Package ‘EpiModel’

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Description Tools for simulating mathematical models of infectious disease dynamics. Epidemic model classes include deterministic compartmental models, stochastic individual-contact models, and stochastic network models. Network models use robust statistical methods of exponential-family random graph models (ERGMs) from the Statnet suite of software packages in R. Standard templates for epidemic modeling include SI, SIR, and SIS disease types. EpiModel features an API for extending these templates to address novel scientific research aims.
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EpiModel-package

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Description

Package: EpiModel
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Version: 1.7.0
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LazyLoad: yes

Details

The EpiModel software package provides tools for building, solving, and visualizing mathematical models of infectious disease dynamics. These tools allow users to simulate epidemic models in multiple frameworks for both pedagogical purposes ("base models") and novel research purposes ("extension models").

Model Classes and Infectious Disease Types

EpiModel provides functionality for three classes of epidemic models:

- **Deterministic Compartmental Models**: these continuous-time models are solved using ordinary differential equations. EpiModel allows for easy specification of sensitivity analyses to compare multiple scenarios of the same model across different parameter values.

- **Stochastic Individual Contact Models**: a novel class of individual-based, microsimulation models that were developed to add random variation in all components of the transmission system, from infection to recovery to vital dynamics (arrivals and departures).

- **Stochastic Network Models**: with the underlying statistical framework of temporal exponential random graph models (ERGMs) recently developed in the Statnet suite of software in R, network models over epidemics simulate edge (e.g., partnership) formation and dissolution stochastically according to a specified statistical model, with disease spread across that network.

EpiModel supports three infectious disease types to be run across all of the three classes.
• **Susceptible-Infectious (SI):** a two-state disease in which there is life-long infection without recovery. HIV/AIDS is one example, although for this case it is common to model infection stages as separate compartments.

• **Susceptible-Infectious-Recovered (SIR):** a three-stage disease in which one has life-long recovery with immunity after infection. Measles is one example, but modern models for the disease also require consideration of vaccination patterns in the population.

• **Susceptible-Infectious-Susceptible (SIS):** a two-stage disease in which one may transition back and forth from the susceptible to infected states throughout life. Examples include bacterial sexually transmitted diseases like gonorrhea.

These basic disease types may be extended in any arbitrarily complex way to simulate specific diseases for research questions.

**Model Parameterization and Simulation**

EpiModel uses three model setup functions for each model class to input the necessary parameters, initial conditions, and control settings:

- `param.dcm`, `param.icm`, and `param.net` are used to input epidemic parameters for each of the three model classes. Parameters include the rate of contacts or acts between actors, the probability of transmission per contact, and recovery and demographic rates for models that include those transitions.

- `init.dcm`, `init.icm`, and `init.net` are used to input the initial conditions for each class. The main conditions are limited to the numbers or, if applicable, the specific agents in the population who are infected or recovered at the simulation outset.

- `control.dcm`, `control.icm`, and `control.net` are used to specify the remaining control settings for each simulation. The core controls for base model types include the disease type, number of time steps, and number of simulations. Controls are also used to input new model functions (for DCMs) and new model modules (for ICMs and network models) to allow the user to simulate fully original epidemic models in EpiModel. See the documentation for the specific control functions help pages.

With the models parameterized, the functions for simulating epidemic models are:

- `dcm` for deterministic compartmental models.

- `icm` for individual contact models.

- Network models are simulated in a three-step process:
  1. `netest` estimates the statistical model for the network structure itself (i.e., how partnerships form and dissolve over time given the parameterization of those processes). This function is a wrapper around the `ergm` and `stergm` functions in the `ergm` and `tergm` packages. The current statistical framework for model simulation is called "egocentric inference": target statistics summarizing these formation and dissolution processes collected from an egocentric sample of the population.

  2. `netdx` runs diagnostics on the dynamic model fit by simulating the base network over time to ensure the model fits the targets for formation and dissolution.

  3. `netsim` simulates the stochastic network epidemic models, with a given network model fit in `netest`. Here the function requires this model fit object along with the parameters, initial conditions, and control settings as defined above.
References

The EpiModel website is at http://epimodel.org/, and the source code is at http://github.com/statnet/EpiModel. Bug reports and feature requests are welcome there.

Our primary methods paper on EpiModel is published in the Journal of Statistical Software. If you use EpiModel for any research or teaching purposes, please cite this reference:


We have also developed an extension package specifically for modeling HIV and related sexually transmitted infections, called EpiModelHIV and available on Github at http://github.com/statnet/EpiModelHIV.

---

**as.data.frame.dcm**

*Extract Model Data for Deterministic Compartmental Models*

**Description**

This function extracts a model run from an object of class `dcm` into a data frame using the generic `as.data.frame` function.

**Usage**

```r
## S3 method for class 'dcm'
as.data.frame(x, row.names = NULL, optional = FALSE, run, ...)
```

**Arguments**

- `x`: An EpiModel object of class `dcm`.
- `row.names`: See `as.data.frame.default`.
- `optional`: See `as.data.frame.default`.
- `run`: Run number for model; used for multiple-run sensitivity models. If not specified, will output data from all runs in a stacked data frame.
- `...`: See `as.data.frame.default`.

**Details**

Model output from `dcm` simulations are available as a data frame with this helper function. The output data frame will include columns for time, the size of each compartment, the overall population size (the sum of compartment sizes), and the size of each flow.

For models with multiple runs (i.e., varying parameters - see example below), the default with the `run` parameter not specified will output all runs in a single stacked data frame.
Examples

```r
## Example 1: One-group SIS model with varying act.rate
param <- param.dcm(inf.prob = 0.2, act.rate = seq(0.05, 0.5, 0.05),
                   rec.rate = 1/50)
init <- init.dcm(s.num = 500, i.num = 1)
control <- control.dcm(type = "SIS", nsteps = 10)
mod1 <- dcm(param, init, control)
as.data.frame(mod1)
as.data.frame(mod1, run = 1)
as.data.frame(mod1, run = 10)

## Example 2: Two-group SIR model with vital dynamics
param <- param.dcm(inf.prob = 0.2, inf.prob.g2 = 0.1,
                   act.rate = 3, balance = "g1",
                   rec.rate = 1/50, rec.rate.g2 = 1/50,
                   a.rate = 1/100, a.rate.g2 = NA,
                   ds.rate = 1/100, ds.rate.g2 = 1/100,
                   di.rate = 1/90, di.rate.g2 = 1/90,
                   dr.rate = 1/100, dr.rate.g2 = 1/100)
init <- init.dcm(s.num = 500, i.num = 1, r.num = 0,
                 s.num.g2 = 500, i.num.g2 = 1, r.num.g2 = 0)
control <- control.dcm(type = "SIR", nsteps = 10)
mod2 <- dcm(param, init, control)
as.data.frame(mod2)
```

Description

This function extracts model simulations for objects of classes `icm` and `netsim` into a data frame using the generic `as.data.frame` function.

Usage

```r
## S3 method for class 'icm'
as.data.frame(x, row.names = NULL, optional = FALSE,
              out = "vals", sim, qval, ...)

## S3 method for class 'netsim'
as.data.frame(x, row.names = NULL, optional = FALSE,
              out = "vals", sim, ...)
```

Arguments

- `x` An EpiModel object of class `icm` or `netsim`.
- `row.names` See `as.data.frame.default`. 

as.data.frame.icm

optional  See as.data.frame.default.

out  Data output to data frame: "mean" for row means across simulations, "sd" for row standard deviations across simulations, "qnt" for row quantiles at the level specified in qval, or "vals" for values from individual simulations.

sim  If out="vals", the simulation number to output. If not specified, then data from all simulations will be output.

qval  Quantile value required when out="qnt".

Details

These methods work for both icm and netsim class models. The available output includes time-specific means, standard deviations, quantiles, and simulation values (compartment and flow sizes) from these stochastic model classes. Means, standard deviations, and quantiles are calculated by taking the row summary (i.e., each row of data corresponds to a time step) across all simulations in the model output.

Examples

## Stochastic ICM SIS model
param <- param.icm(inf.prob = 0.8, act.rate = 2, rec.rate = 0.1)
init <- init.icm(s.num = 500, i.num = 1)
control <- control.icm(type = "SIS", nsteps = 10,
                        nsims = 3, verbose = FALSE)
mod <- icm(param, init, control)

# Default output all simulation runs, default to all in stacked data.frame
as.data.frame(mod)
as.data.frame(mod, sim = 2)

# Time-specific means across simulations
as.data.frame(mod, out = "mean")

# Time-specific standard deviations across simulations
as.data.frame(mod, out = "sd")

# Time-specific quantile values across simulations
as.data.frame(mod, out = "qnt", qval = 0.25)
as.data.frame(mod, out = "qnt", qval = 0.75)

## Not run:
## Stochastic SI network model
mw <- network.initialize(n = 100, directed = FALSE)
formation <- ~edges
target.stats <- 50
coef.diss <- dissolution_coefs(dissolution = ~offset(edges), duration = 20)
est <- netest(mw, formation, target.stats, coef.diss, verbose = FALSE)

param <- param.net(inf.prob = 0.5)
init <- init.net(i.num = 10)
control <- control.net(type = "SI", nsteps = 10, nsims = 3, verbose = FALSE)
mod <- netsim(est, param, init, control)

# Same data extraction methods as with ICMs
as.data.frame(mod)
as.data.frame(mod, sim = 2)
as.data.frame(mod, out = "mean")
as.data.frame(mod, out = "sd")
as.data.frame(mod, out = "qnt", qval = 0.25)
as.data.frame(mod, out = "qnt", qval = 0.75)

## End(Not run)

as.data.frame.netdx Extract Timed Edgelists netdx Objects

Description

This function extracts timed edgelists for objects of class netdx into a data frame using the generic as.data.frame function.

Usage

## S3 method for class 'netdx'
as.data.frame(x, row.names = NULL, optional = FALSE, sim, ...)

Arguments

x An EpiModel object of class netdx.
row.names See as.data.frame.default.
optional See as.data.frame.default.
sim The simulation number to output. If not specified, then data from all simulations will be output.
...
See as.data.frame.default.

Examples

# Initialize and parameterize the network model
nw <- network.initialize(n = 100, directed = FALSE)
formation <- ~edges
target.stats <- 50
coeff.diss <- dissolution_coefs(dissolution = ~offset(edges), duration = 20)

# Model estimation
est <- netest(nw, formation, target.stats, coeff.diss, verbose = FALSE)
# Simulate the network with netdx

dx <- netdx(est, nsims = 3, nsteps = 10, keep.tedgelist = TRUE, verbose = FALSE)

# Extract data from the first simulation

as.data.frame(dx, sim = 1)

# Extract data from all simulations

as.data.frame(dx)

---

### `as.network.transmat`  
*Converts transmat infection tree into a network object*

**Description**

Converts the edges of the infection tree described in the `transmat` object into a `network` object, copying in appropriate edge attributes for `at`, `infDur`, `transProb`, `actRate`, and `finalProb` and constructing a vertex attribute for `at`.

**Usage**

```r
## S3 method for class 'transmat'
as.network(x, ...)
```

**Arguments**

- `x`  
  an object of class `transmat` to be converted into a network object

- `...`  
  unused

---

### `as.phylo.transmat`  
*Converts transmat infection tree into a phylo object*

**Description**

Converts the edgelist matrix in the `transmat` object into a `phylo` object by doing the required reordering and labeling.

**Usage**

```r
## S3 method for class 'transmat'
as.phylo(x, collapse.singles, vertex.exit.times, ...)
```
Arguments

x

An object of class "transmat", the output from get_transmat.

collapse.singles

logical, DEPRECATED

vertex.exit.times

optional numeric vector providing the time of departure of vertices, to be used to scale the lengths of branches reaching to the tips. Index position on vector corresponds to network id. NA indicates no departure, so branch will extend to the end of the tree.

... further arguments (unused)

Details

Converts a transmat object containing information about the history of a simulated infection into a phylo object representation suitable for plotting as a tree with plot.phylo. Each infection event becomes a 'node' (horizontal branch) in the resulting phylo tree, and each network vertex becomes a 'tip' of the tree. The infection events are labeled with the vertex id of the infector to make it possible to trace the path of infection.

The infection timing information is included to position the phylo-nodes, with the lines to the tips drawn to the max time value +1 (unless vertex.exit.times are passed in it effectively assumes all vertices are active/alive until the end of the simulation).

If the transmat contains multiple infection seeds (there are multiple trees with separate root nodes) it will return a list of class 'multiPhylo', each element of which is a phylo object. See read.tree.

Note that in EpiModel versions <= 1.2.4, the phylo tree was constructed differently, translating network vertices to both phylo-nodes and tips and requiring 'collapse.singles' to prune it to an appropriate branching structure.

Examples

set.seed(10)

nw <- network.initialize(n = 100, directed = FALSE)

formation <- ~edges
target.stats <- 50
coeff.diss <- dissolution.coefs(dissolution = ~offset(edges), duration = 20)

est1 <- netest(nw, formation, target.stats, coeff.diss, verbose = FALSE)

param <- param.net(inf.prob = 0.5)
init <- init.net(i.num = 1)
control <- control.net(type = "SI", nsteps = 40, nsims = 1, verbose = FALSE,
 use.pids = FALSE)

mod1 <- netsim(est1, param, init, control)
tm <- get_transmat(mod1)
tmPhylo <- as.phylo.transmat(tm)
plot(tmPhylo, show.node.label = TRUE,
 root.edge = TRUE,
 cex = 0.5)
Calculate Equilibrium for Infection Prevalence

Description
Calculates the relative change in infection prevalence across a time series of an epidemic model to assess equilibrium.

Usage
calc_eql(x, numer = "i.num", denom = "num", nsteps, threshold = 0.001, digits = 4, invisible = FALSE)

Arguments
- x: An EpiModel object of class dcm, icm, or netsim.
- numer: Numerator for prevalence calculation.
- denom: Denominator for prevalence calculation.
- nsteps: Number of time steps at end of model simulation to calculate equilibrium as the absolute value of the difference between the minimum prevalence value and the maximum prevalence value over that time range.
- threshold: Threshold value for determining equilibrium.
- digits: Number of digits to round for table output.
- invisible: If TRUE, function will suppress output to console and return summary statistics invisibly.

Details
This function calculates whether equilibrium in disease prevalence, or any other fraction of two compartments contained in an epidemic model, have reached equilibrium over a time series. Equilibrium is calculated as the absolute value of the difference of the maximum prevalence and minimum prevalence over a specified time series. That time series is specified as the final nsteps time steps of an epidemic model. A larger nsteps specification will therefore calculate differences over a longer time series.

Examples
# Calculate equilibrium for a DOM
param <- param.dcm(inf.prob = 0.2, inf.prob.g2 = 0.1, act.rate = 0.5,
   balance = "g1", rec.rate = 1 / 50, rec.rate.g2 = 1 / 50,
   a.rate = 1 / 100, a.rate.g2 = NA, ds.rate = 1 / 100,
   ds.rate.g2 = 1 / 100, di.rate = 1 / 90,
   di.rate.g2 = 1 / 90)
init <- init.dcm(s.num = 500, i.num = 1,
   s.num.g2 = 500, i.num.g2 = 1)
control <- control.dcm(type = "SIS", nsteps = 500, verbose = FALSE)
check_bip_degdist

Check Degree Distribution for Bipartite Target Statistics

Description

Checks for consistency in the implied network statistics of a bipartite network in which the mode size and mode-specific degree distributions are specified.

Usage

check_bip_degdist(num.m1, num.m2, deg.dist.m1, deg.dist.m2)

Arguments

num.m1 Number of nodes in mode 1.
num.m2 Number of nodes in mode 2.
deg.dist.m1 Vector with fractional degree distribution for mode 1.
deg.dist.m2 Vector with fractional degree distribution for mode 2.

Details

This function outputs the number of nodes of degree 0 to m, where m is the length of a fractional degree distribution vector, given that vector and the size of the mode. This utility is used to check for balance in implied degree given that fractional distribution within bipartite network simulations, in which the degree-constrained counts must be equal across modes.

See Also

For a detailed explanation of this function, see the tutorial: EpiModel Network Utility Functions.
color_tea

Examples

# An imbalanced distribution
check_bip_degdist(num.m1 = 500, num.m2 = 500,
    deg.dist.m2 = c(0.40, 0.55, 0.03, 0.02),
    deg.dist.m1 = c(0.48, 0.41, 0.08, 0.03))

# A balanced distribution
check_bip_degdist(num.m1 = 500, num.m2 = 500,
    deg.dist.m1 = c(0.40, 0.55, 0.04, 0.01),
    deg.dist.m2 = c(0.48, 0.41, 0.08, 0.03))

---

color_tea  

Creates a TEA Variable for Infection Status for ndtv Animations

Description

Creates a new color-named temporally-extended attribute (TEA) variable in a networkDynamic object containing a disease status TEA in numeric format.

Usage

color_tea(nd, old.var = "testatus", old.sus = "s", old.inf = "i",
    old.rec = "r", new.var = "ndtvcol", new.sus, new.inf, new.rec,
    verbose = TRUE)

Arguments

nd  
Old object of class networkDynamic.

old.var  
Old TEA variable name.

old.sus  
Status value for susceptible in old TEA variable.

old.inf  
Status value for infected in old TEA variable.

old.rec  
Status value for recovered in old TEA variable.

new.var  
New TEA variable name to be stored in networkDynamic object.

new.sus  
Status value for susceptible in new TEA variable.

new.inf  
Status value for infected in new TEA variable.

new.rec  
Status value for recovered in new TEA variable.

verbose  
Print progress to console.
Details

The ndtv package ([https://cran.r-project.org/package=ndtv](https://cran.r-project.org/package=ndtv)) produces animated visuals for dynamic networks with evolving edge structures and nodal attributes. Nodal attribute dynamics in ndtv movies require a temporally extended attribute (TEA) containing a standard R color for each node at each time step. By default, the_epiModel package uses TEAs to store disease status history in network model simulations run in netsim. But, that status TEA is in numeric format (0, 1, 2). The color_tea function transforms those numeric values of that disease status TEA into a TEA with color values in order to visualize status changes in ndtv.

The convention in plot.netsem is to color the susceptible nodes as blue, infected nodes as red, and recovered nodes as green. Alternate colors may be specified using the new.sus, new.inf, and new.rec parameters, respectively.

Using the color_tea function with a netsim object requires that TEAs for disease status be used and that the networkDynamic object be saved in the output: both tea.status and save.network must be set to TRUE in control.net.

See Also

netsim and the ndtv package documentation.

---

**comp_plot**

*Plot Compartment Diagram for Epidemic Models*

Description

Plots a compartment flow diagram for deterministic compartmental models, stochastic individual contact models, and stochastic network models.

Usage

```r
comp_plot(x, at, digits, ...)

## S3 method for class 'dcm'
comp_plot(x, at = 1, digits = 3, run = 1, ...)

## S3 method for class 'icm'
comp_plot(x, at = 1, digits = 3, ...)

## S3 method for class 'netsim'
comp_plot(x, at = 1, digits = 3, ...)
```

Arguments

- `x` An EpiModel object of class dcm, icm, or netsim.
- `at` Time step for model statistics.
- `digits` Number of significant digits to print.
...  Additional arguments passed to plot (not currently used).
run  Model run number, for dcm class models with multiple runs (sensitivity analyses).

Details

The comp_plot function provides a visual summary of an epidemic model at a specific time step. The information contained in comp_plot is the same as in the summary functions for a model, but presented graphically as a compartment flow diagram.

For dcm class plots, specify the model run number if the model contains multiple runs, as in a sensitivity analysis. For icm and netsim class plots, the run argument is not used; the plots show the means and standard deviations across simulations at the specified time step.

These plots are currently limited to one-group and one-mode models for each of the three model classes. That functionality may be expanded in future software releases.

Examples

```r
## Example 1: DCM SIR model with varying act.rate
param <- param.dcm(inf.prob = 0.2, act.rate = 5:7,
                  rec.rate = 1/3, a.rate = 1/90, ds.rate = 1/100,
                  di.rate = 1/35, dr.rate = 1/100)
init <- init.dcm(s.num = 1000, i.num = 1, r.num = 0)
control <- control.dcm(type = "SIR", nsteps = 25, verbose = FALSE)
mod1 <- dcm(param, init, control)
comp_plot(mod1, at = 25, run = 3)

## Example 2: ICM SIR model with 3 simulations
param <- param.icm(inf.prob = 0.2, act.rate = 3, rec.rate = 1/50,
               a.rate = 1/100, ds.rate = 1/100,
               di.rate = 1/90, dr.rate = 1/100)
init <- init.icm(s.num = 500, i.num = 1, r.num = 0)
control <- control.icm(type = "SIR", nsteps = 25,
               nsims = 3, verbose = FALSE)
mod2 <- icm(param, init, control)
comp_plot(mod2, at = 25, digits = 1)
```

control.dcm  Control Settings for Deterministic Compartmental Models

Description

Sets the controls for deterministic compartmental models simulated with dcm.

Usage

```
ccontrol.dcm(type, nsteps, dt = 1, odemethod = "rk4", dede = FALSE,
          new.mod = NULL, sens.param = TRUE, print.mod = FALSE,
          verbose = FALSE, ...)```

Arguments

<table>
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<th>Argument</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>type</td>
<td>Disease type to be modeled, with the choice of &quot;SI&quot; for Susceptible-Infected diseases, &quot;SIR&quot; for Susceptible-Infected-Recovered diseases, and &quot;SIS&quot; for Susceptible-Infected-Susceptible diseases.</td>
</tr>
<tr>
<td>nsteps</td>
<td>Number of time steps to solve the model over or vector of times to solve the model over. If the number of time steps, then this must be a positive integer of length 1.</td>
</tr>
<tr>
<td>dt</td>
<td>Time unit for model solutions, with the default of 1. Model solutions for fractional time steps may be obtained by setting this to a number between 0 and 1.</td>
</tr>
<tr>
<td>odemethod</td>
<td>Ordinary differential equation (ODE) integration method, with the default of the &quot;Runge-Kutta 4&quot; method (see ode for other options).</td>
</tr>
<tr>
<td>dede</td>
<td>If TRUE, use the delayed differential equation solver, which allows for time-lagged variables.</td>
</tr>
<tr>
<td>new.mod</td>
<td>If not running an base model type, a function with a new model to be simulated (see details).</td>
</tr>
<tr>
<td>sens.param</td>
<td>If TRUE, evaluate arguments in parameters with length greater than 1 as sensitivity analyses, with one model run per value of the parameter. If FALSE, one model will be run with parameters of arbitrary length.</td>
</tr>
<tr>
<td>print.mod</td>
<td>If TRUE, print the model form to the console.</td>
</tr>
<tr>
<td>verbose</td>
<td>If TRUE, print model progress to the console.</td>
</tr>
<tr>
<td>...</td>
<td>additional control settings passed to model.</td>
</tr>
</tbody>
</table>

Details

control.dcm sets the required control settings for any deterministic compartmental models solved with the dcm function. Controls are required for both base model types and original models. For an overview of control settings for base DCM class models, consult the Basic DCMs tutorial. For all base models, the type argument is a necessary parameter and it has no default.

New Model Functions

The form of the model function for base models may be displayed with the print.mod argument set to TRUE. In this case, the model will not be run. These model forms may be used as templates to write original model functions.

These new models may be input and solved with dcm using the new.mod argument, which requires as input a model function. Details and examples are found in the Solving New DCMs tutorial.

See Also

Use param.dcm to specify model parameters and init.dcm to specify the initial conditions. Run the parameterized model with dcm.
Description

Sets the controls for stochastic individual contact models simulated with icm.

Usage

```control.icm(type, nsteps, nsims = 1, rec.rand = TRUE, a.rand = TRUE, d.rand = TRUE, initialize.FUN = initialize.icm, infection.FUN = infection.icm, recovery.FUN = recovery.icm, departures.FUN = departures.icm, arrivals.FUN = arrivals.icm, get_prev.FUN = get_prev.icm, verbose = FALSE, verbose.int = 0, skip.check = FALSE, ...)```

Arguments

- **type**: Disease type to be modeled, with the choice of "SI" for Susceptible-Infected diseases, "SIR" for Susceptible-Infected-Recovered diseases, and "SIS" for Susceptible-Infected-Susceptible diseases.
- **nsteps**: Number of time steps to solve the model over. This must be a positive integer.
- **nsims**: Number of simulations to run.
- **rec.rand**: If TRUE, use a stochastic recovery model, with the number of recovered at each time step a function of random draws from a binomial distribution with the probability equal to rec.rate. If FALSE, then a deterministic rounded count of the expectation implied by that rate.
- **a.rand**: If TRUE, use a stochastic arrival model, with the number of arrivals at each time step a function of random draws from a binomial distribution with the probability equal to the governing arrival rates. If FALSE, then a deterministic rounded count of the expectation implied by those rates.
- **d.rand**: If TRUE, use a stochastic departure model, with the number of departures at each time step a function of random draws from a binomial distribution with the probability equal to the governing departure rates. If FALSE, then a deterministic rounded count of the expectation implied by those rates.
- **initialize.FUN**: Module to initialize the model at the outset, with the default function of initialize.icm.
- **infection.FUN**: Module to simulate disease infection, with the default function of infection.icm.
- **recovery.FUN**: Module to simulate disease recovery, with the default function of recovery.icm.
- **departures.FUN**: Module to simulate departures or exits, with the default function of departures.icm.
- **arrivals.FUN**: Module to simulate arrivals or entries, with the default function of arrivals.icm.
- **get_prev.FUN**: Module to calculate disease prevalence at each time step, with the default function of get_prev.icm.
- **verbose**: If TRUE, print model progress to the console.
verbose.int    Time step interval for printing progress to console, where 0 (the default) prints
completion status of entire simulation and positive integer x prints progress after
each x time steps.

skip.check    If TRUE, skips the default error checking for the structure and consistency of
the parameter values, initial conditions, and control settings before running base
epidemic models. Setting this to FALSE is recommended when running models
with new modules specified.

...    Additional control settings passed to model.

Details

control.icm sets the required control settings for any stochastic individual contact model solved
with the icm function. Controls are required for both base model types and when passing original
process modules. For an overview of control settings for base ICM class models, consult the Basic
ICMs tutorial. For all base models, the type argument is a necessary parameter and it has no default.

New Modules

Base ICM models use a set of module functions that specify how the individual agents in the pop-
ulation are subjected to infection, recovery, demographics, and other processes. Core modules are
those listed in the .FUN arguments. For each module, there is a default function used in the simula-
tion. The default infection module, for example, is contained in the infection.icm function.

For original models, one may substitute replacement module functions for any of the default func-
tions. New modules may be added to the workflow at each time step by passing a module function
via the ... argument.

See Also

Use param.icm to specify model parameters and init.icm to specify the initial conditions. Run
the parameterized model with icm.

control.net    Control Settings for Stochastic Network Models

Description

Sets the controls for stochastic network models simulated with netsim.

Usage

control.net(type, nsteps, start = 1, nsims = 1, ncores = 1, depend,
rec.rand = TRUE, a.rand = TRUE, d.rand = TRUE, tea.status = TRUE,
attr.rules, epi.by, use.pids = TRUE, pid.prefix,
initialize.FUN = initialize.net, departures.FUN = departures.net,
arrivals.FUN = arrivals.net, recovery.FUN = recovery.net,
edges_correct.FUN = edges_correct, resim_nets.FUN = resim_nets,
infection.FUN = infection.net, get_prev.FUN = get_prev.net,
verbose.FUN = verbose.net, module.order = NULL, set.control.ergm,
set.control.stergm, save.nwstats = TRUE,
nwstats.formula = "formation", delete.nodes = FALSE,
save.transmat = TRUE, save.network = TRUE, save.other,
verbose = TRUE, verbose.int = 1, skip.check = FALSE, ...)

Arguments

type  Disease type to be modeled, with the choice of "SI" for Susceptible-Infected
diseases, "SIR" for Susceptible-Infected-Recovered diseases, and "SIS" for
Susceptible-Infected-Susceptible diseases.

nsteps  Number of time steps to simulate the model over. This must be a positive integer
that is equal to the final step of a simulation. If simulation is restarted with start
argument, this number must be at least one greater than that argument’s value.

start  For dependent simulations, time point to start up simulation. For restarted sim-
ulations, this must be one greater than the final time step in the prior simulation
and must be less than the value in nsteps.

nsims  The total number of disease simulations.

ncores  Number of processor cores to run multiple simulations on, using the foreach
and doParallel implementations.

depend  If TRUE, resimulate the network at each time step. This occurs by default with
two varieties of dependent models: if there are any vital dynamic parameters
in the model (or if non-standard arrival or departures modules are passed into
control.net), or if the network model formation formula includes the "status"
attribute.

rec.rand  If TRUE, use a stochastic recovery model, with the number of recovered at each
time step a function of random draws from a binomial distribution with the prob-
ability equal to rec.rate. If FALSE, then a deterministic rounded count of the
expectation implied by that rate.

a.rand  If TRUE, use a stochastic arrival model, with the number of arrivals at each time
step a function of random draws from a binomial distribution with the probabil-
ity equal to the governing arrival rates. If FALSE, then a deterministic rounded
count of the expectation implied by those rates.

d.rand  If TRUE, use a stochastic departure model, with the number of departures at each
time step a function of random draws from a binomial distribution with the prob-
ability equal to the governing departure rates. If FALSE, then a deterministic
rounded count of the expectation implied by those rates.

tea.status  If TRUE, use a temporally extended attribute (TEA) to store disease status. A
TEA is needed for plotting static networks at different time steps and for ani-
mating dynamic networks with evolving status. TEAs are computationally in-
efficient for large simulations and should be toggled off in those cases. This
argument automatically set to FALSE if delete.nodes=TRUE.

attr.rules  A list containing the rules for setting the attributes of incoming nodes, with one
list element per attribute to be set (see details below).
epi.by
A character vector of length 1 containing a nodal attribute for which subgroup epidemic prevalences should be calculated. This nodal attribute must be contained in the network model formation formula, otherwise it is ignored.

use.pids
If TRUE, use persistent ids for vertices; otherwise, numeric ids will be recycled in models with vital dynamics. For one-mode simulations, this will be a random hexadecimal value; for bipartite simulations, it will be based on pid.prefix.

pid.prefix
For bipartite network simulations with vital dynamics, a character vector of length 2 containing the prefixes, with the default of c("F", "M").

initialize.FUN
Module to initialize the model at time 1, with the default function of initialize.net.

departures.FUN
Module to simulate departure or exit, with the default function of departures.net.

arrivals.FUN
Module to simulate arrivals or entries, with the default function of arrivals.net.

recovery.FUN
Module to simulate disease recovery, with the default function of recovery.net.

edges_correct.FUN
Module to adjust the edges coefficient in response to changes to the population size, with the default function of edges_correct that preserves mean degree.

resim_nets.FUN
Module to resimulate the network at each time step, with the default function of resim_nets.

infection.FUN
Module to simulate disease infection, with the default function of infection.net.

get_prev.FUN
Module to calculate disease prevalence at each time step, with the default function of get_prev.net.

verbose.FUN
Module to print simulation progress to screen, with the default function of verbose.net.

module.order
A character vector of module names that lists modules the order in which they should be evaluated within each time step. If NULL, the modules will be evaluated as follows: first any new modules supplied through ... in the order in which they are listed, then the built-in modules in their order of the function listing. The initialize.FUN will always be run first and the verbose.FUN always last.

set.control.ergm
Control arguments passed to simulate.ergm. See the help file for netdx for details and examples on specifying this parameter.

set.control.stergm
Control arguments passed to simulate.stergm. See the help file for netdx for details and examples on specifying this parameter.

save.nwstats
If TRUE, save network statistics in a data frame. The statistics to be saved are specified in the nwstats.formula argument.

nwstats.formula
A right-hand sided ERGM formula that includes network statistics of interest, with the default to the formation formula terms.

delete.nodes
If TRUE, delete inactive nodes from the network after each time step, otherwise deactivate them but keep them in the network object. Deleting nodes increases computational efficiency in large network simulations.

save.transmat
If TRUE, save a transmission matrix for each simulation. This object contains one row for each transmission event (see discord_edgelist).
save.network  If TRUE, save a networkDynamic object containing full edge history for each simulation. If delete.nodes is set to TRUE, this will only contain a static network with the edge configuration at the final time step of each simulation.

save.other  A vector of elements on the dat master data list to save out after each simulation. One example for base models is the attribute list, "attr", at the final time step.

verbose  If TRUE, print model progress to the console.

verbose.int  Time step interval for printing progress to console, where 0 prints completion status of entire simulation and positive integer x prints progress after each x time steps. The default is to print progress after each time step.

skip.check  If TRUE, skips the default error checking for the structure and consistency of the parameter values, initial conditions, and control settings before running base epidemic models. Setting this to FALSE is recommended when running models with new modules specified.

...  Additional control settings passed to model.

Details

control.net sets the required control settings for any network model solved with the netsim function. Controls are required for both base model types and when passing original process modules. For an overview of control settings for base models, consult the Basic Network Models tutorial. For all base models, the type argument is a necessary parameter and it has no default.

The attr.rules Argument

The attr.rules parameter is used to specify the rules for how nodal attribute values for incoming nodes should be set. These rules are only necessary for models in which there are incoming nodes (i.e., arrivals) and there is also a nodal attribute in the network model formation formula set in netest. There are three rules available for each attribute value:

- "current": new nodes will be assigned this attribute in proportion to the distribution of that attribute among existing nodes at that current time step.
- "t1": new nodes will be assigned this attribute in proportion to the distribution of that attribute among nodes at time 1 (that is, the proportions set in the original network for netest).
- <Value>: all new nodes will be assigned this specific value, with no variation.

For example, the rules list attr.rules = list(race = "t1", sex = "current", status = "s") specifies how the race, sex, and status attributes should be set for incoming nodes. By default, the rule is "current" for all attributes except status, in which case it is "s" (that is, all incoming nodes are susceptible).

New Modules

Base network models use a set of module functions that specify how the individual nodes in the network are subjected to infection, recovery, demographics, and other processes. Core modules are those listed in the .FUN arguments. For each module, there is a default function used in the simulation. The default infection module, for example, is contained in the infection.net function.

For original models, one may substitute replacement module functions for any of the default functions. New modules may be added to the workflow at each time step by passing a module function
via the \ldots argument. Consult the New Network Models tutorial. One may remove existing modules, such as arrivals.FUN, from the workflow by setting the parameter value for that argument to NULL.

See Also

Use \texttt{param.net} to specify model parameters and \texttt{init.net} to specify the initial conditions. Run the parameterized model with \texttt{netsim}.

---

\section*{dcm  
\textit{Deterministic Compartmental Models}}

\subsection*{Description}

Solves deterministic compartmental epidemic models for infectious disease.

\subsection*{Usage}

\begin{verbatim}
dcm(param, init, control)
\end{verbatim}

\subsection*{Arguments}

\begin{itemize}
  \item \texttt{param} Model parameters, as an object of class \texttt{param.dcm}.
  \item \texttt{init} Initial conditions, as an object of class \texttt{init.dcm}.
  \item \texttt{control} Control settings, as an object of class \texttt{control.dcm}.
\end{itemize}

\subsection*{Details}

The \texttt{dcm} function uses the ordinary differential equation solver in the \texttt{deSolve} package to model disease as a deterministic compartmental system. The parameterization for these models follows the standard approach in \texttt{EpiModel}, with epidemic parameters, initial conditions, and control settings. A description of solving DCMs with the \texttt{dcm} function may be found in the Basic DCMs tutorial.

The \texttt{dcm} function performs modeling of both base model types and original models with new structures. Base model types include one-group and two-group models with disease types for Susceptible-Infected (SI), Susceptible-Infected-Recovered (SIR), and Susceptible-Infected-Susceptible (SIS). New model types may be written and input into \texttt{dcm} following the steps outlined in the Solving New DCMs tutorial. Both base and original models require the \texttt{param}, \texttt{init}, and \texttt{control} inputs.

\subsection*{Value}

A list of class \texttt{dcm} with the following elements:

\begin{itemize}
  \item \texttt{param}: the epidemic parameters passed into the model through \texttt{param}, with additional parameters added as necessary.
  \item \texttt{control}: the control settings passed into the model through \texttt{control}, with additional controls added as necessary.
\end{itemize}
- **epi**: a list of data frames, one for each epidemiological output from the model. Outputs for base models always include the size of each compartment, as well as flows in, out of, and between compartments.

**References**


**See Also**

Extract the model results with `as.data.frame.dcm`. Summarize the time-specific model results with `summary.dcm`. Plot the model results with `plot.dcm`. Plot a compartment flow diagram with `comp_plot`.

**Examples**

```r
## Example 1: SI Model (One-Group)
# Set parameters
param <- param.dcm(inf.prob = 0.2, act.rate = 0.25)
init <- init.dcm(s.num = 500, i.num = 1)
control <- control.dcm(type = "SI", nsteps = 500)
mod1 <- dcm(param, init, control)
mod1
plot(mod1)

## Example 2: SIR Model with Vital Dynamics (One-Group)
param <- param.dcm(inf.prob = 0.2, act.rate = 5,
                    rec.rate = 1/3, a.rate = 1/90, ds.rate = 1/100,
                    di.rate = 1/35, dr.rate = 1/100)
init <- init.dcm(s.num = 500, i.num = 1, r.num = 0)
control <- control.dcm(type = "SIR", nsteps = 500)
mod2 <- dcm(param, init, control)
mod2
plot(mod2)

## Example 3: SIS Model with act.rate Sensitivity Parameter
param <- param.dcm(inf.prob = 0.2, act.rate = seq(0.1, 0.5, 0.1),
                    rec.rate = 1/50)
init <- init.dcm(s.num = 500, i.num = 1)
control <- control.dcm(type = "SIS", nsteps = 500)
mod3 <- dcm(param, init, control)
mod3
plot(mod3)

## Example 4: SI Model with Vital Dynamics (Two-Group)
param <- param.dcm(inf.prob = 0.4, inf.prob.g2 = 0.1,
                    act.rate = 0.25, balance = "g1",
                    a.rate = 1/100, a.rate.g2 = NA,
                    ds.rate = 1/100, ds.rate.g2 = 1/100,
                    di.rate = 1/50, di.rate.g2 = 1/50)
init <- init.dcm(s.num = 500, i.num = 1,
```

Dissolution Coefficients for Stochastic Network Models

Description
Calculates dissolution coefficients, given a dissolution model and average edge duration, to pass as offsets to an ERGM/STERGM model fit in netest.

Usage

\[
\text{dissolution\_coes}(\text{dissolution, duration, d\_rate} = 0)
\]

Arguments

- `dissolution`: Right-hand sided STERGM dissolution formula (see netest). See below for list of supported dissolution models.
- `duration`: A vector of mean edge durations in arbitrary time units.
- `d\_rate`: Departure or exit rate from the population, as a single homogenous rate that applies to the entire population.

Details
This function performs two calculations for dissolution coefficients used in a network model estimated with netest:

1. **Transformation**: the mean duration of edges in a network are mathematically transformed to logit coefficients.
2. **Adjustment**: in a dynamic network simulation in an open population (in which there are departures), it is further necessary to adjust these coefficients for dynamic simulations; this upward adjustment accounts for departure as a competing risk to edge dissolution.

The current dissolution models supported by this function and in network model estimation in netest are as follows:

- `~offset(edges)`: a homogeneous dissolution model in which the edge duration is the same for all partnerships. This requires specifying one duration value.
- `~offset(edges) + offset(nodematch("<attr>"))`: a heterogeneous model in which the edge duration varies by whether the nodes in the dyad have similar values of a specified attribute. The duration vector should now contain two values: the first is the mean edge duration of non-matched dyads, and the second is the duration of the matched dyads.
dissolution_coefs

- `~offset(edges) + offset(nodemix("<attr>"))`: a heterogenous model that extends the nodematch model to include non-binary attributes for homophily. The duration vector should first contain the base value, then the values for every other possible combination in the term.

- `~offset(edges) + offset(nodefactor("<attr>"))`: a heterogenous model in which the edge duration varies by a specified attribute. The duration vector should first contain the base value, then the values for every other value of that attribute in the term.

Value

A list of class disso coef with the following elements:

- **dissolution**: right-hand sided STERGM dissolution formula passed in the function call.
- **duration**: mean edge durations passed into the function.
- **coef.crude**: mean durations transformed into logit coefficients.
- **coef.adj**: crude coefficients adjusted for the risk of departure on edge persistence, if the d.rate argument is supplied.
- **d.rate**: the departure rate.

See Also

The theory and details of this function are explained in detail in the EpiModel Network Utility Functions tutorial.

Examples

```r
# Homogeneous dissolution model with no departures
dissolution_coefs(dissolution = ~offset(edges), duration = 25)

# Homogeneous dissolution model with departures
dissolution_coefs(dissolution = ~offset(edges), duration = 25, d.rate = 0.001)

# Heterogeneous dissolution model in which same-race edges have shorter duration compared to mixed-race edges, with no departures
dissolution_coefs(dissolution = ~offset(edges) + offset(nodematch("race")), duration = c(20, 10))

# Heterogeneous dissolution model in which same-race edges have shorter duration compared to mixed-race edges, with departures
dissolution_coefs(dissolution = ~offset(edges) + offset(nodematch("race")), duration = c(20, 10), d.rate = 0.001)
```
edgelist_censor  

Table of Edge Censoring

Description

Outputs a table of the number and percent of edges that are left-censored, right-censored, both-censored, or uncensored for a networkDynamic object.

Usage

edgelist_censor(el)

Arguments

el  
Timed edgelist with start and end times extracted from a networkDynamic object using the as.data.frame.networkDynamic function.

Details

Given a STERGM simulation over a specified number of time steps, the edges within that simulation may be left-censored (started before the first step), right-censored (continued after the last step), right and left-censored, or uncensored. The amount of censoring will increase when the average edge duration approaches the length of the simulation.

Examples

# Initialize and parameterize network model
nw <- network.initialize(n = 100, directed = FALSE)
formation <- ~edges
target.stats <- 50
coef.diss <- dissolution_coefs(dissolution = ~offset(edges), duration = 20)

# Model estimation
est <- netest(nw, formation, target.stats, coef.diss, verbose = FALSE)

# Simulate the network and extract a timed edgelist
dx <- netdx(est, nsims = 1, nsteps = 100, keep.edgelist = TRUE, verbose = FALSE)
el <- as.data.frame(dx)

# Calculate censoring
edgelist_censor(el)
epiweb

Description

Runs a web browser-based GUI of deterministic compartmental models, stochastic individual contact models, and basic network models.

Usage

epiweb(class, ...)

Arguments

class  Model class, with options of "dcm", "icm" and "net".
...

Additional arguments passed to shiny::runApp.

Details

epiweb runs a web-based GUI of one-group deterministic compartmental models, stochastic individual contact models, and stochastic network models with user input on model type, state sizes, and parameters. Model output may be plotted, summarized, and saved as raw data using the core EpiModel functionality for these model classes. These applications are built using the shiny package framework.

References


See Also

dcm, icm, netsim

Examples

## Not run:
## Deterministic compartmental models
epiweb(class = "dcm")

## Stochastic individual contact models
epiweb(class = "icm")

## Stochastic network models
epiweb(class = "net")

## End(Not run)
Description

Plots quantile bands given a data.frame with stochastic model results from icm or netsim.

Usage

geom_bands(mapping, lower = 0.25, upper = 0.75, alpha = 0.25, ...)

Arguments

- mapping: standard aesthetic mapping aes() input for ggplot2.
- lower: Lower quantile for the time series.
- upper: Upper quantile for the time series.
- alpha: Transparency of the ribbon fill.
- ...: Additional arguments passed to stat_summary.

Details

This is a wrapper around ggplot::stat_summary with a ribbon geom as aesthetic output.

Examples

```r
param <- param.icm(inf.prob = 0.2, act.rate = 0.25)
init <- init.icm(s.num = 500, i.num = 1)
control <- control.icm(type = "SI", nsteps = 250, nsims = 5)
mod1 <- icm(param, init, control)
df <- as.data.frame(mod1)
df.mean <- as.data.frame(mod1, out = "mean")
library(ggplot2)
ggplot() +
  geom_line(data = df, mapping = aes(time, i.num, group = sim), alpha = 0.25,
            lwd = 0.25, color = "firebrick") +
  geom_bands(data = df, mapping = aes(time, i.num),
             lower = 0.1, upper = 0.9, fill = "firebrick") +
  geom_line(data = df.mean, mapping = aes(time, i.num)) +
  theme_minimal()
```
get_degree

Get Individual Degree from Network or Edgelist

Description

A fast method for querying the current degree of all individuals within a network.

Usage

get_degree(x)

Arguments

x

Either an object of class network or edgelist generated from a network. If x is an edgelist, then it must contain an attribute for the total network size, n.

Details

Individual-level data on the current degree of nodes within a network is often useful for summary statistics and modeling complex interactions between degree. Given a network class object, net, one way to look up the current degree is to get a summary of the ERGM term, sociality, as in: summary(net ~ sociality(base = 0)). But that is computationally inefficient for a number of reasons. This function provide a fast method for generating the vector of degree using a query of the edgelist. It is even faster if the parameter x is already transformed as an edgelist.

Examples

nw <- network.initialize(500, directed = FALSE)
set.seed(1)
fit <- ergm(nw ~ edges, target.stats = 250)
sim <- simulate(fit)

# Slow ERG-based method
ergm.method <- unname(summary(sim ~ sociality(base = 0)))
ergm.method

# Fast tabulate method with network object
deg.net <- get_degree(sim)
deg.net

# Even faster if network already transformed into an edgelist
el <- as.edgelist(sim)
deg.el <- get_degree(el)
deg.el

identical(as.integer(ergm.method), deg.net, deg.el)
get_formula_term_attr  Outputs ERGM Formula Attributes into a Character Vector

Description

Given a formation formula for a network model, outputs it into a character vector of vertex attributes to be used in netsim simulations.

Usage

get_formula_term_attr(form, nw)

Arguments

form  an ergm model formula
nw  a network object

get_network  Extract networkDynamic and network Objects from Network Simulations

Description

Extracts the networkDynamic object from a either a network epidemic model object generated with netsim or a network diagnostic simulation generated with netdx, with the option to collapse the extracted networkDynamic object down to a static network object.

Usage

get_network(x, sim = 1, network = 1, collapse = FALSE, at)

Arguments

x  An EpiModel object of class netsim or netdx.
sim  Simulation number of extracted network.
network  Network number, for netsim objects with multiple overlapping networks (advanced use, and not applicable to netdx objects).
collapse  If TRUE, collapse the networkDynamic object to a static network object at a specified time step.
at  If collapse is TRUE, the time step at which the extracted network should be collapsed.
**get_nwstats**

Extract Network Statistics from netsim or netdx Object

### Description

Extracts a data frame of network statistics from a network epidemic model simulated with netsim or a network diagnostics object simulated with netdx.

### Usage

```r
get_nwstats(x, sim, network = 1)
```
get_sims

Extract Network Simulations

Description

Subsets the entire netsim object to a subset of simulations, essentially functioning like a reverse of merge.

Usage

get_sims(x, sims, var)

Arguments

x
An EpiModel object of class netsim or netdx.
sim
A vector of simulation numbers from the extracted object
network
Network number, for netsim objects with multiple overlapping networks (advanced use, and not applicable to netdx objects).

Examples

# Bipartite Bernoulli random graph TERGM
nw <- network.initialize(n = 100, bipartite = 50, directed = FALSE)
formation <- ~edges
target.stats <- ~50
coeff.diss <- dissolution_coefs(dissolution = ~offset(edges), duration = 20)
est <- netest(nw, formation, target.stats, coeff.diss, verbose = FALSE)

dx <- netdx(est, nsim = 3, nsteps = 10, verbose = FALSE,
            nwstats.formula = ~edges + isolates)
get_nwstats(dx)
get_nwstats(dx, sim = 1)

# SI epidemic model
param <- param.net(inf.prob = 0.3, inf.prob.m2 = 0.15)
init <- init.net(i.num = 10, i.num.m2 = 10)
control <- control.net(type = "SI", nsteps = 10, nsims = 3,
                         nwstats.formula = ~edges + meandeg + degree(0:5),
                         verbose = FALSE)
mod <- netsim(est, param, init, control)

# Extract the network statistics from all or sets of simulations
get_nwstats(mod)
get_nwstats(mod, sim = 2)
get_nwstats(mod, sim = c(1, 3))

# On the fly summary stats
summary(get_nwstats(mod))
colMeans(get_nwstats(mod))
Arguments

x  An object of class netsim.

sims  A numeric vector of simulation numbers to retain in the output object, or "mean" which selects the one simulation with the value of the variable specified in var closest to the mean of var across all simulations.

var  A character vector of variables to retain from x if sims is a numeric vector, or a single variable name for selecting the average simulation from the set if sims = "mean".

Examples

# Network model estimation
nw <- network.initialize(n = 100, directed = FALSE)
formation <- ~edges
target.stats <- 50
coeff.diss <- dissolution.coefs(dissolution = ~offset(edges), duration = 20)
est1 <- netest(nw, formation, target.stats, coeff.diss, verbose = FALSE)

# Epidemic model
param <- param.net(inf.prob = 0.3)
init <- init.net(i.num = 10)
control <- control.net(type = "SI", nsteps = 10, nsims = 3, verbose.int = 0)
mod1 <- netsim(est1, param, init, control)

# Get sim 2
sim2 <- get_sims(mod1, sims = 2)

# Get sims 2 and 3 and keep only a subset of variables
sim2.small <- get_sims(mod1, sims = 2:3, var = c("i.num", "si.flow"))

# Extract the mean simulation for the variable i.num
sim.mean <- get_sims(mod1, sims = "mean", var = "i.num")

icm  Stochastic Individual Contact Models

Description

Simulates stochastic individual contact epidemic models for infectious disease.

Usage

icm(param, init, control)
Arguments

param  Model parameters, as an object of class `param.icm`.
init   Initial conditions, as an object of class `init.icm`.
control Control settings, as an object of class `control.icm`.

Details

Individual contact models are intended to be the stochastic microsimulation analogs to deterministic compartmental models. ICMs simulate disease spread on individual agents in discrete time as a function of processes with stochastic variation. The stochasticity is inherent in all transition processes: infection, recovery, and demographics. A detailed description of these models may be found in the Basic ICMs tutorial.

The `icm` function performs modeling of both the base model types and original models. Base model types include one-group and two-group models with disease types for Susceptible-Infected (SI), Susceptible-Infected-Recovered (SIR), and Susceptible-Infected-Susceptible (SIS). Original models may be built by writing new process modules that either take the place of existing modules (for example, disease recovery), or supplement the set of existing processes with a new one contained in an original module.

Value

A list of class `icm` with the following elements:

- **param**: the epidemic parameters passed into the model through `param`, with additional parameters added as necessary.
- **control**: the control settings passed into the model through `control`, with additional controls added as necessary.
- **epi**: a list of data frames, one for each epidemiological output from the model. Outputs for base models always include the size of each compartment, as well as flows in, out of, and between compartments.

See Also

Extract the model results with `as.data.frame.icm`. Summarize the time-specific model results with `summary.icm`. Plot the model results with `plot.icm`. Plot a compartment flow diagram with `comp_plot`.

Examples

```r
# Not run:
# Example 1: SI Model
param <- param.icm(inf.prob = 0.2, act.rate = 0.25)
init <- init.icm(s.num = 500, i.num = 1)
control <- control.icm(type = "SI", nsteps = 500, nsims = 10)
mod1 <- icm(param, init, control)
plot(mod1)
```
### Example 2: SIR Model
```
param <- param.icm(inf.prob = 0.2, act.rate = 0.25, rec.rate = 1/50)
init <- init.icm(s.num = 500, i.num = 1, r.num = 0)
control <- control.icm(type = "SIR", nsteps = 500, nsims = 10)
mod2 <- icm(param, init, control)
plot(mod2)
```

### Example 3: SIS Model
```
param <- param.icm(inf.prob = 0.2, act.rate = 0.25, rec.rate = 1/50)
init <- init.icm(s.num = 500, i.num = 1)
control <- control.icm(type = "SIS", nsteps = 500, nsims = 10)
mod3 <- icm(param, init, control)
plot(mod3)
```

### Example 4: SI Model with Vital Dynamics (Two-Group)
```
param <- param.icm(inf.prob = 0.4, inf.prob.g2 = 0.1, act.rate = 0.25, balance = "g1", a.rate = 1/100, a.rate.g2 = NA, ds.rate = 1/100, ds.rate.g2 = 1/100, di.rate = 1/50, di.rate.g2 = 1/50)
init <- init.icm(s.num = 500, i.num = 1, s.num.g2 = 500, i.num.g2 = 0)
control <- control.icm(type = "SI", nsteps = 500, nsims = 10)
mod4 <- icm(param, init, control)
plot(mod4)
```

### End (Not run)

---

**init.dcm**

*Initial Conditions for Deterministic Compartmental Models*

**Description**

Sets the initial conditions for deterministic compartmental models simulated with dcm.

**Usage**

```
init.dcm(s.num, i.num, r.num, s.num.g2, i.num.g2, r.num.g2, ...)
```

**Arguments**

- `s.num` Number of initial susceptible. For two-group models, this is the number of initial group 1 susceptible.
- `i.num` Number of initial infected. For two-group models, this is the number of initial group 1 infected.
**init.icm**

**Initial Conditions for Stochastic Individual Contact Models**

**Description**

Sets the initial conditions for stochastic individual contact models simulated with icm.

**Usage**

```
init.icm(s.num, i.num, r.num, s.num.g2, i.num.g2, r.num.g2, ...)
```

**Arguments**

- **s.num**: Number of initial susceptible. For two-group models, this is the number of initial group 1 susceptible.
- **i.num**: Number of initial infected. For two-group models, this is the number of initial group 1 infected.
- **r.num**: Number of initial recovered. For two-group models, this is the number of initial group 1 recovered. This parameter is only used for the SIR model type.
s.num.g2  Number of initial susceptible in group 2. This parameter is only used for two-group models.

i.num.g2  Number of initial infected in group 2. This parameter is only used for two-group models.

r.num.g2  Number of initial recovered in group 2. This parameter is only used for two-group SIR models.

... Additional initial conditions passed to model.

Details

The initial conditions for a model solved with icm should be input into the init.icm function. This function handles initial conditions for both base models and original models using new modules. For an overview of initial conditions for base ICM class models, consult the Basic ICMs tutorial.

See Also

Use param.icm to specify model parameters and control.icm to specify the control settings. Run the parameterized model with icm.

init.net  

Initial Conditions for Stochastic Network Models

Description

Sets the initial conditions for stochastic network models simulated with netsim.

Usage

init.net(i.num, r.num, i.num.m2, r.num.m2, status.vector, infTime.vector, ...

Arguments

i.num  Number of initial infected. For bipartite models, this is the number of initial mode 1 infected.

r.num  Number of initial recovered. For bipartite models, this is the number of initial mode 1 recovered. This parameter is only used for the SIR model type.

i.num.m2  Number of initial infected in mode 2. This parameter is only used for bipartite models.

r.num.m2  Number of initial recovered in mode 2. This parameter is only used for bipartite SIR models.

status.vector  A vector of length equal to the size of the input network, containing the status of each node. Setting status here overrides any inputs passed in the .num arguments.
infTime.vector A vector of length equal to the size of the input network, containing the (historical) time of infection for each of those nodes with a current status of "i". Can only be used if status.vector is used, and must contain NA values for any nodes whose status is not "i".

... Additional initial conditions passed to model.

Details

The initial conditions for a model solved with netsim should be input into the init.net function. This function handles initial conditions for both base models and new modules. For an overview of specifying initial conditions across a variety of base network models, consult the Basic Network Models tutorial.

See Also

Use param.net to specify model parameters and control.net to specify the control settings. Run the parameterized model with netsim.

Examples

# Example of using status.vector and infTime.vector together
n <- 100
status <- sample(c("s", "i"), size = n, replace = TRUE, prob = c(0.8, 0.2))
infTime <- rep(NA, n)
inftime[which(status == "i")]

init.net(status.vector = status, infTime.vector = infTime)

is.transmat

Extract Transmissions Matrix from Network Epidemic Model

Description

Extracts the matrix of transmission data for each transmission event that occurred within a network epidemic model.

Usage

is.transmat(x)

get_transmat(x, sim = 1)

Arguments

x An EpiModel object of class netsim.
sim Simulation number of extracted network.
**merge.icm**

**Value**

A data frame with the following columns

- **at**: the time step at which the transmission occurred.
- **sus**: the ID number of the susceptible (newly infected) node.
- **inf**: the ID number of the infecting node.
- **infDur**: the duration of the infecting node’s disease at the time of the transmission.
- **transProb**: the probability of transmission per act.
- **actRate**: the rate of acts per unit time.
- **finalProb**: the final transmission probability for the transmission event.

**Examples**

```r
## Simulate SI epidemic on bipartite Bernoulli random graph
nw <- network.initialize(n = 100, bipartite = 50, directed = FALSE)
formation <- ~edges
target.stats <- ~0
coeff.diss <- dissolution.coefs(dissolution = ~offset(edges), duration = 20)
est <- netest(nw, formation, target.stats, coe1.diss, verbose = FALSE)
param <- param.net(inf.prob = 0.3, inf.prob.m2 = 0.15)
init <- init.net(i.num = 10, i.num.m2 = 10)
control <- control.net(type = "SI", nsteps = 10, nsims = 3, verbose = FALSE)
mod <- netsim.net(est, param, init, control)

## Extract the transmission matrix from simulation 2
get_transmat(mod, sim = 2)
```

**merge.icm**

*Merge Data across Stochastic Individual Contact Model Simulations*

**Description**

Merges epidemiological data from two independent simulations of stochastic individual contact models from icm.

**Usage**

```r
## S3 method for class 'icm'
merge(x, y, ...)
```

**Arguments**

- **x**: An EpiModel object of classicm.
- **y**: Another EpiModel object of classicm, with the identical model parameterization as x.
- **...**: Additional merge arguments (not used).
Details

This merge function combines the results of two independent simulations of icm class models, simulated under separate function calls. The model parameterization between the two calls must be exactly the same, except for the number of simulations in each call. This allows for manual parallelization of model simulations.

This merge function does not work the same as the default merge, which allows for a combined object where the structure differs between the input elements. Instead, the function checks that objects are identical in model parameterization in every respect (except number of simulations) and binds the results.

Examples

```r
param <- param.icm(inf.prob = 0.2, act.rate = 0.8)
init <- init.icm(s.num = 1000, i.num = 100)
control <- control.icm(type = "SI", nsteps = 10,
                        nsims = 3, verbose = FALSE)
x <- icm(param, init, control)

control <- control.icm(type = "SI", nsteps = 10,
                        nsims = 1, verbose = FALSE)
y <- icm(param, init, control)

z <- merge(x, y)
x$epi
y$epi
z$epi
```

merge.netsim  
Merge Model Simulations Across netsim Objects

Description

Merges epidemiological data from two independent simulations of stochastic network models from netsim.

Usage

```r
## S3 method for class 'netsim'
merge(x, y, keep.transmat = TRUE, keep.network = TRUE,
      keep.nwstats = TRUE, keep.other = TRUE, param.error = TRUE, ...)
```

Arguments

- `x`  
  An EpiModel object of class netsim.

- `y`  
  Another EpiModel object of class netsim, with the identical model parameterization as `x`.  

merge.netsim

keep.transmat  If TRUE, keep the transmission matrices from the original x and y elements.
keep.network   If TRUE, keep the networkDynamic objects from the original x and y elements.
keep.nwstats   If TRUE, keep the network statistics (as set by the nwstats.formula parameter in control.netsim) from the original x and y elements.
keep.other     If TRUE, keep the other simulation elements (as set by the save.other parameter in control.netsim) from the original x and y elements.
param.error    If TRUE, if x and y have different params (in param.net) or controls (passed in control.net) an error will prevent the merge. Use FALSE to override that check.

Additional merge arguments (not currently used).

Details

This merge function combines the results of two independent simulations of netsim class models, simulated under separate function calls. The model parameterization between the two calls must be exactly the same, except for the number of simulations in each call. This allows for manual parallelization of model simulations.

This merge function does not work the same as the default merge, which allows for a combined object where the structure differs between the input elements. Instead, the function checks that objects are identical in model parameterization in every respect (except number of simulations) and binds the results.

Examples

# Network model
nw <- network.initialize(n = 100, directed = FALSE)
coef.diss <- dissolution.coefs(dissolution = ~offset(edges), duration = 10)
est <- netest(nw, formation = ~edges, target.stats = 25,
              coef.diss = coef.diss, verbose = FALSE)

# Epidemic models
param <- param.net(inf.prob = 1)
init <- init.net(i.num = 1)
control <- control.net(type = "SI", nsteps = 20, nsims = 2,
save.nwstats = TRUE,
            nwstats.formula = ~edges + degree(0),
            verbose = FALSE)
x <- netsim(est, param, init, control)
y <- netsim(est, param, init, control)

# Merging
z <- merge(x, y)
x$epi
y$epi
z$epi
Description

Stochastic individual contact models of infectious disease simulate epidemics in which contacts between individuals are instantaneous events in discrete time. They are intended to be the stochastic microsimulation analogs to deterministic compartmental models.

The `icm` function handles both the simulation tasks. Within this function are a series of modules that initialize the simulation and then simulate new infections, recoveries, and vital dynamics at each time step. A module also handles the basic bookkeeping calculations for disease prevalence.

Writing original ICMs will require modifying the existing modules or adding new modules to the workflow in `icm`. The existing modules may be used as a template for replacement or new modules.

This help page presents a brief overview of the module functions in the order in which they are used within `icm`, in order to help guide users in writing their own module functions. These module functions are not shown on the help index since they are not called directly by the end-user. To understand these functions in more detail, review the separate help pages listed below.

Initialization Module

This function sets up agent attributes, like disease status, on the network at the starting time step of disease simulation, \( t_1 \). For multiple-simulation function calls, these are reset at the beginning of each simulation.

- `initialize.icm`: sets which agents are initially infected, through the initial conditions passed in `init.icm`.

Disease Status Modification Modules

The main disease simulation occurs at each time step given the current state of the population at that step. Infection of agents is simulated as a function of disease parameters and population composition. Recovery of agents is likewise simulated with respect to infected nodes. These functions also analyze the flows for summary measures such as disease incidence.

- `infection.icm`: randomly draws an edgelist given the parameters, subsets the list for discordant pairs, and simulates transmission on those discordant pairs through a series of draws from a binomial distribution.
- `recovery.icm`: simulates recovery from infection either to a lifelong immune state (for SIR models) or back to the susceptible state (for SIS models), as a function of the recovery rate specified in the `rec.rate` parameter. The recovery rate may vary for two-group models.

Demographic Modules

Vital dynamics such as arrival and departure processes are simulated at each time step to update entries into and exits from the population. These are used in open-population ICMs.
• **departures.icm**: randomly simulates departures or exits for agents given the departure rate specified in the disease-state and group-specific departure parameters in `param.icm`. This involves deactivating agents from the population, but their historical data is preserved in the simulation.

• **arrivals.icm**: randomly simulates new arrivals into the population given the current population size and the arrival rate parameters. This involves adding new agents into the population.

**Bookkeeping Module**

Simulations require bookkeeping at each time step to calculate the summary epidemiological statistics used in the model output analysis.

• **get_prev.icm**: calculates the number in each disease state (susceptible, infected, recovered) at each time step for those active agents in the population.

**Description**

Stochastic network models of infectious disease in EpiModel require statistical modeling of networks, simulation of those networks forward through time, and simulation of epidemic dynamics on top of those evolving networks. The `netsim` function handles both the network and epidemic simulation tasks. Within this function are a series of modules that initialize the simulation and then simulate new infections, recoveries, and demographics on the network. Modules also handle the resimulation of the network and some bookkeeping calculations for disease prevalence.

Writing original network models that expand upon our “base” model set will require modifying the existing modules or adding new modules to the workflow in `netsim`. The existing modules may be used as a template for replacement or new modules.

This help page provides an orientation to these module functions, in the order in which they are used within `netsim`, to help guide users in writing their own functions. These module functions are not shown on the help index since they are not called directly by the end-user. To understand these functions in more detail, review the separate help pages listed below.

**Initialization Module**

This function sets up nodal attributes, like disease status, on the network at the starting time step of disease simulation, $t_1$. For multiple-simulation function calls, these are reset at the beginning of each individual simulation.

• **initialize.net**: sets up the master data structure used in the simulation, initializes which nodes are infected (via the initial conditions passed in `init.net`), and simulates a first time step of the networks given the network model fit from `netest`. 
Disease Status Modification Modules

The main disease simulation occurs at each time step given the current state of the network at that step. Infection of nodes is simulated as a function of attributes of the nodes and the edges. Recovery of nodes is likewise simulated as a function of nodal attributes of those infected nodes. These functions also calculate summary flow measures such as disease incidence.

- **infection.net**: simulates disease transmission given an edgelist of discordant partnerships by calculating the relevant transmission and act rates for each edge, and then updating the nodal attributes and summary statistics.
- **recovery.net**: simulates recovery from infection either to a lifelong immune state (for SIR models) or back to the susceptible state (for SIS models), as a function of the recovery rate parameters specified in `param.net`.

Demographic Modules

Demographics such as arrival and departure processes are simulated at each time step to update entries into and exits from the network. These are used in dependent network models, in which the network is resimulated at each time step to account for the nodal changes affecting the edges.

- **departures.net**: randomly simulates departure for nodes given their disease status (susceptible, infected, recovered), and their mode-specific departure rates specified in `param.net`. Departures involve deactivating nodes, which are then deleted from the network if `delete.nodes=True` is set in `control.net`.
- **arrivals.net**: randomly simulates new arrivals into the network given the current population size and the arrival rate specified in the `a.rate` parameters. This involves adding new nodes into the network.

Network Resimulation Module

In dependent network models, the network object is resimulated at each time step to account for changes in the size of the network (changed through entries and exits), and the disease status of the nodes.

- **edges_correct**: adjusts the edges coefficient of a network model to account for changes in the population size due to entries and exits. The default behavior is to preserve the mean degree (average number of edges per person) in response to change population sizes.
- **resim_nets**: resimulates the network object one time step forward given the set of formation and dissolution coefficients estimated in `netest`. This function also deletes the inactive nodes if the `delete.nodes` control is set to `TRUE`.

Bookkeeping Module

Network simulations require bookkeeping at each time step to calculate the summary epidemiological statistics used in the model output analysis.

- **get_prev.net**: calculates the number in each disease state (susceptible, infected, recovered) at each time step for those active nodes in the network. If the `epi.by` control is used, it calculates these statistics by a set of specified nodal attributes.
- **verbose.net**: summarizes the current state of the simulation and prints this to the console.
mutate_epi

Add New Epidemiology Variables

Description

Inspired by dplyr::mutate, mutate_epi adds new variables to the epidemiological and related variables within simulated model objects of any class in EpiModel.

Usage

```r
mutate_epi(x, ...)
```

Arguments

- `x`: An EpiModel object of class dcm, icm, or netsim.
- `...`: Name-value pairs of expressions (see examples below).

Examples

```r
# DCM example
param <- param.dcm(inf.prob = 0.2, act.rate = 0.25)
init <- init.dcm(s.num = 500, i.num = 1)
control <- control.dcm(type = "SI", nsteps = 500)
mod1 <- dcm(param, init, control)
mod1 <- mutate_epi(mod1, prev = i.num/num)
plot(mod1, y = "prev")

# Network model example
nw <- network.initialize(n = 100, bipartite = 50, directed = FALSE)
formation <- ~edges
target.stats <- 50
coef.diss <- dissolusion_coefs(dissolution = ~offset(edges), duration = 20)
est1 <- netest(nw, formation, target.stats, coef.diss, verbose = FALSE)

param <- param.net(inf.prob = 0.3, inf.prob.m2 = 0.15)
init <- init.net(i.num = 1, i.num.m2 = 0)
control <- control.net(type = "SI", nsteps = 10, nsims = 3, verbose = FALSE)
mod1 <- netsim(est1, param, init, control)
mod1

# Add the prevalences to the dataset
mod1 <- mutate_epi(mod1, i.prev = i.num / num,
                   i.prev.m2 = i.num.m2 / num.m2)
plot(mod1, y = c("i.prev", "i.prev.m2"), qnts = 0.5, legend = TRUE)

# Add incidence rate per 100 person years (assume time step = 1 week)
mod1 <- mutate_epi(mod1, irr100 = 5200*(si.flow + si.flow.m2) / (s.num + s.num.m2))
```
Dynamic Network Model Diagnostics

Description

Runs dynamic diagnostics on an ERGM/STERGM estimated through netest.

Usage

netdx(x, nsims = 1, dynamic = TRUE, nsteps,
      nwstats.formula = "formation", set.control.ergm, set.control.stergm,
      sequential = TRUE, keep.tedgelist = FALSE, keep.tnetwork = FALSE,
      verbose = TRUE, ncores = 1)

Arguments

x An EpiModel object of class netest.
nsims Number of simulations to run.
dynamic If TRUE, runs dynamic diagnostics. If FALSE and the netest object was fit with
         the Edges Dissolution approximation method, simulates from the static ERGM
         fit.
nsteps Number of time steps per simulation (dynamic simulations only).

set.control.ergm Control arguments passed to simulate.ergm (see details).
set.control.stergm Control arguments passed to simulate.stergm (see details).
sequential For static diagnostics (dynamic=FALSE): if FALSE, each of the nsims simulated
            Markov chains begins at the initial network; If TRUE, the end of one simulation
            is used as the start of the next.

keep.tedgelist If TRUE, keep the timed edgelist generated from the dynamic simulations. Re-
                  turned in the form of a list of matrices, with one entry per simulation. Accessible
                  at $tedgelist.
keep.tnetwork If TRUE, keep the full networkDynamic objects from the dynamic simulations.
               Returned in the form of a list of nD objects, with one entry per simulation. Accessible
               at $tnetwork.
verbose Print progress to the console.
ncores Number of processor cores to run multiple simulations on, using the foreach
         and doParallel implementations.
Details

The netdx function handles dynamic network diagnostics for network models fit with the netest function. Given the fitted model, netdx simulates a specified number of dynamic networks for a specified number of time steps per simulation. The network statistics in nwstats.formula are saved for each time step. Summary statistics for the formation model terms, as well as dissolution model and relational duration statistics, are then calculated and can be accessed when printing or plotting the netdx object.

Control Arguments

Models fit with the full STERGM method in netest (setting edapprox argument to FALSE) require only a call to simulate.stergm. Control parameters for those simulations may be set using set.control.stergm in netdx. The parameters should be input through the control.simulate.stergm() function, with the available parameters listed in the control.simulate.stergm help page in the tergm package.

Models fit with the ERGM method with the edges dissolution approximation (setting edapprox to TRUE) require a call first to simulate.ergm for simulating an initial network, and second to simulate.network for simulating that static network forward through time. Control parameters may be set for both processes in netdx. For the first, the parameters should be input through the control.simulate.ergm() function, with the available parameters listed in the control.simulate.ergm help page in the ergm package. For the second, parameters should be input through the control.simulate.network() function, with the available parameters listed in the control.simulate.network help page in the tergm package. An example is shown below.

See Also

Plot these model diagnostics with plot.netdx.

Examples

```r
# Not run:
# Network initialization and model parameterization
nw <- network.initialize(100, directed = FALSE)
formation <- ~edges
target.stats <- 50
coeff.diss <- dissolution_coefs(dissolution = ~offset(edges), duration = 25)

# Estimate the model
est <- netest(nw, formation, target.stats, coeff.diss, verbose = FALSE)

# Static diagnostics on the ERGM fit
dx1 <- netdx(est, nsims = 1e4, dynamic = FALSE,
             nwstats.formula = ~edges + meandeg + concurrent)
dx1
plot(dx1, method = "b", stats = c("edges", "concurrent"))

# Dynamic diagnostics on the STERGM approximation
dx2 <- netdx(est, nsims = 5, nsteps = 500,
              nwstats.formula = ~edges + meandeg + concurrent,
              set.control.ergm = control.simulate.ergm(MCMC.burnin = 1e6))
```
netest

Dynamic Network Model Estimation

Description

Estimates statistical network models using the exponential random graph modeling (ERGM) framework with extensions for dynamic/temporal models (STERGM).

Usage

netest(nw, formation, target.stats, coef.diss, constraints, 
   coef.form = NULL, edapprox = TRUE, set.control.ergm, 
   set.control.stergm, verbose = FALSE)

Arguments

nw An object of class network.
formation Right-hand sided STERGM formation formula in the form ~edges + ..., where ... are additional network statistics.
target.stats Vector of target statistics for the formation model, with one number for each network statistic in the model.
coef.diss An object of class disscoef output from the dissolution_coefs function.
constraints Right-hand sided formula specifying constraints for the modeled network, in the form ~..., where ... are constraint terms. By default, no constraints are set.
coef.form Vector of coefficients for the offset terms in the formation formula.
edapprox If TRUE, use the indirect edges dissolution approximation method for the dynamic model fit, otherwise use the more time-intensive full STERGM estimation (see details).
set.control.ergm Control arguments passed to simulate.ergm (see details).
set.control.stergm Control arguments passed to simulate.stergm (see details).
verbose Print model fitting progress to console.
Details

`netest` is a wrapper function for the `ergm` and `stergm` functions that estimate static and dynamic network models, respectively. Network model estimation is the first step in simulating a stochastic network epidemic model in `epimodel`. The output from `netest` is a necessary input for running the epidemic simulations in `netsim`. With a fitted network model, one should always first proceed to model diagnostics, available through the `netdx` function, to check model fit. A detailed description of fitting these models, along with examples, may be found in the Basic Network Models tutorial.

Edges Dissolution Approximation

The edges dissolution approximation method is described in Carnegie et al. This approximation requires that the dissolution coefficients are known, that the formation model is being fit to cross-sectional data conditional on those dissolution coefficients, and that the terms in the dissolution model are a subset of those in the formation model. Under certain additional conditions, the formation coefficients of a STERGM model are approximately equal to the coefficients of that same model fit to the observed cross-sectional data as an ERGM, minus the corresponding coefficients in the dissolution model. The approximation thus estimates this ERGM (which is typically much faster than estimating a STERGM) and subtracts the dissolution coefficients.

The conditions under which this approximation best hold are when there are few relational changes from one time step to another; i.e. when either average relational durations are long, or density is low, or both. Conveniently, these are the same conditions under which STERGM estimation is slowest. Note that the same approximation is also used to obtain starting values for the STERGM estimate when the latter is being conducted. The estimation does not allow for calculation of standard errors, p-values, or likelihood for the formation model; thus, this approach is of most use when the main goal of estimation is to drive dynamic network simulations rather than to conduct inference on the formation model. The user is strongly encouraged to examine the behavior of the resulting simulations to confirm that the approximation is adequate for their purposes. For an example, see the vignette for the package `tergm`.

Control Arguments

The `ergm` and `stergm` functions allow control settings for the model fitting process. When fitting a STERGM directly (setting `edapprox` to `FALSE`), control parameters may be passed to the `stergm` function with the `set.control.stergm` argument in `netest`. The controls should be input through the `control.stergm()` function, with the available parameters listed in the `control.stergm` help page in the `tergm` package.

When fitting a STERGM indirectly (setting `edapprox` to `TRUE`), control settings may be passed to the `ergm` function using `set.control.ergm` in `netest`. The controls should be input through the `control.ergm()` function, with the available parameters listed in the `control.ergm` help page in the `ergm` package. An example is below.

References


See Also

Use `netdx` to diagnose the fitted network model, and `netsim` to simulate epidemic spread over a simulated dynamic network consistent with the model fit.

Examples

```r
# Initialize a network of 100 nodes
nw <- network.initialize(n = 100, directed = FALSE)

# Set formation formula
formation <- ~edges + concurrent

# Set target statistics for formation
target.stats <- c(50, 25)

# Obtain the offset coefficients
coef.diss <- dissolution_coefs(dissolution = ~offset(edges), duration = 10)

# Estimate the STERGM using the edges dissolution approximation
est <- netest(nw, formation, target.stats, coef.diss,
              set.control.ergm = control.ergm(MCMC.burnin = 1e5,
                                             MCMC.interval = 1000))

est

# To estimate the STERGM directly, use edapprox = FALSE
# est2 <- netest(nw, formation, target.stats, coef.diss, edapprox = FALSE)
```

netsim

### Stochastic Network Models

Simulates stochastic network epidemic models for infectious disease.

#### Usage

```r
netsim(x, param, init, control)
```

#### Arguments

- `x`  Fitted network model object, as an object of class `netest`. Alternatively, if restarting a previous simulation, may be an object of class `netsim`.
- `param` Model parameters, as an object of class `param.net`.
- `init` Initial conditions, as an object of class `init.net`.
- `control` Control settings, as an object of class `control.net`.
Details

Stochastic network models explicitly represent phenomena within and across edges (pairs of nodes that remain connected) over time. This enables edges to have duration, allowing for repeated transmission-related acts within the same dyad, specification of edge formation and dissolution rates, control over the temporal sequencing of multiple edges, and specification of network-level features. A detailed description of these models, along with examples, is found in the Basic Network Models tutorial.

The netsim function performs modeling of both the base model types and original models. Base model types include one-mode and bipartite models with disease types for Susceptible-Infected (SI), Susceptible-Infected-Recovered (SIR), and Susceptible-Infected-Susceptible (SIS).

Original models may be parameterized by writing new process modules that either take the place of existing modules (for example, disease recovery), or supplement the set of existing processes with a new one contained in a new module. This functionality is documented in the Solving New Network Models tutorial. The list of modules within netsim available for modification is listed in modules.net.

Value

A list of class netsim with the following elements:

- **param**: the epidemic parameters passed into the model through param, with additional parameters added as necessary.
- **control**: the control settings passed into the model through control, with additional controls added as necessary.
- **epi**: a list of data frames, one for each epidemiological output from the model. Outputs for base models always include the size of each compartment, as well as flows in, out of, and between compartments.
- **stats**: a list containing two sublists, nwstats for any network statistics saved in the simulation, and transmat for the transmission matrix saved in the simulation. See control.net and the Tutorial for further details.
- **network**: a list of networkDynamic objects (or network objects if delete.nodes was set to TRUE), one for each model simulation.

References


See Also

Extract the model results with as.data.frame.netsim. Summarize the time-specific model results with summary.netsim. Plot the model results with plot.netsim.

Examples

```r
## Not run:
## Example 1: Independent SI Model
```
# Network model estimation
nw <- network.initialize(n = 100, bipartite = 50, directed = FALSE)
formation <- ~edges
target.stats <- 50
coeff.diss <- dissolution_coefs(dissolution = ~offset(edges), duration = 20)
est1 <- netest(nw, formation, target.stats, coeff.diss, verbose = FALSE)

# Epidemic model
param <- param.net(inf.prob = 0.3, inf.prob.m2 = 0.15)
init <- init.net(i.num = 10, i.num.m2 = 10)
control <- control.net(type = "SI", nsteps = 100, nsims = 5, verbose.int = 0)
mod1 <- netsim(est1, param, init, control)

# Print, plot, and summarize the results
mod1
plot(mod1)
summary(mod1, at = 50)

## Example 2: Dependent SIR Model
# Recalculate dissolution coefficient with departure rate
coeff.diss <- dissolution_coefs(dissolution = ~offset(edges), duration = 20,
d.rate = 0.0021)

# Reestimate the model with new coefficient
est2 <- netest(nw, formation, target.stats, coeff.diss, verbose = FALSE)

# Reset parameters to include demographic rates
param <- param.net(inf.prob = 0.3, inf.prob.m2 = 0.15,
rec.rate = 0.02, rec.rate.m2 = 0.02,
a.rate = 0.002, a.rate.m2 = NA,
ds.rate = 0.001, ds.rate.m2 = 0.001,
di.rate = 0.001, di.rate.m2 = 0.001,
dr.rate = 0.001, dr.rate.m2 = 0.001)
init <- init.net(i.num = 10, i.num.m2 = 10,
r.num = 0, r.num.m2 = 0)
control <- control.net(type = "SIR", nsteps = 100, nsims = 5)

# Simulate the model with new network fit
mod2 <- netsim(est2, param, init, control)

# Print, plot, and summarize the results
mod2
plot(mod2)
summary(mod2, at = 100)

## End(Not run)
Description

Sets the epidemic parameters for deterministic compartmental models simulated with dcm.

Usage

```
param.dcm(inf.prob, inter.eff, inter.start, act.rate, rec.rate, a.rate, 
           ds.rate, di.rate, dr.rate, inf.prob.g2, act.rate.g2, rec.rate.g2, 
           a.rate.g2, ds.rate.g2, di.rate.g2, dr.rate.g2, balance, ...)
```

Arguments

- `inf.prob`  Probability of infection per transmissible act between a susceptible and an infected person. In two-group models, this is the probability of infection for the group 1 members.
- `inter.eff` Efficacy of an intervention which affects the per-act probability of infection. Efficacy is defined as 1 - the relative hazard of infection given exposure to the intervention, compared to no exposure.
- `inter.start` Time step at which the intervention starts, between 1 and the number of time steps specified in the model. This will default to 1 if the `inter.eff` is defined but this parameter is not.
- `act.rate`  Average number of transmissible acts per person per unit time. For two-group models, this is the number of acts per group 1 persons per unit time; a balance between the acts in groups 1 and 2 is necessary, and set using the balance parameter (see details).
- `rec.rate`  Average rate of recovery with immunity (in SIR models) or re-susceptibility (in SIS models). The recovery rate is the reciprocal of the disease duration. For two-group models, this is the recovery rate for group 1 persons only. This parameter is only used for SIR and SIS models.
- `a.rate`   Arrival or entry rate. For one-group models, the arrival rate is the rate of new arrivals per person per unit time. For two-group models, the arrival rate may be parameterized as a rate per group 1 person time (with group 1 persons representing females), and with the `a.rate.g2` rate set as described below.
- `ds.rate`  Departure or exit rate for susceptible. For two-group models, it is the rate for the group 1 susceptible only.
- `di.rate`  Departure or exit rate for infected. For two-group models, it is the rate for the group 1 infected only.
- `dr.rate`  Departure or exit rate for recovered. For two-group models, it is the rate for the group 1 recovered only. This parameter is only used for SIR models.
- `inf.prob.g2` Probability of infection per transmissible act between a susceptible group 2 person and an infected group 1 person. It is the probability of infection to group 2 members.
- `act.rate.g2` Average number of transmissible acts per group 2 person per unit time; a balance between the acts in groups 1 and 2 is necessary, and set using the balance parameter (see details).
rec.rate.g2  Average rate of recovery with immunity (in SIR models) or re-susceptibility (in SIS models) for group 2 persons. This parameter is only used for two-group SIR and SIS models.

a.rate.g2  Arrival or entry rate for group 2. This may either be specified numerically as the rate of new arrivals per group 2 persons per unit time, or as NA in which case the group 1 rate, a.rate, governs the group 2 rate. The latter is used when, for example, the first group is conceptualized as female, and the female population size determines the arrival rate. Such arrivals are evenly allocated between the two groups.

d.s.rate.g2  Departure or exit rate for group 2 susceptible.

di.rate.g2  Departure or exit rate for group 2 infected.

dr.rate.g2  Departure or exit rate for group 2 recovered. This parameter is only used for SIR model types.

balance  For two-group models, balance the act.rate to the rate set for group 1 (with balance="g1") or group 2 (with balance="g2"). See details.

...  Additional arguments passed to model.

Details

`param.dcm` sets the epidemic parameters for deterministic compartmental models solved with the `dcm` function. The models may use the base types, for which these parameters are used, or original model specifications for which these parameters may be used (but not necessarily). A detailed description of DCM parameterization for base models is found in the Basic DCMs tutorial.

For base models, the model specification will be selected as a function of the model parameters entered here and the control settings in `control.dcm`. One-group and two-group models are available, where the former assumes a homogenous mixing in the population and the latter assumes a purely heterogenous mixing between two distinct partitions in the population (e.g., men and women). Specifying any group two parameters (those with a .g2) implies the simulation of a two-group model. All the parameters for a desired model type must be specified, even if they are zero.

Act Balancing

In two-group models, a balance between the number of acts for group 1 members and those for group 2 members must be maintained. With purely heterogenous mixing, the product of one group size and act rate must equal the product of the other group size and act rate: $N_1\alpha_1 = N_2\alpha_2$, where $N_i$ is the group size and $\alpha_i$ the group-specific act rates at time $t$. The balance parameter here specifies which group’s act rate should control the others with respect to balancing. See the Basic DCMs tutorial for further details.

Sensitivity Analyses

doctr.dcm has been designed to easily run DCM sensitivity analyses, where a series of models varying one or more of the model parameters is run. This is possible by setting any parameter as a vector of length greater than one. See both the example below and the Basic DCMs tutorial.
New Model Types

To build original model specifications outside of the base models, start by consulting the Solving New DCMs with EpiModel tutorial. Briefly, an original model may use either the existing model parameters named here, an original set of parameters, or a combination of both. The \ldots argument allows the user to pass an arbitrary set of new model parameters into `param.dcm`. Whereas there are strict checks for base models that the model parameters are valid, parameter validity is the user’s responsibility with these original models.

See Also

Use `init.dcm` to specify the initial conditions and `control.dcm` to specify the control settings. Run the parameterized model with `dcm`.

\begin{quote}
\textbf{Description}

Sets the epidemic parameters for stochastic individual contact models simulated with `icm`.
\end{quote}

\begin{quote}
\textbf{Usage}

`param.icm(inf.prob, inter.eff, inter.start, act.rate, rec.rate, a.rate, 
  ds.rate, di.rate, dr.rate, inf.prob.g2, act.rate.g2, rec.rate.g2, 
  a.rate.g2, ds.rate.g2, di.rate.g2, dr.rate.g2, balance, \ldots)`
\end{quote}

\begin{quote}
\textbf{Arguments}

\begin{itemize}
  \item \texttt{inf.prob} Probability of infection per transmissible act between a susceptible and an infected person. In two-group models, this is the probability of infection for the group 1 members.
  \item \texttt{inter.eff} Efficacy of an intervention which affects the per-act probability of infection. Efficacy is defined as $1 - \text{the relative hazard of infection given exposure to the intervention, compared to no exposure}$.
  \item \texttt{inter.start} Time step at which the intervention starts, between 1 and the number of time steps specified in the model. This will default to 1 if the \texttt{inter.eff} is defined but this parameter is not.
  \item \texttt{act.rate} Average number of transmissible acts per person per unit time. For two-group models, this is the number of acts per group 1 persons per unit time; a balance between the acts in groups 1 and 2 is necessary, and set using the \texttt{balance} parameter (see details).
  \item \texttt{rec.rate} Average rate of recovery with immunity (in SIR models) or re-susceptibility (in SIS models). The recovery rate is the reciprocal of the disease duration. For two-group models, this is the recovery rate for group 1 persons only. This parameter is only used for SIR and SIS models.
\end{itemize}
\end{quote}
param.icm

a.rate Arrival or entry rate. For one-group models, the arrival rate is the rate of new arrivals per person per unit time. For two-group models, the arrival rate may be parameterized as a rate per group 1 person time (with group 1 persons representing females), and with the a.rate.g2 rate set as described below.

ds.rate Departure or exit rate for susceptible. For two-group models, it is the rate for the group 1 susceptible only.

di.rate Departure or exit rate for infected. For two-group models, it is the rate for the group 1 infected only.

dr.rate Departure or exit rate for recovered. For two-group models, it is the rate for the group 1 recovered only. This parameter is only used for SIR models.

inf.prob.g2 Probability of infection per transmissible act between a susceptible group 2 person and an infected group 1 person. It is the probability of infection to group 2 members.

act.rate.g2 Average number of transmissible acts per group 2 person per unit time; a balance between the acts in groups 1 and 2 is necessary, and set using the balance parameter (see details).

rec.rate.g2 Average rate of recovery with immunity (in SIR models) or re-susceptibility (in SIS models) for group 2 persons. This parameter is only used for two-group SIR and SIS models.

a.rate.g2 Arrival or entry rate for group 2. This may either be specified numerically as the rate of new arrivals per group 2 persons per unit time, or as NA in which case the group 1 rate, a.rate, governs the group 2 rate. The latter is used when, for example, the first group is conceptualized as female, and the female population size determines the arrival rate. Such arrivals are evenly allocated between the two groups.

ds.rate.g2 Departure or exit rate for group 2 susceptible.

di.rate.g2 Departure or exit rate for group 2 infected.

dr.rate.g2 Departure or exit rate for group 2 recovered. This parameter is only used for SIR model types.

balance For two-group models, balance the act.rate to the rate set for group 1 (with balance="g1") or group 2 (with balance="g2"). See details.

... Additional arguments passed to model.

Details

param.icm sets the epidemic parameters for the stochastic individual contact models simulated with the icm function. Models may use the base types, for which these parameters are used, or new process modules which may use these parameters (but not necessarily). A detailed description of ICM parameterization for base models is found in the Basic ICMs tutorial.

For base models, the model specification will be chosen as a result of the model parameters entered here and the control settings in control.icm. One-group and two-group models are available, where the former assumes a homogenous mixing in the population and the latter assumes a purely heterogenous mixing between two distinct partitions in the population (e.g., men and women). Specifying any group two parameters (those with a .g2) implies the simulation of a two-group model. All the parameters for a desired model type must be specified, even if they are zero.
Act Balancing

In two-group models, a balance between the number of acts for group 1 members and those for group 2 members must be maintained. With purely heterogeneous mixing, the product of one group size and act rate must equal the product of the other group size and act rate: $N_1 \alpha_1 = N_2 \alpha_2$, where $N_i$ is the group size and $\alpha_i$ the group-specific act rates at time $t$. The balance parameter here specifies which group’s act rate should control the others with respect to balancing. See the Basic DCMs tutorial.

New Modules

To build original models outside of the base models, new process modules may be constructed to replace the existing modules or to supplement the existing set. These are passed into the control settings in control.icm. New modules may use either the existing model parameters named here, an original set of parameters, or a combination of both. The . . . allows the user to pass an arbitrary set of original model parameters into param.icm. Whereas there are strict checks with default modules for parameter validity, these checks are the user’s responsibility with new modules.

See Also

Use init.icm to specify the initial conditions and control.icm to specify the control settings. Run the parameterized model with icm.

param.net

Epidemic Parameters for Stochastic Network Models

Description

Sets the epidemic parameters for stochastic network models simulated with netsim.

Usage

```
param.net(inf.prob, inter.eff, inter.start, act.rate, rec.rate, a.rate,
          ds.rate, di.rate, dr.rate, inf.prob.m2, rec.rate.m2, a.rate.m2,
          ds.rate.m2, di.rate.m2, dr.rate.m2, . . .)
```

Arguments

- `inf.prob`: Probability of infection per transmissible act between a susceptible and an infected person. In bipartite models, this is the probability of infection to the mode 1 nodes. This may also be a vector of probabilities, with each element corresponding to the probability in that time step of infection (see Time-Varying Parameters below).
- `inter.eff`: Efficacy of an intervention which affects the per-act probability of infection. Efficacy is defined as 1 - the relative hazard of infection given exposure to the intervention, compared to no exposure.
inter.start  Time step at which the intervention starts, between 1 and the number of time steps specified in the model. This will default to 1 if the inter.eff is defined but this parameter is not.

act.rate  Average number of transmissible acts per partnership per unit time (see act.rate Parameter below). This may also be a vector of rates, with each element corresponding to the rate in that time step of infection (see Time-Varying Parameters below).

rec.rate  Average rate of recovery with immunity (in SIR models) or re-susceptibility (in SIS models). The recovery rate is the reciprocal of the disease duration. For bipartite models, this is the recovery rate for mode 1 persons only. This parameter is only used for SIR and SIS models. This may also be a vector of rates, with each element corresponding to the rate in that time step of infection (see Time-Varying Parameters below).

a.rate  Arrival or entry rate. For one-mode models, the arrival rate is the rate of new arrivals per person per unit time. For bipartite models, the arrival rate may be parameterized as a rate per mode 1 person time (with mode 1 persons representing females), and with the a.rate.g2 rate as described below.

ds.rate  Departure or exit rate for susceptible. For bipartite models, it is the rate for the mode 1 susceptible only.

di.rate  Departure or exit rate for infected. For bipartite models, it is the rate for the mode 1 infected only.

dr.rate  Departure or exit rate for recovered. For bipartite models, it is the rate for the mode 1 recovered only. This parameter is only used for SIR models.

inf.prob.m2  Probability of transmission given a transmissible act between a susceptible mode 2 person and an infected mode 1 person. It is the probability of transmission to mode 2 members.

rec.rate.m2  Average rate of recovery with immunity (in SIR models) or re-susceptibility (in SIS models) for mode 2 persons. This parameter is only used for bipartite SIR and SIS models.

a.rate.m2  Arrival or entry rate for mode 2. This may either be specified numerically as the rate of new arrivals per mode 2 persons per unit time, or as NA in which case the mode 1 rate, a.rate, governs the mode 2 rate. The latter is used when, for example, the first mode is conceptualized as female, and the female population size determines the arrival rate. Such arrivals are evenly allocated between the two modes.

ds.rate.m2  Departure or exit rate for mode 2 susceptible.

di.rate.m2  Departure or exit rate for mode 2 infected.

dr.rate.m2  Departure or exit rate for mode 2 recovered. This parameter is only used for SIR model types.

...  Additional arguments passed to model.

Details

param.net sets the epidemic parameters for the stochastic network models simulated with the netsim function. Models may use the base types, for which these parameters are used, or new
process modules which may use these parameters (but not necessarily). A detailed description of network model parameterization for base models is found in the Basic Network Models tutorial.

For base models, the model specification will be chosen as a result of the model parameters entered here and the control settings in control.net. One-mode and two-mode models are available, where the latter assumes a heterogeneous mixing between two distinct partitions in the population (e.g., men and women). Specifying any bipartite parameters (those with a \(N_{R}^{M2}\)) implies the simulation of a bipartite model. All the parameters for a desired model type must be specified, even if they are zero.

The **act.rate** Parameter

A key difference between these network models and DCM/ICM classes is the treatment of transmission events. With DCM and ICM, contacts or partnerships are mathematically instantaneous events: they have no duration in time, and thus no changes may occur within them over time. In contrast, network models allow for partnership durations defined by the dynamic network model, summarized in the model dissolution coefficients calculated in dissolution_coefs. Therefore, the act.rate parameter has a different interpretation here, where it is the number of transmissible acts *per partnership* per unit time.

Time-Varying Parameters

The inf.prob, act.rate, rec.rate arguments (and their \(m2\) companions) may be specified as time-varying parameters by passing in a vector of probabilities or rates, respectively. The value in each position on the vector then corresponds to the probability or rate at that discrete time step for the infected partner. For example, an inf.prob of \(c(0.5, 0.5, 0.1)\) would simulate a 0.5 transmission probability for the first two time steps of a person's infection, followed by a 0.1 for the third time step. If the infected person has not recovered or exited the population by the fourth time step, the third element in the vector will carry forward until one of those events occurs or the simulation ends. For further examples, see the NME tutorial, Time-Varying Biology & Behavior.

New Modules

To build original models outside of the base models, new process modules may be constructed to replace the existing modules or to supplement the existing set. These are passed into the control settings in control.net. New modules may use either the existing model parameters named here, an original set of parameters, or a combination of both. The ... allows the user to pass an arbitrary set of original model parameters into param.net. Whereas there are strict checks with default modules for parameter validity, these checks are the user's responsibility with new modules.

See Also

Use init.net to specify the initial conditions and control.net to specify the control settings. Run the parameterized model with netsim.
plot.dcm

Plot Data from a Deterministic Compartmental Epidemic Model

Description

Plots epidemiological data from a deterministic compartment epidemic model solved with dcm.

Usage

```r
## S3 method for class 'dcm'
plot(x, y, popfrac = FALSE, run, col, lwd, lty,
     alpha = 0.9, legend, leg.name, leg.cex = 0.8, axs = "r",
     grid = FALSE, add = FALSE, ...)
```

Arguments

- `x`: An EpiModel object of class dcm.
- `y`: Output compartments or flows from dcm object to plot.
- `popfrac`: If TRUE, plot prevalence of values rather than numbers (see details).
- `run`: Run number to plot, for models with multiple runs (default is run 1).
- `col`: Color for lines, either specified as a single color in a standard R color format, or alternatively as a color palette from RColorBrewer (see details).
- `lwd`: Line width for output lines.
- `lty`: Line type for output lines.
- `alpha`: Transparency level for lines, where 0 = transparent and 1 = opaque (see transco).
- `legend`: Type of legend to plot. Values are "n" for no legend, "full" for full legend, and "lim" for limited legend (see details).
- `leg.name`: Character string to use for legend, with the default determined automatically based on the y input.
- `leg.cex`: Legend scale size.
- `axs`: Plot axis type (see par for details), with default of "r".
- `grid`: If TRUE, a grid is added to the background of plot (see grid for details), with default of nx by ny.
- `add`: If TRUE, new plot window is not called and lines are added to existing plot window.
- `...`: Additional arguments to pass to main plot window (see plot.default).

Details

This function plots epidemiological outcomes from a deterministic compartmental model solved with dcm. Depending on the number of model runs (sensitivity analyses) and number of groups, the default plot is the fractional proportion of each compartment in the model over time. The specific compartments or flows to plot may be set using the y parameter, and in multiple run models the specific run may also be specified.
The `popfrac` Argument

Compartment prevalences are the size of a compartment over some denominator. To plot the raw numbers from any compartment, use `popfrac=FALSE`; this is the default. The `popfrac` parameter calculates and plots the denominators of all specified compartments using these rules: 1) for one-group models, the prevalence of any compartment is the compartment size divided by the total population size; 2) for two-group models, the prevalence of any compartment is the compartment size divided by the group size.

Color Palettes

Since `dcm` supports multiple run sensitivity models, plotting the results of such models uses a complex color scheme for distinguishing runs. This is accomplished using the `RColorBrewer` color palettes, which include a range of linked colors using named palettes. For `plot.dcm`, one may either specify a brewer color palette listed in `brewer.pal.info`, or, alternatively, a vector of standard R colors (named, hexadecimal, or positive integers; see `col2rgb`).

Plot Legends

There are three automatic legend types available, and the legend is added by default for plots. To turn off the legend, use `legend="n"`. To plot a legend with values for every line in a sensitivity analysis, use `legend="full"`. With models with many runs, this may be visually overwhelming. In those cases, use `legend="lim"` to plot a legend limited to the highest and lowest values of the varying parameter in the model. In cases where the default legend names are not helpful, one may override those names with the `leg.name` argument.

See Also

dcm, brewer.pal.info

Examples

```r
# Deterministic SIR model with varying act rate
param <- param.dcm(inf.prob = 0.2, act.rate = 1:10,
                   rec.rate = 1/3, a.rate = 0.011, ds.rate = 0.01,
                   di.rate = 0.03, dr.rate = 0.01)
init <- init.dcm(s.num = 1000, i.num = 1, r.num = 0)
control <- control.dcm(type = "SIR", nsteps = 100, dt = 0.25)
mod <- dcm(param, init, control)

# Plot disease prevalence by default
plot(mod)

# Plot prevalence of susceptibles
plot(mod, y = "s.num", popfrac = TRUE, col = "Greys")

# Plot number of susceptibles
plot(mod, y = "s.num", popfrac = FALSE, col = "Greys", grid = TRUE)

# Plot multiple runs of multiple compartments together
plot(mod, y = c("s.num", "i.num"),
```
run = 5, xlim = c(0, 50), grid = TRUE)
plot(mod, y = c("s.num", "i.num"),
     run = 10, lty = 2, legend = "n", add = TRUE)

plot.icm Plot Data from a Stochastic Individual Contact Epidemic Model

Description

Plots epidemiological data from a stochastic individual contact model simulated with icm.

Usage

## S3 method for class 'icm'
plot(x, y, popfrac = FALSE, sim.lines = FALSE, sims,
     sim.col, sim.lwd, sim.alpha, mean.line = TRUE, mean.smooth = TRUE,
     mean.col, mean.lwd = 2, mean.lty = 1, qnts = 0.5, qnts.col,
     qnts.alpha, qnts.smooth = TRUE, legend, leg.cex = 0.8, axs = "r",
     grid = FALSE, add = FALSE, ...)  

Arguments

x An EpiModel model object of class netsim.
y Output compartments or flows from icm object to plot.
popfrac If TRUE, plot prevalence of values rather than numbers (see details).
sim.lines If TRUE, plot individual simulation lines. Default is to plot lines for one-group models but not for two-group models.
sims If type="epi" or "formation", a vector of simulation numbers to plot. If type="network", a single simulation number for network plot, or else "min" to plot the simulation number with the lowest disease prevalence, "max" for the simulation with the highest disease prevalence, or "mean" for the simulation with the prevalence closest to the mean across simulations at the specified time step.
sim.col Vector of any standard R color format for simulation lines.
sim.lwd Line width for simulation lines.
sim.alpha Transparency level for simulation lines, where 0 = transparent and 1 = opaque (see transco).
mean.line If TRUE, plot mean of simulations across time.
mean.smooth If TRUE, use a lowess smoother on the mean line.
mean.col Vector of any standard R color format for mean lines.
mean.lwd Line width for mean lines.
mean.lty Line type for mean lines.
qnts
If numeric, plot polygon of simulation quantiles based on the range implied by the argument (see details). If FALSE, suppress polygon from plot.

qnts.col
Vector of any standard R color format for polygons.

qnts.alpha
Transparency level for quantile polygons, where 0 = transparent and 1 = opaque (see transco).

qnts.smooth
If TRUE, use a lowess smoother on quantile polygons.

legend
If TRUE, plot default legend.

leg.cex
Legend scale size.

axs
Plot axis type (see par for details), with default to "r".

grid
If TRUE, a grid is added to the background of plot (see grid for details), with default of nx by ny.

add
If TRUE, new plot window is not called and lines are added to existing plot window.

... additional arguments to pass.

See Also

icm

Examples

## Example 1: Plotting multiple compartment values from SIR model
param <- param.icm(inf.prob = 0.5, act.rate = 0.5, rec.rate = 0.02)
init <- init.icm(s.num = 500, i.num = 1, r.num = 0)
control <- control.icm(type = "SIR", nsteps = 100,
                       nsims = 3, verbose = FALSE)
mod <- icm(param, init, control)
plot(mod, grid = TRUE)

## Example 2: Plot only infected with specific output from SI model
param <- param.icm(inf.prob = 0.25, act.rate = 0.25)
init <- init.icm(s.num = 500, i.num = 10)
control <- control.icm(type = "SI", nsteps = 100,
                       nsims = 3, verbose = FALSE)
mod2 <- icm(param, init, control)

# Plot prevalence
plot(mod2, y = "i.num", mean.line = FALSE, sim.lines = TRUE)

# Plot incidence
par(mfrow = c(1, 2))
plot(mod2, y = "si.flow", mean.smooth = TRUE, grid = TRUE)
plot(mod2, y = "si.flow", qnts.smooth = FALSE, qnts = 1)
Description

Plots dynamic network model diagnostics calculated in netdx.

Usage

```r
## S3 method for class 'netdx'
plot(x, type = "formation", method = "l", sims, stats,
sim.lines, sim.col, sim.lwd, mean.line = TRUE, mean.smooth = TRUE,
mean.col, mean.lwd = 2, mean.lty = 1, qnts = 0.5, qnts.col,
qnts.alpha, qnts.smooth = TRUE, targ.line = TRUE, targ.col,
targ.lwd = 2, targ.lty = 2, plots.joined, legend, grid = FALSE,
...)
```

Arguments

- `x` An EpiModel object of class `netdx`.
- `type` Plot type, with options of "formation" for network model formation statistics, "duration" for dissolution model statistics for average edge duration, or "dissolution" for dissolution model statistics for proportion of ties dissolved per time step.
- `method` Plot method, with options of "l" for line plots and "b" for boxplots.
- `sims` If `type="epi"` or "formation", a vector of simulation numbers to plot. If `type="network"`, a single simulation number for network plot, or else "min" to plot the simulation number with the lowest disease prevalence, "max" for the simulation with the highest disease prevalence, or "mean" for the simulation with the prevalence closest to the mean across simulations at the specified time step.
- `stats` Network statistics to plot, among those specified in the call to `netdx`, with the default to plot all statistics contained in the object.
- `sim.lines` If TRUE, plot individual simulation lines. Default is to plot lines for one-group models but not for two-group models.
- `sim.col` Vector of any standard R color format for simulation lines.
- `sim.lwd` Line width for simulation lines.
- `mean.line` If TRUE, plot mean of simulations across time.
- `mean.smooth` If TRUE, use a lowess smoother on the mean line.
- `mean.col` Vector of any standard R color format for mean lines.
- `mean.lwd` Line width for mean lines.
- `mean.lty` Line type for mean lines.
The plot function for netdx objects will generate plots of two types of model diagnostic statistics that run as part of the diagnostic tools within that function. The formation plot shows the summary statistics requested in nwstats.formula, where the default includes those statistics in the network model formation formula specified in the original call to netest.

The duration plot shows the average age of existing edges at each time step, up until the maximum time step requested. This is calculated with the edgelist_meanage function. The age is used as an estimator of the average duration of edges in the equilibrium state.

The dissolution plot shows the proportion of the extant ties that are dissolved at each time step, up until the maximum time step requested. Typically, the proportion of ties that are dissolved is the reciprocal of the mean relational duration. This plot thus contains similar information to that in the duration plot, but should reach its expected value more quickly, since it is not subject to censoring.

The plots.joined argument will control whether the statistics in the formation plot are joined in one plot or plotted separately. The default is based on the number of network statistics requested. The layout of the separate plots within the larger plot window is also based on the number of statistics.

See Also

netdx

Examples

## Not run:
# Network initialization and model parameterization
nw <- network.initialize(100, directed = FALSE)
nw <- set.vertex.attribute(nw, "sex", rbinom(100, 1, 0.5))
formation <- ~edges + nodematch("sex")
target.stats <- c(50, 40)
coef.diss <- dissolution_coefs(dissolution = ~offset(edges), duration = 50)

# Estimate the model
est <- netest(nw, formation, target.stats, coef.diss, verbose = FALSE)

# Static diagnostics
dx1 <- netdx(est, nsims = 1e4, dynamic = FALSE, 
    nwstats.formula = ~edges + meandeg + concurrent + 
        nodefactor("sex", base = 0) + 
        nodematch("sex"))
dx1

# Plot diagnostics
plot(dx1)
plot(dx1, stats = c("edges", "concurrent"), mean.col = "black", 
    sim.lines = TRUE, plots.joined = FALSE)
plot(dx1, stats = "edges", method = "b", 
    col = "seagreen3", grid = TRUE)

# Dynamic diagnostics
dx2 <- netdx(est, nsims = 10, nsteps = 500, 
    nwstats.formula = ~edges + meandeg + concurrent + 
        nodefactor("sex", base = 0) + 
        nodematch("sex"))
dx2

# Formation statistics plots, joined and separate
plot(dx2, grid = TRUE)
plot(dx2, type = "formation", plots.joined = TRUE)
plot(dx2, type = "formation", sims = 10, plots.joined = TRUE, 
    qnts = FALSE, sim.lines = TRUE, mean.line = FALSE)
plot(dx2, type = "formation", plots.joined = FALSE, 
    stats = c("edges", "concurrent"), grid = TRUE)

plot(dx2, method = "b", col = "bisque", grid = TRUE)
plot(dx2, method = "b", stats = "meandeg", col = "dodgerblue")

# Duration statistics plot
plot(dx2, type = "duration", mean.col = "black", grid = TRUE)
plot(dx2, type = "duration", sims = 10, mean.line = FALSE, sim.line = TRUE, 
    sim.col = "steelblue", sim.lwd = 3, targ.lty = 1, targ.lwd = 0.5)

# Dissolution statistics plot
plot(dx2, type = "dissolution", mean.col = "black", grid = TRUE)
plot(dx2, type = "dissolution", method = "b", col = "pink1")

## End(Not run)
Description

Plots epidemiological and network data from a stochastic network model simulated with \texttt{netsim}.

Usage

\begin{verbatim}
## S3 method for class 'netsim'
plot(x, type = "epi", y, popfrac = FALSE,
     sim.lines = FALSE, sims, sim.col, sim.lwd, sim.alpha,
     mean.line = TRUE, mean.smooth = TRUE, mean.col, mean.lwd = 2,
     mean.lty = 1, qnts = 0.5, qnts.col, qnts.alpha, qnts.smooth = TRUE,
     legend, leg.cex = 0.8, axs = "r", grid = FALSE, add = FALSE,
     network = 1, at = 1, col.status = FALSE, shp.bip = NULL, stats,
     targ.line = TRUE, targ.col, targ.lwd = 2, targ.lty = 2,
     plots.joined, ...)
\end{verbatim}

Arguments

- **x**: An \texttt{EpiModel} model object of class \texttt{netsim}.
- **type**: Type of plot: "epi" for epidemic model results, "network" for a static network plot (\texttt{plot.network}), or "formation" for network formation statistics.
- **y**: Output compartments or flows from \texttt{icm} object to plot.
- **popfrac**: If \texttt{TRUE}, plot prevalence of values rather than numbers (see details).
- **sim.lines**: If \texttt{TRUE}, plot individual simulation lines. Default is to plot lines for one-group models but not for two-group models.
- **sims**: If \texttt{type} = "epi" or "formation", a vector of simulation numbers to plot. If \texttt{type} = "network", a single simulation number for network plot, or else "min" to plot the simulation number with the lowest disease prevalence, "max" for the simulation with the highest disease prevalence, or "mean" for the simulation with the prevalence closest to the mean across simulations at the specified time step.
- **sim.col**: Vector of any standard R color format for simulation lines.
- **sim.lwd**: Line width for simulation lines.
- **sim.alpha**: Transparency level for simulation lines, where 0 = transparent and 1 = opaque (see \texttt{transco}).
- **mean.line**: If \texttt{TRUE}, plot mean of simulations across time.
- **mean.smooth**: If \texttt{TRUE}, use a lowess smoother on the mean line.
- **mean.col**: Vector of any standard R color format for mean lines.
- **mean.lwd**: Line width for mean lines.
- **mean.lty**: Line type for mean lines.
plot.netsim

qnts If numeric, plot polygon of simulation quantiles based on the range implied by the argument (see details). If FALSE, suppress polygon from plot.
qnts.col Vector of any standard R color format for polygons.
qnts.alpha Transparency level for quantile polygons, where 0 = transparent and 1 = opaque (see transco).
qnts.smooth If TRUE, use a lowess smoother on quantile polygons.
legend If TRUE, plot default legend.
leg.cex Legend scale size.
axs Plot axis type (see par for details), with default to "r".
grid If TRUE, a grid is added to the background of plot (see grid for details), with default of nx by ny.
add If TRUE, new plot window is not called and lines are added to existing plot window.
network Network number, for simulations with multiple networks representing the population.
at If type="network", time step for network graph.
col.status If TRUE and type="network", automatic disease status colors (blue = susceptible, red = infected, green = recovered).
shp.bip If type="network" and a bipartite simulation, shapes for the mode 2 vertices, with acceptable inputs of "triangle" and "square". Mode 1 vertices will be circles.
stats If type="formation", network statistics to plot, among those specified in nwstats.formula of control.net, with the default to plot all statistics.
targ.line If TRUE, plot target or expected value line for the statistic of interest.
targ.col Vector of standard R colors for target statistic lines, with default colors based on RColorBrewer color palettes.
targ.lwd Line width for the line showing the target statistic values.
targ.lty Line type for the line showing the target statistic values.
plots.joined If TRUE and type="formation", combine all target statistics in one plot, versus one plot per target statistic if FALSE.
... additional arguments to pass.

Details

This plot function can produce three types of plots with a stochastic network model simulated through netsim:

1. type="epi": epidemic model results (e.g., disease prevalence and incidence) may be plotted.
2. type="network": a static network plot will be generated. A static network plot of a dynamic network is a cross-sectional extraction of that dynamic network at a specific time point. This plotting function wraps the plot.network function in the network package. Consult the help page for plot.network for all of the plotting parameters. In addition, four plotting parameters specific to netsim plots are available: sim, at, col.status, and shp.bip.
3. type="formation": summary network statistics related to the network model formation are plotted. These plots are similar to the formation plots for netdx objects. When running a netsim simulation, one must specify there that save.nwstats=TRUE; the plot here will then show the network statistics requested explicitly in nwstats$formula, or will use the formation formula set in netest otherwise.

When type="epi", this plotting function will extract the epidemiological output from a model object of class netsim and plot the time series data of disease prevalence and other results. The summary statistics that the function calculates and plots are individual simulation lines, means of the individual simulation lines, and quantiles of those individual simulation lines. The mean line, toggled on with mean.line=TRUE is calculated as the row mean across simulations at each time step.

Compartment prevalences are the size of a compartment over some denominator. To plot the raw numbers from any compartment, use popfrac=FALSE; this is the default for any plots of flows. The popfrac parameter calculates and plots the denominators of all specified compartments using these rules: 1) for one-group models, the prevalence of any compartment is the compartment size divided by the total population size; 2) for two-group models, the prevalence of any compartment is the compartment size divided by the group population size. For any prevalences that are not automatically calculated, the mutate_epi may be used to add new variables to the netsim object to plot or analyze.

The quantiles show the range of outcome values within a certain specified quantile range. By default, the interquartile range is shown: that is the middle 50% of the data. This is specified by qnts=0.5. To show the middle 95% of the data, specify qnts=0.95. To toggle off the polygons where they are plotted by default, specify qnts=FALSE.

When type="network", this function will plot cross sections of the simulated networks at specified time steps. Because it is only possible to plot one time step from one simulation at a time, it is necessary to enter these in the at and sims parameters. To aide in visualizing representative and extreme simulations at specific time steps, the sims parameter may be set to "mean" to plot the simulation in which the disease prevalence is closest to the average across all simulations, "min" to plot the simulation in which the prevalence is lowest, and "max" to plot the simulation in which the prevalence is highest.

See Also

plot.network, mutate_epi

Examples

```r
## Independent SI Model
# Initialize network and set network model parameters
nw <- network.initialize(n = 100, bipartite = 50, directed = FALSE)
formation <- ~edges
target.stats <- 50
coeff.diss <- dissolution.coefs(dissolution = ~offset(edges), duration = 20)

# Estimate the network model
est <- netest(nw, formation, target.stats, coeff.diss, verbose = FALSE)

# Simulate the epidemic model
```
plot.transmat

Plot transmat infection tree in one of several styles

Description

Plots the infection tree described in a transmat object in one of several styles: phylogenetic tree, an un-rooted network, a hierarchical tree, or a transmissionTimeline.
Usage

```r
### S3 method for class 'transmat'
plot(x, style = c("phylo", "network", "transmissionTimeline"), ...)
```

Arguments

- `x`: A `transmat` object to be plotted
- `style`: Character name of plot style. One of "phylo", "network", or "transmissionTimeline"
- `...`: Additional plot arguments to be passed to lower-level plot functions (plot.network, plot.phylo, etc)

Details

The phylo plot requires the ape package. The ndtv::transmissionTimeline requires that the ndtv package is installed. All of the options are essentially wrappers to other plot calls with some appropriate preset arguments.

See Also

- `plot.network`, `plot.phylo`

---

**summary.dcm**

Summary Model Statistics

Description

Extracts and prints model statistics solved with dcm.

Usage

```r
### S3 method for class 'dcm'
summary(object, at, run = 1, digits = 3, ...)
```

Arguments

- `object`: An EpiModel object of class dcm.
- `at`: Time step for model statistics.
- `run`: Model run number, for dcm class models with multiple runs (sensitivity analyses).
- `digits`: Number of significant digits to print.
- `...`: Additional summary function arguments (not used).
Details

Summary statistics for the main epidemiological outcomes (state and transition size and prevalence) from an dcm model. Time-specific summary measures are provided, so it is necessary to input a time of interest. For multiple-run models (sensitivity analyses), input a model run number. See examples below.

See Also
dcm

Examples

```r
## Deterministic SIR model with varying act.rate
param <- param.dcm(inf.prob = 0.2, act.rate = 2/4, rec.rate = 1/3,
                   a.rate = 0.011, ds.rate = 0.01,
                   di.rate = 0.03, dr.rate = 0.01)
init <- init.dcm(s.num = 1000, i.num = 1, r.num = 0)
control <- control.dcm(type = "SIR", nsteps = 50)
mod <- dcm(param, init, control)
summary(mod, at = 25, run = 1)
summary(mod, at = 25, run = 3)
summary(mod, at = 26, run = 3)
```

Description

Extracts and prints model statistics simulated with icm.

Usage

```r
## S3 method for class 'icm'
summary(object, at, digits = 3, ...)
```

Arguments

- **object**: An EpiModel object of class icm.
- **at**: Time step for model statistics.
- **digits**: Number of significant digits to print.
- **...**: Additional summary function arguments.

Details

Summary statistics for the main epidemiological outcomes (state and transition size and prevalence) from an icm model. Time-specific summary measures are provided, so it is necessary to input a time of interest.
See Also

icm

Examples

## Stochastic ICM SI model with 3 simulations
param <- param.icm(inf.prob = 0.2, act.rate = 1)
init <- init.icm(s.num = 500, i.num = 1)
control <- control.icm(type = "SI", nsteps = 50,
                        nsims = 5, verbose = FALSE)
mod <- icm(param, init, control)
summary(mod, at = 25)
summary(mod, at = 50)
Examples

```r
## Not run:
## Independent SI Model
# Initialize network and set network model parameters
nw <- network.initialize(n = 100, bipartite = 50, directed = FALSE)
formation <- ~edges
target.stats <- 50
coeff.diss <- dissolution_coefs(dissolution = ~offset(edges), duration = 20)

# Estimate the ERGM models (see help for netest)
est1 <- netest(nw, formation, target.stats, coeff.diss, verbose = FALSE)

# Parameters, initial conditions, and controls for model
param <- param.net(inf.prob = 0.3, inf.prob.m2 = 0.15)
init <- init.net(i.num = 10, i.num.m2 = 10)
control <- control.net(type = "SI", nsteps = 100, nsims = 5, verbose.int = 0)

# Run the model simulation
mod <- netsim(est1, param, init, control)

summary(mod, at = 1)
summary(mod, at = 50)
summary(mod, at = 100)

## End(Not run)
```

### truncate_sim

**Truncate Simulation Time Series**

**Description**

Left-truncates a simulation epidemiological summary statistics and network statistics at a specified time step.

**Usage**

`truncate_sim(x, at)`

**Arguments**

- `x` Object of class `netsim` or `icm`
- `at` Time step at which to left-truncate the time series.

**Details**

This function would be used when running a follow-up simulation from time steps `b` to `c` after a burnin period from time `a` to `b`, where the final time window of interest for data analysis is `b` to `c` only.
update_dissolution

Examples

```r
param <- param.icm(inf.prob = 0.2, act.rate = 0.25)
init <- init.icm(s.num = 500, i.num = 1)
control <- control.icm(type = "SI", nsteps = 200, nsims = 1)
mod1 <- icm(param, init, control)
df <- as.data.frame(mod1)
print(df)
plot(mod1)
mod1$control$nsteps

mod2 <- truncate_sim(mod1, at = 150)
df2 <- as.data.frame(mod2)
print(df2)
plot(mod2)
mod2$control$nsteps
```

Description

Adjusts the dissolution component of an dynamic ERGM fit using the netest function with the edges dissolution approximation method.

Usage

`update_dissolution(old.netest, new.coef.diss)`

Arguments

- `old.netest`: An object of class netest, from the `netest` function.
- `new.coef.diss`: An object of class disscoef, from the `dissolution_coefs` function.

Details

Fitting an ERGM is a computationally intensive process when the model includes dyadic dependent terms. With the edges dissolution approximation method of Carnegie et al, the coefficients for a temporal ERGM are approximated by fitting a static ERGM and adjusting the formation coefficients to account for edge dissolution. This function provides a very efficient method to adjust the coefficients of that model when one wants to use a different dissolution model; a typical use case may be to fit several different models with different average edge durations as targets. The example below exhibits that case.
Examples

```r
## Not run:
mw <- network.initialize(1000, directed = FALSE)

# Two dissolutions: an average duration of 300 versus 200
diss.300 <- dissolution_coefs(~offset(edges), 300, 0.001)
diss.200 <- dissolution_coefs(~offset(edges), 200, 0.001)

# Fit the two reference models
est300 <- netest(nw = mw,
                formation = ~edges,
                target.stats = c(500),
                coef.diss = diss.300)
est200 <- netest(nw = mw,
                formation = ~edges,
                target.stats = c(500),
                coef.diss = diss.200)

# Alternatively, update the 300 model with the 200 coefficients
est200.compare <- update_dissolution(est300, diss.200)

identical(est200$coef.form, est200.compare$coef.form)

## End(Not run)
```
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