

Package ‘tsna’

April 23, 2021

Version 0.3.3

Date 2021-04-23

Title Tools for Temporal Social Network Analysis

Type Package

Depends network (≥ 1.13), networkDynamic (≥ 0.9), R (≥ 3.0)

Imports statnet.common

Suggests networkDynamicData, testthat, sna, knitr, rmarkdown,
relevent, ergm (≥ 3.10)

Description Temporal SNA tools for continuous- and discrete-time longitudinal networks having vertex, edge, and attribute dynamics stored in the 'networkDynamic' format. This work was supported by grant R01HD68395 from the National Institute of Health.

License GPL-3

LazyLoad yes

URL <http://statnet.org>

VignetteBuilder knitr

NeedsCompilation no

Author Skye Bender-deMoll [aut, cre],
Martina Morris [aut],
James Moody [ctb]

Maintainer Skye Bender-deMoll <skyebend@uw.edu>

Repository CRAN

Date/Publication 2021-04-23 19:50:02 UTC

R topics documented:

as.network.tPath	2
duration	3
formation_and_dissolution	5
moodyContactSim	6
paths	8

plotPaths	11
pShiftCount	13
reachable	15
tDegree	16
temporal density	17
tErgmStats	19
tiedDuration	20
timeProjectedNetwork	22
tReach	24
tsna	25
tSnaStats	27

Index 31

as.network.tPath	<i>Create a network object from a tPath object – the results of a path search</i>
------------------	---

Description

Takes the results of a temporal path search (a [tPath](#)) as input and creates a new network object representing the path tree which can be plotted for debugging, etc.

Usage

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

Arguments

x	A tPath list with several elements, the output of a path search.
...	possible additional arguments

Details

Attributes of original network are not copied

Value

a directed `networkDynamic` object representing the path information from the input. Each edge has the onset time indicated by its distance in the path.

Note

this is probably not the final form of this function

Author(s)

skyebend

See Also

See also [paths](#).

Examples

```
data(moodyContactSim)
v1path<-tPath(moodyContactSim,v=1)
v1tree<-as.network(v1path)
plot(v1tree,displaylabels=TRUE)
```

duration	<i>Compute Observed Activity Durations or Event Counts for Edges or Vertices</i>
----------	--

Description

Computes observed activity durations or event counts for edges or vertices, aggregating at the edges, spell, or dyads level.

Usage

```
edgeDuration(nd, mode = c("duration", "counts"), subject = c("edges", "spells", "dyads"),
             e = seq_along(nd$mel), start = NULL, end = NULL, active.default = TRUE)

vertexDuration(nd, mode = c("duration", "counts"), subject = c("vertices", "spells"),
              v = seq_len(network.size(nd)), active.default = TRUE)
```

Arguments

nd	networkDynamic object to be evaluated
mode	option determining if the 'duration' of the spells should be summed, or simply the 'counts' of the number of spells. The later option is useful when the network contains events of zero duration.
subject	option describing the unit of analysis that the durations or counts should be aggregated at. 'spells' considers each event independently. For tVertexDuration, 'vertices' sums all the spells corresponding to a single vertex id. For edgeDuration, 'edges' sums all of the spells corresponding to a single edge id and 'dyads' sums all of the spells corresponding to a single (directed) tail-head pair (this means spells from multiplex edges connecting the same vertices will be added together).
e	numeric vector of edge ids to consider.
v	numeric vector of vertex ids to consider.
start	optional numeric value to be used to censor onset times. (not yet supported for vertices, must use net.obs.period instead.)
end	optional numeric value to be used to censor terminus times. (not yet supported for vertices, must use net.obs.period instead.)
active.default	logical, should edges or vertices with no timing information be considered always active by default?

Details

The function sums the durations of edge or vertex events or, in order to provide a useful metric for networks having zero-duration events, simply counts them. It is implemented by wrapping a call to [as.data.frame.networkDynamic](#) or [get.vertex.activity](#). In many cases the output of the function will be fed to another statistical summary function like `summary` or `hist`. The level of aggregation can be selected by setting the subject to either `spells`, `edges`, or `dyads`.

Note that the 'observed' durations may not match the 'true' (statistically estimated) durations for a network due to the censoring of edges/vertices.

Value

A vector of values corresponding to the selected subjects with the count or duration of events. If the network contains no edges/vertices, `numeric(0)` will be returned.

Note

This is an early implementation of the function and its name and arguments are subject to change

Author(s)

skyebend

See Also

See also [as.data.frame.networkDynamic](#)

Examples

```
# look at the distributions of edge durations for
# a real-world contact network
## Not run:
require(networkDynamicData)
data(hospital_contact)
summary(edgeDuration(hospital,subject='edges'))
summary(edgeDuration(hospital,mode='counts',subject='edges'))

## End(Not run)
# look at the vertex durations for a network where
# vertices are not present every day
require(networkDynamic)
data(windsurfers)
vertexDuration(windsurfers)
```

 formation_and_dissolution

Counts or fractions of edge transitions in a networkDynamic object

Description

The functions `tEdgeFormation` and `tEdgeDissolution` evaluate a network object at multiple time points and return counts (or fractions) of the number of edges forming (edge onset at time point) and dissolving (edge terminus at time point). The counts are returned as numeric vector which is a time-series object (class `ts`).

Usage

```
tEdgeFormation(nd, start, end, time.interval = 1,
               result.type=c('count','fraction'), include.censored=FALSE)
```

```
tEdgeDissolution(nd, start, end, time.interval = 1,
                 result.type=c('count','fraction'), include.censored=FALSE)
```

Arguments

<code>nd</code>	a <code>networkDynamic</code> object
<code>start</code>	optional numeric time value at which evaluation should start (default is first observed time)
<code>end</code>	optional numeric time value at which evaluation should end (default is last observed time)
<code>time.interval</code>	optional numeric value giving time interval between evaluations (default is 1)
<code>result.type</code>	either 'count' indicating that results should be returned as counts of tie changes or 'fraction' meaning that results should be returned as fraction of ties dissolving (for dissolution) or fraction of empty dyads forming ties (for formation). In the later case the number of dyads is corrected for network directedness, loops, and bipartite partition size.
<code>include.censored</code>	logical, should ties with truncated/censored onset or termination times be included in the respective formation or dissolution counts?

Details

Uses `as.data.frame.networkDynamic` internally. TODO: dyad formation rate is not yet corrected for vertex activity, uses the aggregate, not the momentary, network size.

When `result.type='fraction'`:

- formation returns the ratio of number of ties forming to the number of possible empty dyads that could have formed ties. So value of 1 would mean all empty dyads formed ties, value of 0 means no ties formed. In sparse networks, the numbers will tend to be very, very small.

- dissolution returns the ratio of the number of ties dissolving to the number preexisting ties that could have dissolved. So value of 1 means all ties dissolved, 0 means no ties dissolved.

When `include.censored=FALSE` spells of edges which onset outside of the query range will not be included in formation counts.

Value

For `tEdgeFormation` and `tEdgeDissolution`, a numeric vector of class `ts` giving the formation and dissolution counts (respectively) as a time-series. For `edgeFormationAt` and `edgeDissolutionsAt`, a single numeric value

Note

should add additional args to allow binning other than 'at' for working with non-discrete time, options to deal with how censored edges are calculated.

Author(s)

skyebend@uw.edu

Examples

```
library(networkDynamicData)
data(concurrencyComparisonNets)
# plot formation and dissolution counts time-series
plot(tEdgeFormation(base),col='green',
     main='edge formation and dissolution rates per timestep of base')
points(tEdgeDissolution(base),col='red',type='l')
## Not run:
# compute fraction of ties dissolving every 10 steps
tEdgeDissolution(base,time.interval = 10,result.type = 'fraction')
# compute fraction of empty dyads forming ties every 10 steps
tEdgeFormation(base,time.interval = 10,result.type = 'fraction')

## End(Not run)
```

moodyContactSim

Jim Moody's example dynamic contact simulation network

Description

A `networkDynamic` object containing the output of a simulation of 1000 timestep simulation of a sex contact network with 16 vertices and 18 edges. Each edge has a single activity spell.

Usage

```
data(moodyContactSim)
```

Format

A networkDynamic object.

Details

The object has a `net.obs.period` attribute describing the observation model. This is a useful network for testing path-based algorithms because it is small enough to visually inspect.

Source

Figure 5 of James Moody (2008) "Static Representations of Dynamic Networks" Duke Population Research Institute On-line Working Paper Series. http://www.soc.duke.edu/~jmoody77/StatDyn_5.pdf

Examples

```
data(moodyContactSim)
# plot a view of network with edge and vertex labels
plot(moodyContactSim,
      displaylabels=TRUE,
      label.cex=0.8,
      label.pos=5,
      vertex.col='white',
      vertex.cex=2,
      edge.label=sapply(get.edge.activity(moodyContactSim),function(e){
        paste('(',e[,1],'-',e[,2],')',sep='')
      }),
      edge.label.col='blue',
      edge.label.cex=0.8
    )
## Not run:
# data object was created with
moodyContactSim<-network.initialize(16,directed=FALSE)
tel<-matrix(c(674,701,1,9,
              214,247,1,11,
              621,651,1,12,
              583,615,1,16,
              749,793,11,8,
              719,745,8,13,
              712,739,13,5,
              634,660,13,3,
              769,795,13,7,
              453,479,13,4,
              494,524,13,2,
              224,256,7,10,
              40,72,10,4,
              665,692,4,14,
              709,740,2,15,
              575,599,2,16,
              748,782,4,16,
              701,733,16,6),
            ncol=4,byrow=TRUE)
```

```

moodyContactSim<-networkDynamic(moodyContactSim,edge.spells=tel)
obs<-moodyContactSim%%'net.obs.period'
obs$mode<-'discrete'
obs$time.increment<-1
obs$time.unit<-'step'
obs$observations<-list(c(0,1000))
moodyContactSim%%'net.obs.period'<-obs

## End(Not run)

```

paths

Temporally Reachable Paths in a networkDynamic Object

Description

Functions to search out the sequence and distances of vertices in a `networkDynamic` object reachable from an initial vertex by following paths constrained by edge timing.

Usage

```

tPath(nd, v, direction=c('fwd','bkwd'),
      type=c('earliest.arrive', 'latest.depart'),
      start, end, active.default = TRUE, graph.step.time = 0)

is.tPath(x)

```

Arguments

<code>nd</code>	networkDynamic object to be searched for temporal paths
<code>v</code>	integer id of the vertex to be used as the starting point of the search
<code>direction</code>	option indicating the temporal direction in which the network should be searched: 'fwd' means search forwards in time and forward along edge directions, 'bkwd' means search backwards in time and backwards along edge directions.
<code>type</code>	option indicating the type of path (temporal constraint of the path) be searched for: <ul style="list-style-type: none"> 'earliest.arrive' will find the paths that arrive first at the target vertices, 'latest.depart' will find the paths that leave the source vertex at the latest possible time. Additional options will be added as implemented.
<code>start</code>	time at which to begin searching. Edges that terminate before this time will not be considered. If not specified, defaults to earliest time observed on the network according to <code>get.change.times</code> .
<code>end</code>	time to end the path search. Edges that onset on or after this time will not be considered in the path search.

<code>active.default</code>	Boolean, default TRUE. Should edges with no timing information be considered active by default?
<code>graph.step.time</code>	numeric. How much time should be added for each edge traversal (graph hop)? Default is 0, meaning that path distances returned will be purely temporal and will not incorporate graph path distances and 'transmission' can cross multiple edges in a single instant. A value of 1 would correspond to counting path distances like a traditional centrality score or discrete time simulation.
<code>x</code>	an object to be tested for inheriting the class 'tPath'

Details

A *temporal path* in a dynamic network is a sequence of vertices and edges such that the onset times of successive elements are greater than or equal than those of the previous. In other words, the path is a directed traversal of the network that respects the constraints of edge activity spells and permits 'waiting' at intermediate vertices for 'future' edges to form.

When set to use `direction='fwd'`, `type='earliest.arrive'` `tPath` performs a time-minimizing Dijkstra's style Depth First Search to find the set of vertices reachable on a *forward temporal path* from the initial seed vertex v while respecting the constraints of edge timing. The path found is a *earliest arriving* (in contrast to the *earliest leaving* or *quickest* or *latest arriving* path). When there are multiple equivalent paths only a single one will be arbitrarily returned. NOTE THAT THE PATH-FINDING ALGORITHM WILL NOT GIVE CORRECT RESULTS IF ANY SPELLS CONTAIN VALUES LESS THAN 0.

When set to `direction='bkwd'` and `type='latest.depart'` the path will be found by searching backwards in time from the end point. In other words, it returns the set of vertices that can reach v , along with latest possible departure times from those vertices. Note that in this case the elapsed time values returned for `tdist` will be negative, indicating time measured backwards from the end bound.

When set to `type='fewest.steps'` the path returned will be a 'shortest' (fewest steps/graph hops) time-respecting path. This would not be necessarily the quickest or earliest route, but would pass across the fewest possible number of edges (requires the fewest number of transmission steps).

The `graph.step.time` parameter allows specifying an explicit duration for edge traversals. In this case the algorithm considers both the onset and terminus times of activity spells to ensure that sufficient time remains for an edge traversal to be made. If `graph.step.time >` the remaining duration of an edge's activity spell, the edge is considered non-traverseable. The primary use case for this parameter is to align the paths discovered with those that might be found by a discrete time transmission simulation in which a path can only spread a single graph hop per model timestep.

Vertex activity is currently ignored, and it is assumed that once a path reaches a vertex, all future edges from the vertex are accessible. The path search can be constrained in time using the `start` and `end` parameters to bound the time span to be explored by the path search.

'`bkwd`' '`latest.depart`' is essentially the inverse of `fwd earliest arrive`. It finds the latest time paths backwards from the initial seed vertex. This is the *latest-leaving* time. Note that the distance returned are positive, but represent the latest distance back in time from the end parameter time at which a vertex can reach v .

The `is.tPath` function checks if an object has the class `tPath`.

Value

Currently an object of class `tPath` which is essentially list with several elements providing information on the path found.

<code>tdist</code>	A numeric vector with length equal to network size in which each element contains the earliest/latest <i>temporal</i> distance at which the corresponding vertex could reach / be reached from the seed vertex. Values are elapsed time, as measured from the <code>start</code> parameter. Unreachable vertices are marked with <code>Inf</code>
<code>previous</code>	A numeric vector with length equal to network size in which each element indicates the previous vertex along (a possible) reachable path. Can be used to reconstruct the path tree. The initial vertex and unreachable vertices are marked with <code>0</code>
<code>gsteps</code>	A numeric vector (of length equal to network size) in which each element indicates the number of steps in the path (number of graph hops) to the vertex along the temporal path found starting at the seed vertex.
<code>start</code>	the numeric start value that was used as the earliest bound for the path calculation (may not have been explicitly set)
<code>end</code>	the numeric end value that was used as the latest bound for the path calculation (may not have been explicitly set)
<code>direction</code>	The direction 'fwd' or 'bkwd' of the path
<code>type</code>	The type of temporal constraint for the path

Note

Temporal distances are in terms of time measured from the `start` parameter, so to recover the model times at which each vertex was reached for forward paths use `$tdist+start` and backward paths with `end-$tdist`. This is an early draft of the function, its name and arguments are subject to change before release.

Author(s)

Skye Bender-deMoll

References

Unpublished discussions with James Moody and Martina Morris and the statnet team.

Useful background information (for a slightly different algorithm) can be found in: B. Bui Xuan, Afonso Ferreira, Aubin Jarry. "Computing shortest, fastest, and foremost journeys in dynamic networks." RR-4589, 2002. <https://hal.inria.fr/inria-00071996/document>

B. Bui Xuan, Afonso Ferreira, Aubin Jarry. Evolving graphs and least cost journeys in dynamic networks. WiOpt'03: Modeling and Optimization in Mobile, Ad Hoc and Wireless Networks, Mar 2003, Sophia Antipolis, France. 10 p., 2003 <https://hal.inria.fr/inria-00466676/document>

Examples

```
require(networkDynamicData)
data(hospital_contact)
hosPath<-tPath(hospital,v=1)
```

plotPaths *Network Plots a Highlighting Temporal Path(s)*.

Description

Wrapper for [plot.network](#) with appropriate defaults to plot a highlighted path, or over-plot highlighted paths on a on top of a static aggregate network plot.

Usage

```
plotPaths(nd, paths, path.col = rainbow(length(paths), alpha = 0.5),
          displaylabels = TRUE, coord=NULL, ...)
```

```
## S3 method for class 'tPath'
plot(x, edge.col = "red",
     edge.label.col = edge.col,
     edge.lwd = 10,
     edge.label.cex = 0.7,
     displaylabels = TRUE,
     displayisolates = FALSE,
     jitter = FALSE,
     vertex.lwd = (x$gsteps == 0) * 4 + 1,
     vertex.cex = (x$gsteps == 0) * 1.5,
     vertex.col = NA, ...)
```

Arguments

nd	a networkDynamic object to be plotted.
paths	a tPath object containing temporal path (presumably extracted from nd) to be plotted over the network, or a list of paths to be plotted together on the same network.
path.col	vector of valid colors (possibly transparent) to be used for each path. Default will created semi-transparent colors from the rainbow palette.
x	object (assumed to be tPath) to be plotted on top of a static aggregate network plot
...	additional arguments to be passed to plot.network and plot.tPath .
coord	optional numeric matrix of coordinates for positioning vertices. See plot.network
edge.col	color for drawing edges (paths). See plot.network
edge.label.col	color for edge labels. Default to same color as edges. See plot.network
edge.lwd	numeric expansion factor for edge line widths. See plot.network
edge.label.cex	numeric expansion factor for edge labels. See plot.network
displaylabels	logical, should vertex labels be included on the plot? See plot.network

displayisolates	logical, should isolated vertices be included in the plot? See plot.network
jitter	adds random noise to positions (disabled by default) See plot.network
vertex.lwd	Vertex border line with. See plot.network
vertex.cex	Vertex expansion factor. Default is to scale up the origin vertex for the path, and not draw the other vertices. See plot.network
vertex.col	Color for vertices. Default is to leave them un-colored. See plot.network

Details

plotPaths plots the networkDynamic object using the normal plot.network function and ... arguments. Then calls plot.tPath for each tPath object in paths to over-plot the edges of path onto the network plot using the corresponding path.col color. Use of semi-transparent colors can help (somewhat) improve readability when paths overlap on the same edges.

plot.tPath plots the path information encoded in a single tPath object. It first creates a network using as.network.tPath and then calls plot.network with suitable defaults for drawing (or over-drawing) the path (doesn't display isolated vertices, draws times as edge labels, draws a color around the source vertex, etc.)

Value

Generates a network plot with a highlighted path, invisibly returns the plot coordinates.

Author(s)

skyebend

See Also

See also [tPath](#)

Examples

```
data(moodyContactSim)
v10path<-tPath(moodyContactSim,v=10,start=0)
# plot just the path from v10
plot(v10path)

# plot the path from v10 on top of the network
plotPaths(moodyContactSim,v10path)

# plot the paths from both v10 and v1
v1path<-tPath(moodyContactSim,v=1,start=0)
plotPaths(moodyContactSim,list(v10path,v1path))

# if ndtv package is installed, along with Graphviz system library,
# nice hierarchical trees can be drawn
## Not run:
plot(v10path,
     coord=network.layout.animate.Graphviz(
```

```

        as.network(v10path),
        layout.par = list(gv.engine='dot')
    ),
    jitter=FALSE
)

## End(Not run)

```

pShiftCount

Compute Counts of Gibson's Participation Shifts

Description

Uses the relevent package to compute counts of dyadic turn-taking events using a typology outlined by Gibson (2003)

Usage

```
pShiftCount(nd, start = NULL, end = NULL, output = c("final", "full"))
```

Arguments

nd	networkDynamic object to be evaluated
start	numeric initial time point to start evaluation from
end	numeric ending time point to finish evaluation
output	chracter value indicating if only the 'final' counts should be reported, or the 'full' matrix with updated counts for each event.

Details

Uses the accum.ps function in the package relevent to build counts of accumulated dyad participation shifts (turn-taking changes) using the dynamic information on tie changes represented in a directed networkDynamic object. The P-shifts are given in the order used in Gibson's 2003 Social Forces paper, namely:

- Turn Receiving:
 - [1] AB->BA (Alex talks to Brett, then Brett replies)
 - [2] AB->B0 (Alex talks to Brett, then Brett addresses the group)
 - [3] AB->BY (Alex talks to Brett, then Brett talks to Yuki)
- Turn Claiming:
 - [4] A0->X0 (Alex talks to the group, then Xuan talks to the group)
 - [5] A0->XA (Alex talks to the group, then Xuan talks to Alex)
 - [6] A0->XY (Alex talks to the group, then Xuan talks to Yuki)
- Turn Usurping:
 - [7] AB->X0 (Alex talks to Brett, then Xuan talks to the group)

- [8] AB->XA (Alex talks to Brett, then Xuan talks to Alex)
- [9] AB->XB (Alex talks to Brett, then Xuan talks to Brett)
- [10] AB->XY (Alex talks to Brett, then Xuan talks to Yuki)
- Turn Continuing:
 - [11] A0->AY (Alex talks to the group, then addresses Yuki)
- [12] AB->A0 (Alex talks to Brett, then makes remark to the group)
- [13] AB->AY (Alex talks to Brett, then to Yuki)

This uses Gibson's notation, in which A is the initial source, B is the initial target, X is a new (shifted) speaker, Y is a new (shifted) target, and 0 is used where no well-defined speaker or target is present. (Here, this would occur when NA is given for source or destination, not currently supported)

It is worth noting that not all adjacent event pairs induce P-shifts, and hence the shift counts will not increment with every event. In particular, the first event does not induce a shift (since there is no prior event), and neither does a repetition of a previous event (e.g., AB->AB or A0->A0). The full set is thus affinely independent in general, although they will have a near (or even full) dimension of affine dependence on most data sets.

Event order is determined by sorting the network's edge spells by on the onset time of edge and then by the terminus. Gibson's typology assumes that edges/ties directed 'at the group' are distinguishable those directed at individuals, and has a strong assumption of sequential non-simultaneous events. Because the networkDynamic object does not explicitly code for 'group' utterances, simultaneous edges originating from a speaker (same onset, terminus, and tail vertex) are assumed to be directed at the group, even if not all group members are reached by the ties.

Value

For output='final' (the default), the output is a matrix with one row containing counts for each of the 13 P-shift types accumulated over the time period requested. For output='full', the output is a data.frame with rows corresponding to each edge spell event. The first 13 rows are the counts of P-shift types, and the remaining four rows are the 'onset', 'terminus', 'tail', 'head', and a 'group' column indicating if the event was considered as a group-directed.

Author(s)

Carter Butts buttsc@uci.edu, Skye Bender-deMoll skyebend@uw.edu

References

- Gibson, D.R. (2003) 'Participation Shifts: Order and Differentiation in Group Conversation' *Social Forces* 81 (4): 1335-1380 <https://doi.org/10.1353/sof.2003.0055>
- Carter T. Butts (2008). A Relational Event Framework for Social Action. *Sociological Methodology*, 38(1), 155-200.

Examples

```
data(McFarland_cls33_10_16_96)
pShiftCount(cls33_10_16_96)
```

reachable	<i>Find the set of vertices reachable from a given set using only paths moving forward in time</i>
-----------	--

Description

Does a breadth-first search from the specified set of vertices, respecting the direction and timing of edges. TODO: vertex activity.

Usage

```
forward.reachable(nd, v, start = NULL, end = NULL, per.step.depth = Inf)
```

Arguments

nd	a network (usually a networkDynamic) object
v	numeric vector giving the set of initial vertex.ids to start from
start	The beginning of the time range to start from
end	End of the time range to search to
per.step.depth	How many steps (default=1) to search per unit of time.

Details

The default value of per.step.depth=Inf is equivalent to assuming that the ‘process’ takes no time to travel along vertices

Value

A numeric vector of vertex.ids reachable from the initial set of vertex.id by ‘traveling’ forward in time along active vertices and edges subject to bounding paramters.

Note

This is a pure R implementation, probably very slow.

This function could be ill-defined when using non-Inf per.step.depth with networks with instantaneous (onset=terminus) spells as it will treat elements active at time t as active until the next change in the network.

TODO: should be able to specify edge weight attribute to be included in time calculations.

Author(s)

skyebend

See Also

See also [tPath](#) for a dramatically faster implementation

tDegree	<i>Report momentary degree of a networkDynamic object at multiple timepoints</i>
---------	--

Description

Calculates the degree of vertices at a sequence of time points over a network's temporal evolution

Usage

```
tDegree(nd, start, end, time.interval = 1, cmode = c("freeman", "indegree", "outdegree"))
```

Arguments

nd	the <code>networkDynamic</code> object to be evaluated
start	optional numeric time value at which evaluation should start (default is first observed time)
end	optional numeric time value at which evaluation should end (default is last observed time)
time.interval	optional numeric value giving time interval between evaluations (default is 1)
cmode	mode for evaluating degree. one of "freeman", "indegree", "outdegree"

Details

Evaluates the momentary degrees of a network at multiple time points and returns results in a form suitable for summarizing the distributions. If a vertex is not active at a time point, its degree will be recorded as NA.

Value

A `ts` (time series) object, a numeric matrix with giving the momentary degree of each vertex at each time point. Columns corresponding to each vertex in the input network and row corresponding to each time point at which degree was evaluated.

Author(s)

skyebend

See Also

See also `tSnaStats(nd, 'degree')` and `tErgmStats(nd, 'sociality')` for alternate ways to compute degree using external packages.

Examples

```

data(McFarland_cls33_10_16_96)
tDegree(cls33_10_16_96)
# compute mean temporal degree
mean(tDegree(cls33_10_16_96),na.rm=TRUE)
## Not run:
library(networkDynamicData)
data(concurrencyComparisonNets)
# compute mean for each network, sampled at 11 time points
mean(colMeans(tDegree(base,start = 0,end=102,time.interval = 10)))
mean(colMeans(tDegree(middle,start = 0,end=102,time.interval = 10)))
mean(colMeans(tDegree(monog,start = 0,end=102,time.interval = 10)))

# plot distribution of vertices' mean momentary degree
hist(rowMeans(tDegree(base,start = 0,end=102,time.interval = 10)))

# plot distribution of momentary degrees of vertices
hist(tDegree(base,start = 0,end=102,time.interval = 10))

## End(Not run)

```

temporal density

Functions to compute temporal density-related measures on dynamic networks

Description

These functions provide various network-level statistics giving information on the fraction of time edges are active in `networkDynamic` objects

Usage

```

tEdgeDensity(nd,mode=c('duration','event'),
             agg.unit=c('edge','dyad'),active.default=TRUE)

```

Arguments

<code>nd</code>	a <code>networkDynamic</code> object to evaluate density on
<code>mode</code>	option indicating if 'duration' of edge spells should be considered or only the 'event' count (for networks in which events have zero-durations)
<code>agg.unit</code>	option indicating how to calculate the possible observable time to be used as the denominator: 'edge' only counts existing edges 'dyad' counts all possible dyads.
<code>active.default</code>	logical, default TRUE. should edges without explicit timing information be considered active by default?

Details

The `tEdgeDensity` measure by default (`mode='duration'`, `agg.unit='edge'`) computes the total duration of activity of all the edges in the network and divides by the total amount of observable time for all the dyads *between which edges are ever observed*. Can be interpreted as the average fraction of observed edges active at any time. A value of 1 corresponds to a network in which all of the observed edges are always active (but the network still may be topologically sparse, having a low density)

The `tEdgeDensity` function with `mode='event'` computes the number of events (spells) occurring on each edge the network and divides it by the total amount of observable time per dyad ever observed to have an edge within the time bounds of the network. Can be interpreted as the fraction of existing ties toggling in a unit time step?

The `agg.unit='dyad'` measure computes the total duration (or count of events) of activity of all the edges in the network, and divides by the total amount of observable time for all the *possible dyads* (existing and non-existing edges). Value of 1 corresponds to a fully-connected network in which all edges are always active, value of 0 would be a network with no active edges. Can be interpreted as the average fraction of possible edges active at any time.

For networks with instantaneous spells, the event measures would be used in preference to the duration measures, as all of the events will have zero durations.

Note that all of these measures depend on having an accurate value for the temporal bounds of the network. If a `net.obs.period` exists, it will determine the range of observations. If it does not exist, the range will be the (non-Inf) range of earliest and latest events found on the network by `get.change.times`. If no non-Inf range exists (presumably because all ties are always active or always inactive), the range (0-1) will be used.

For sensible results on discrete networks, the measures are effectively making the assumption that the time increment is 1. TODO: read time increment from `net.obs.period` if it exists?

Networks with no edges or vertices will return 0, although they are technically undefined.

Behavior with multiplex ties? dyad measures could range above 1, edge measures will re-normalize.

Value

A numeric value representing the network-level measure of the density metric applied

Note

These are experimental functions, names and arguments still subject to change. Should these be collapsed to a single measure with multiple arguments?

Author(s)

skyebend

References

none yet

Examples

```
## Not run:
require(networkDynamicData)
data(hospital_contact)
tEdgeDensity(hospital)

## End(Not run)
```

tErgmStats

*Calculate network summary statistics at multiple time points***Description**

Applies a ergm-style formula of network statistics to cross-sectional networks collapsed from a networkDynamic at multiple time points to construct a matrix of values describing the change in statistics over time.

Usage

```
tErgmStats(nd, formula, start, end, time.interval = 1, aggregate.dur, rule)
```

Arguments

nd	networkDynamic object to be evaluated
formula	a character string providing an ergm term name or the 'right hand side' of an ergm formula. For example '~ edges + concurrent'
start	optional numeric time value at which evaluation should start (default is first observed time)
end	optional numeric time value at which evaluation should end (default is last observed time)
time.interval	optional numeric value giving time interval between evaluations (default is 1)
aggregate.dur	optional numeric value giving the duration of time bin to aggregate over for each evaluation (default 0). See network.collapse
rule	character vector describing rule to be used if multiple attribute values are encountered when using non-zero aggregate.dur. Default is latest. See network.collapse for details

Details

Constructs a set of times to evaluate based on start,end and time.interval. Extracts a static network at each time point and uses it to construct a formula with f. The formula is passed to ergm's [summary_formula](#) function to calculate the net value of the change statistics for each term in the formula. The values of the statistics are grouped into a time-series object (class [ts](#)). The ts object can be thought of as a matrix such that each column is a formula term and each row is the time point at which the statistics were evaluated. See [ergm-terms](#) for a list of available term statistics.

The `aggregate.dur` can be used to specify the duration of the aggregation bin, especially useful when working with continuous time networks. Usually the `time.interval` would be set to the same value to ensure non-overlapping bins.

Be aware that if the network's vertex activity dynamics imply cross-sectional networks of different sizes, the interpretation of the statistic at each time point may not be the same.

Value

A time-series (`ts`) object containing term statistics in which each column corresponds to a statistic and each row is the time point at which the statistic was evaluated

Author(s)

skyebend@uw.edu

See Also

See also [summary_formula](#) and [ergm-terms](#). For more information about time-series objects, see [ts](#) and [plot.ts](#) for plotting quickly plotting timelines for multiple statistics. The `summary_formula.networkDynamic` function in the `tergm` package offers very similar functionality.

Examples

```
## Not run:
data(windsurfers)
tErgmStats(windsurfers, '~edges+degree(c(1,2))')
library(networkDynamicData)
data(concurrencyComparisonNets)
tErgmStats(base, '~edges+concurrent',
           start=0, end=100, time.interval = 10)
# show as multiple plots
plot(
  tErgmStats(base, '~edges+concurrent',
            start=0, end=100, time.interval = 10),
)

## End(Not run)
```

tiedDuration

Compute the duration of time (or count of events) that each vertex is tied/connected to others by an edge

Description

Computes the total duration that each vertex in the network is tied to other vertices by incident edges. Alternately, if mode="counts", computes the total number of incident edge spells each vertex is tied by. The later is especially useful for continuous time networks tied by edges with 0-duration events. For directed networks, the durations can be filtered using the neighborhood argument to include only incoming, outgoing, or all ties combined in order to return out-tied or in-tied durations.

Usage

```
tiedDuration(nd, mode = c("duration", "counts"),
             active.default = TRUE,
             neighborhood = c("out", "in", "combined"))
```

Arguments

nd	a networkDynamic object describing the network for which durations should be calculated
mode	either "duration" or "count" indicating if the sum of edge durations or the count of the number of edge events should be returned
active.default	logical, should edges with no defined activity spells be considered active by default?
neighborhood	value of "out", "in" or "combined" indicating if – for directed networks – the durations (counts) should be limited to the vertices' ties outgoing, incoming, or combined (both).

Details

Implemented internally using the [as.data.frame.networkDynamic](#) function and so follows the same truncation conventions for handling censored edges (edges that are active before or after the observation window of the network)

Value

a numeric vector of length equal to the number of vertices in the network with a value equal to the sum of durations (or counts) of active edges incident upon the vertex.

Note

Should the default neighborhood for directed network be 'combined'?

Author(s)

skyebend@uw.edu

Examples

```

data(moodyContactSim)
tiedDuration(moodyContactSim)

data(McFarland_cls33_10_16_96)
# compute ratio of incoming vs. outgoing speech acts
outDur <- tiedDuration(cls33_10_16_96, mode='counts',neighborhood = 'out')
inDur <- tiedDuration(cls33_10_16_96, mode='counts',neighborhood = 'in')
outDur / inDur

```

timeProjectedNetwork *Construct a time-projected ("multi-slice") network by binning a networkDynamic object*

Description

Builds a new static representation of a dynamic network constructed by binning the dynamic network into static slices and constructing new directed 'identity-arcs' between the vertices' realizations in successive time slices.

Usage

```

timeProjectedNetwork(nd, start = NULL, end = NULL,
                    time.increment = NULL, onsets = NULL, termini = NULL,
                    ...)

```

Arguments

nd	the <code>networkDynamic</code> object for which the time projected network should be constructed
start	optional numeric start time to be use as lower bound for binning interval (default is what is observed in network)
end	optional numeric end time to be use as upper bound for binning interval (default is what is observed in network)
time.increment	value for the offset (and duration) between successive samples. Will default to 1 if not otherwise specified
onsets	A numeric vector containing the onset times of the networks to be extracted. This must be accompanied by <code>termini</code> of the same length.
termini	A numeric vector containing the terminus times of the networks to be extracted. This must be accompanied by <code>onsets</code> of the same length.
...	Additional arguments to <code>network.collapse</code> (such as <code>rule</code> , <code>active.default</code>)

Details

Uses [network.collapse](#) to bin the nd network into a list of static networks, aggregates them into a new network with size equal to original network size X number of slices. To assist with plotting, an edge attribute `edge.type` is added to all of the edges, having the value `'within_slice'` for edges existing in the original network and `'identity_arc'` for edges linking the vertices in time. Vertex attributes (possibly collapsed TEAs) are copied from the original network to the projected network. Because of the assumed directionality of time, the output network will always be directed, with the identity arcs pointing forward in time. If the input network is undirected, two corresponding directed edges (one in each direction) will be added in the projected network. Edge attributes (possibly collapsed TEAs) will be copied from the original network to the corresponding within-slice edges in the projected network.

Vertex activity is currently ignored in the projected network (`retain.all.vertices` is set to TRUE internally to force all time slice networks to have the same size).

As with all discrete representations of dynamic processes, the time projected graph is an approximation and may over- or under-represent some transmission potential depending on the choice of bin size. Binning is performed by [get.networks](#), so will use its defaults if not specified.

Value

a [network](#) object that encodes a discrete time representation of the temporal evolution of the input [networkDynamic](#) object.

Author(s)

Skye Bender-deMoll (skyebend@uw.edu), James Moody

References

James Moody (2015) Static Representations of Dynamic Networks (DRAFT)
 Earlier citations?

See Also

[network.collapse](#)

Examples

```
data(moodyContactSim)

# use slices at each changing time point
library(networkDynamicData)
data(vanDeBunt_students)
times<-get.change.times(vanDeBunt_students)
vanDProj<-timeProjectedNetwork(vanDeBunt_students,onsets = times,termini = times)
# plot it with gray for the time edges
plot(vanDProj,
      arrowhead.cex = 0,
      edge.col=ifelse(vanDProj$e%'edge.type'=='within_slice','black','gray'),
```

```

    vertex.cex=0.7,mode='kamadakawai')
## Not run:

# compute shortest temporal path distances from each vertex in first slice
# to each vertex in last slice
library(sna)
geodist(vanDProj)$gdist[1:32,193:224]

# bin the moody sim into 100 timestep chunks
# (this will over-represent some transmission potential)
moodyProj<-timeProjectedNetwork(moodyContactSim,time.increment=100)
plot(moodyProj,arrowhead.cex = 0,
     edge.col=ifelse(moodyProj$edge.type=='within_slice','black','gray'),
     vertex.cex=0.7,displaylabels = TRUE,label.cex=0.6)

## End(Not run)

```

tReach

computes sizes of temporally reachable sets in a dynamicNetwork

Description

computes sizes of temporally reachable sets in a dynamicNetwork, using either a full census or sample of starting vertices of the specified size

Usage

```
tReach(nd, direction = c("fwd","bkwd"), sample=network.size(nd),
       start, end, graph.step.time=0)
```

Arguments

nd	a networkDynamic object
direction	currently only 'fwd' works, to calculate the sizes forward-reachable sets (as opposed to backwards-reachable)
sample	numeric, indicates the size of the sample of vertices to use to calculate the reachable sets
start	optional numeric start time to begin path search
end	optional numeric time to end path search
graph.step.time	How much time should be added for each edge traversal (graph hop)? See tPath for details.

Details

tReach calls `link{tPath}` on with each starting vertex to determine the sizes of the sets of vertices that are reachable. If `sample` is set to something less than the size of the network, it will sample that many vertices instead of doing the (expensive) full census. Note that when the vertices are chosen as a sample, results may vary between calls to this function

Value

a vector of length equal to `sample` giving the sizes of the set of vertices reachable from each seed vertex within the specified time bounds

Note

Needs implementation of backwards sets

Author(s)

skyebend

See Also

See also as [tPath](#)

Examples

```
data(moodyContactSim)
tReach(moodyContactSim)

# only sample 3 paths
tReach(moodyContactSim,sample=3)

# what fraction of the network could each vertex reach?
tReach(moodyContactSim)/network.size(moodyContactSim)

# what fraction of the network could each vertex be reached by?
tReach(moodyContactSim,direction='bkwd')/network.size(moodyContactSim)
```

Description

Temporal SNA tools for continuous- and discrete-time longitudinal networks. having vertex, edge, and attribute dynamics stored in the `networkDynamic` format. This work was supported by grant R01HD68395 from the National Institute of Health.

Details

This package provides tools for working with longitudinal network data in [networkDynamic-package](#) format. This data structure is essentially a list in the [network](#) format in which elements also have an attached [activity.attribute](#), a matrix of spells indicating when vertex or edge is active. The [networkDynamic](#) package provides tools ([networkDynamic](#)) for translating longitudinal data from various formats (timed edge lists, lists of toggles, sets of matrices, etc).

Currently the package consists of several groups of functions

- wrappers for 'static' social network analysis metrics and apply them at multiple time points
- functions that construct or use temporal paths through networks
- basic tools for measuring durations of ties, rates of change, etc
- utility functions for plotting, etc

The sections below provide some additional details. The package vignette (`browseVignettes(package='tsna')`) gives additional examples and illustrations of key concepts.

It is the intention that, like the [networkDynamic](#) package, [tsna](#) should support both continuous time and discrete time representations of networks. However, we are prioritizing development of discrete time measures suitable for use with simulation data (i.e. [stergm](#) models) so many of the functions are still missing the necessary arguments to facilitate binning.

Standard 'static' Sna metrics

These functions operate by collapsing the dynamic network into a static network at a series of regular intervals and returning the results as a time series [ts](#) object. They can provide general description of trends in a network dataset. Generally assumes that vertex set is not substantially changing.

- [tErgmStats](#) – descriptive stats (ergm terms) from the [ergm](#) package
- [tSnaStats](#) – descriptive stats from the [sna](#) package. Both graph- and vertex-level measures. centralities, components, reciprocity, betweenness, triad-census, etc.

Temporal path based metrics

These functions compute and use temporal paths (network geodesics that are constrained by the activity times of edges) through a network.

- [tPath](#)
- [tReach](#)

Rates and Duration

These functions can be used to compute distributions of (observed) activity durations in a data structure. Note that due to censoring (edges that begin before or end after the time observation window for the network) the observed durations may be biased away from the 'real' values (or model parameters). The duration estimate functions use various types of survival analysis to return estimates of these values.

- [edgeDuration](#)

- `vertexDuration`
- `tiedDuration`
- `tEdgeDissolution`
- `tEdgeFormation`
- `tiedDuration`

tsna Utilities

- `as.network.tPath`
- `plotPaths`
- `timeProjectedNetwork`

Data Sets

- `moodyContactSim`
- additional useful datasets provided by the `networkDynamicData` and `networkDynamic` packages

Source

This package is part of the statnet suite of packages <http://statnet.org>. For citation information see `citation('tsna')`.

tSnaStats	<i>Apply the sna package's static graph- and vertex-level network descriptive statistics at multiple time points</i>
-----------	--

Description

Samples collapsed static networks at regular intervals along a network dynamic object, applies the named static `sna` descriptive statistic function to each network, and returns the result as a time series. Additional arguments to the function can be included via `...`. Set the `sna` function's directedness and self-loops flags appropriately by default.

Usage

```
tSnaStats(nd, snafun, start, end, time.interval = 1, aggregate.dur=0, rule='latest', ...)
```

Arguments

nd	a <code>networkDynamic</code> object to be evaluated
snafun	character string giving the name of the <code>sna</code> package function to be applied. i.e 'mutuality'
start	optional numeric time value at which evaluation should start (default is first observed time)

<code>end</code>	optional numeric time value at which evaluation should end (default is last observed time)
<code>time.interval</code>	optional numeric value giving time interval between evaluations (default is 1)
<code>aggregate.dur</code>	optional numeric value giving the duration of time bin to aggregate over for each evaluation (default 0). See network.collapse
<code>rule</code>	character vector describing rule to be used if multiple attribute values are encountered when using non-zero <code>aggregate.dur</code> . Default is <code>latest</code> . See network.collapse for details
<code>...</code>	additional arguments to be passed on to the <code>sna</code> function. See docs for each function for possible arguments.

Details

This wrapper directly calls functions in the [sna](#) package, so it will only work if that package is installed. Below is a list of supported functions:

Graph-Level statistics:

- [components](#) Number of (Maximal) Components Within a Given Graph
- [triad.census](#) Davis and Leinhardt Triad Census
- [connectedness](#) Graph Connectedness Scores
- [dyad.census](#) Holland and Leinhardt MAN Dyad Census
- [efficiency](#) Graph Efficiency Scores
- [gden](#) Graph Density
- [grecip](#) Graph Reciprocity
- [gtrans](#) Graph Transitivity
- [hierarchy](#) Graph Hierarchy Scores
- [lubness](#) Graph LUBness Scores
- [mutuality](#) Graph Mutuality
- [centralization](#) Graph Centralization (must provide centrality measure)

Vertex-level statistics:

- [closeness](#) Vertex Closeness Centrality Scores
- [betweenness](#) Vertex Betweenness Centrality Scores
- [bonpow](#) Vertex Bonacich Power Centrality Scores
- [degree](#) Vertex Degree Centrality Scores
- [evcent](#) Vertex Eigenvector Centrality Scores
- [flowbet](#) Vertex Flow Betweenness Scores
- [graphcent](#) Vertex (Harary) Graph Centrality Scores
- [infocent](#) Vertex Information Centrality Scores
- [loadcent](#) Vertex Load Centrality Scores
- [prestige](#) Vertex Prestige Scores

Most of the sna functions involve converting the network to a matrix and can be quite expensive to calculate for a single time point, so use care when applying to large or long-duration networks.

Some of the sna functions are undefined or produce numerical errors when applied to networks with certain configurations (such as zero edges).

The sna functions generally cannot handle networks with no vertices, so stats will be replaced with NA when they are encountered.

There may be some overlap with ergm terms available through [tErgmStats](#) and the ergm version will generally be faster

Value

a `ts` (time series) object. A matrix in which rows correspond to the time points evaluated and columns correspond to values of statistics produced. In the case of vertex-level indices, there will be one column per vertex. For the census measures, each column will correspond to a census element.

Note

Note that this is an early DRAFT implementation. Does not yet include binning options needed for non-discrete time networks, and has not been tested with networks that have changing vertex activity.

Author(s)

skyebend@uw.edu

References

Carter T. Butts (2014). sna: Tools for Social Network Analysis. R package version 2.3-2. <http://CRAN.R-project.org/package=sna>

See Also

See also [tErgmStats](#),

Examples

```
library(networkDynamicData)
data(harry_potter_support)

# compute triad census scores for each time point
tSnaStats(harry_potter_support, snafun='triad.census')

# compute graph transitivity
tSnaStats(harry_potter_support, snafun='gtrans')
## Not run:
data(concurrencyComparisonNets)
# since these are big nets, with lots of timepoints,
# set time.interval to avoid evaluating every step
tSnaStats(base, 'prestige', time.interval=25, rescale=TRUE)
```

```
# since it is time series, easy to plot
plot(tSnaStats(base, 'components', time.interval=10))

## End(Not run)
```

Index

* datasets

- moodyContactSim, 6
- activity.attribute, 26
- as.data.frame.networkDynamic, 4, 21
- as.network.tPath, 2, 12, 27
- betweenness, 28
- bonpow, 28
- centralization, 28
- closeness, 28
- components, 28
- connectedness, 28
- degree, 28
- duration, 3
- dyad.census, 28
- edgeDuration, 26
- edgeDuration(duration), 3
- efficiency, 28
- evcent, 28
- flowbet, 28
- formation_and_dissolution, 5
- forward.reachable(reachable), 15
- gden, 28
- get.networks, 23
- get.vertex.activity, 4
- graphcent, 28
- grecip, 28
- gtrans, 28
- hierarchy, 28
- infocent, 28
- is.tPath(paths), 8
- loadcent, 28
- lubness, 28
- moodyContactSim, 6, 27
- mutuality, 28
- net.obs.period, 3
- network, 23, 26
- network.collapse, 19, 22, 23, 28
- networkDynamic, 5, 16, 17, 19, 21–23, 26
- paths, 3, 8
- plot.network, 11, 12
- plot.tPath, 11, 12
- plot.tPath(plotPaths), 11
- plot.ts, 20
- plotPaths, 11, 27
- prestige, 28
- pShiftCount, 13
- reachable, 15
- sna, 27, 28
- summary_formula, 19, 20
- tDegree, 16
- tEdgeDensity(temporal density), 17
- tEdgeDissolution, 27
- tEdgeDissolution
 - (formation_and_dissolution), 5
- tEdgeFormation, 27
- tEdgeFormation
 - (formation_and_dissolution), 5
- temporal density, 17
- temporalPath(paths), 8
- tErgmStats, 19, 26, 29
- tiedDuration, 20, 27
- timeProjectedNetwork, 22, 27
- tPath, 2, 11, 12, 15, 24–26
- tPath(paths), 8
- tReach, 24, 26
- triad.census, 28

ts, [5](#), [16](#), [19](#), [20](#), [26](#), [29](#)

tsna, [25](#)

tSnaStats, [26](#), [27](#)

vertexDuration, [27](#)

vertexDuration (duration), [3](#)