcmc.diagnostics(samplk12)
summary(samplk12)

samplk12.gof <- gof(samplk12)

samplk12.gof

plot(samplk12.gof)

plot(samplk12.gof, plotlogodds=TRUE)

# Fit a transition from Time 1 to Time 2 and from Time 2 to Time 3 jointly
samplk123 <- tergm(list(samplk1, samplk2, samplk3)~
                   Form(~edges+mutual+transitiveties+cyclicalties)+
                   Diss(~edges+mutual+transitiveties+cyclicalties),
                   estimate="CMLE")

mcmc.diagnostics(samplk123)
summary(samplk123)
```

`tergm.godfather` *A function to apply a given series of changes to a network.*

Description

Gives the network a series of timed proposals it can't refuse. Returns the statistics of the network, and, optionally, the final network.

Usage

```
tergm.godfather(
  formula,
  changes = NULL,
  toggles = changes[, -4, drop = FALSE],
  start = NULL,
  end = NULL,
  end.network = FALSE,
  stats.start = FALSE,
  verbose = FALSE,
  control = control.tergm.godfather()
)
```

Arguments

`formula`	An `summary.formula()`-style formula, with either a `network` or a `networkDynamic` as the LHS and statistics to be computed on the RHS. If LHS is a `networkDynamic`, it will be used to derive the changes to the network whose statistics are wanted. Otherwise, either `changes` or `toggles` must be specified, and the LHS `network` will be used as the starting network.
`changes`	A matrix with four columns: time, tail, head, and new value, describing the changes to be made. Can only be used if LHS of `formula` is not a `networkDynamic`.
`toggles`	A matrix with three columns: time, tail, and head, giving the dyads which had changed. Can only be used if LHS of `formula` is not a `networkDynamic`.
`start`	Time from which to start applying changes. Note that the first set of changes will take effect at `start + 1`. Defaults to the time point 1 before the earliest change passed.
`end`	Time at which to finish applying changes. Defaults to the last time point at which a change occurs.
`end.network`	Whether to return the network that results. Defaults to `FALSE`.
`stats.start`	Whether to return the network statistics at `start` (before any changes are applied) as the first row of the statistics matrix. Defaults to `FALSE`, to produce output similar to that of `simulate()` for TERGMs when `output="stats"`, where initial network's statistics are not returned.

verbose — A logical or an integer to control the amount of progress and diagnostic information to be printed. FALSE/0 produces minimal output, with higher values producing more detail. Note that very high values (5+) may significantly slow down processing.

control — A control list generated by control.tergm.godfather().

Value

If end.network is FALSE (the default), an mcmc object with the requested network statistics associated with the network series produced by applying the specified changes. Its mcmc attributes encode the timing information: so start(out) gives the time point associated with the first row returned, and end(out) out the last. The "thinning interval" is always 1.

If end.network is TRUE, return a network object with lasttoggle "extension", representing the final network, with a matrix of statistics described in the previous paragraph attached to it as an attr-style attribute "stats".

See Also

simulate.tergm(), simulate_formula.network(), simulate_formula.networkDynamic()

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