Network Diffusion of Innovations in R: Introducing **netdiffuseR**

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Acknowledgements

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netdiffuseR *has benefited from input provided by participants of the Center for Applied Network Analysis (CANA), and the Computational Social Science Lab (CSSL) at the University of Southern California.*

netdiffuseR*'s original code was developed by* **Thomas Valente***, improved by* **Stephanie Dyal** *and* **Timothy Hayes***, and extended by* **George Vega Yon***.*

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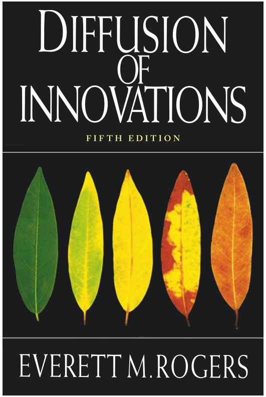
Motivation

Network Diffusion of Innovations



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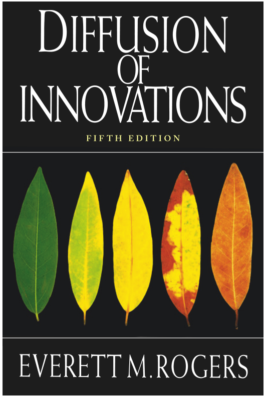

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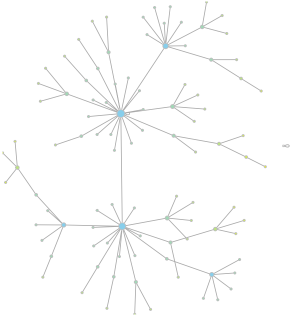

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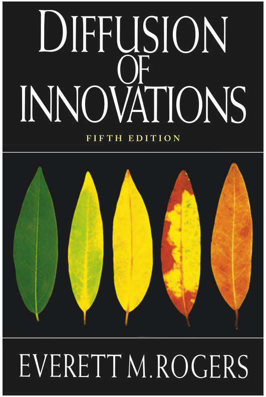

DIFFUSION OF INNOVATIONS
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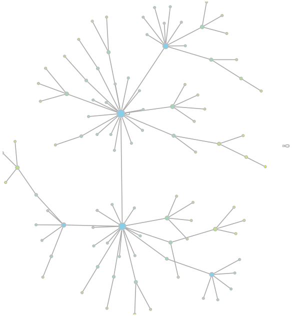

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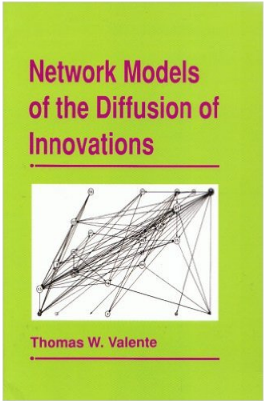

Network Models of the Diffusion of Innovations
Thomas W. Valente

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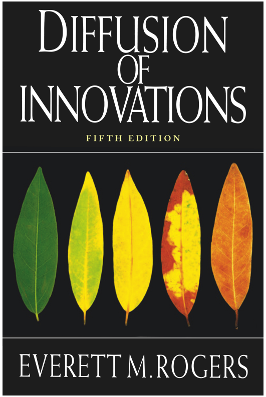

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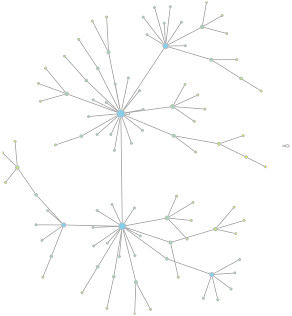

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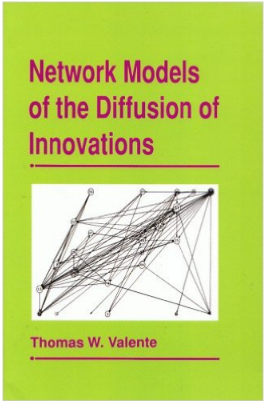

Network Models of the Diffusion of Innovations

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So what is Network Diffusion of Innovations anyway?

Motivation

Network Diffusion of Innovations

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- More complex than *contagion* $\Longrightarrow$ a single tie is no longer enough for an innovation to spread across a social system.

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- We think of this in terms of adoption thresholds and social exposure.

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Network Diffusion of Innovations

The basic idea

- Network thresholds (Valente, 1995), τ, are defined as the required proportion or number of neighbors that leads you to adopt a particular behavior (innovation), $a = 1$. In (very) general terms

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$$a_i = \begin{cases} 1 & \text{if } \tau_i \leq E_i \\ 0 & \text{Otherwise} \end{cases} \qquad E_i \equiv \frac{\sum_{j\neq i} \mathbf{X}_{ij} a_j}{\sum_{j\neq i} \mathbf{X}_{ij}} \tag{1}$$

Where E_i is i's exposure to the innovation and $\mathbf{X}$ is the adjacency matrix (the network).

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So now, what is **netdiffuseR**?

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- Already on CRAN (2 iterations) with 700 downloads since its first version, Feb 2016,
- A lot of features to make it easy to read network (dynamic) data, making it a nice companion of other net packages.

netdiffuseR: network diffusion of innovations in R

netdiffuseR distributes classical diffusion of innovations datasets:

	Medical Innovation	**Brazilian Farmers**	**Korean Family Planning**
Country	USA	Brazil	Korea
N Respondents	125 Doctors	692 Farmers	1,047 Women
N Communities	4	11	25
Innovation	Tetracycline	Hybrid Corn Seed	Family Planning
Time for Diffusion	18 Months	20 Years	11 Years
Year Data Collected	1955-1956	1966	1973
Ave. Time to 0.50	6	16	7
Highest Saturation	0.89	0.98	0.83
Lowest Saturation	0.81	0.29	0.44
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Very nice. . . But it's better to show it with examples!

The basics: Reading data

```r
library(netdiffuseR)
print(head(fakesurveyDyn))

##   id  toa group net1 net2 net3 age gender
## 1  1 1991     1   NA   NA   NA  30      M
## 2  2 1990     1    3    1   NA  35      F
## 3  3 1991     1   NA    2   NA  31      F
## 4  4 1990     1    6    5   NA  30      M
## 5  5 1991     1    4    4    3  40      F
## 6  1 1991     2    3    4    8  29      F
##                                                  note time
## 1                          First wave: No nominations 1990
## 2                           First wave: Nothing weird 1990
## 3                  First wave: Only nominates in net2 1990
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We can use the `survey_to_diffnet` function!

The basics: Reading data

```r
mydiffnet <- survey_to_diffnet(
  fakesurveyDyn,
  idvar     = "id",                     # Id of each vertex
  netvars   = c("net1", "net2", "net3"), # Net nominations (e.g. 'name 3 closest friends')
  toavar    = "toa",                    # Time of Adoption
  groupvar = "group",                   # Group (e.g. neighbor, village, etc.)
  timevar   = "time"                    # Timestamp
  )

# Print method
mydiffnet


## Dynamic network of class -diffnet-
##  # of nodes         : 9 (101, 102, 103, 104, 105, 201, 202, 205, ...)
##  # of time periods  : 2 (1990 - 1991)
##  Type               : directed
##  Final prevalence   : 1.00
##  Static attributes  : -
##  Dynamic attributes : group, net1, net2, net3, age, gender, note, time (8)
```

This is a `diffnet` object.

The basics: `diffnet` objects

`diffnet` are

Lists that contains (among other things):

- A list of `dgCMatrix` objects (sparse matrices),
- A set of `data.frames` with vertex attributes,
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Nice objects with a lot of methods

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`print, summary, plot`	The usual deal
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Other special functions

`exposure (threshold)`	Basic net-diff stats
`infection, susceptibility`	Some friends from epi
`struct_equiv`	Burt's (1987) structural equivalence
`struct_test`	We'll see this later. . .

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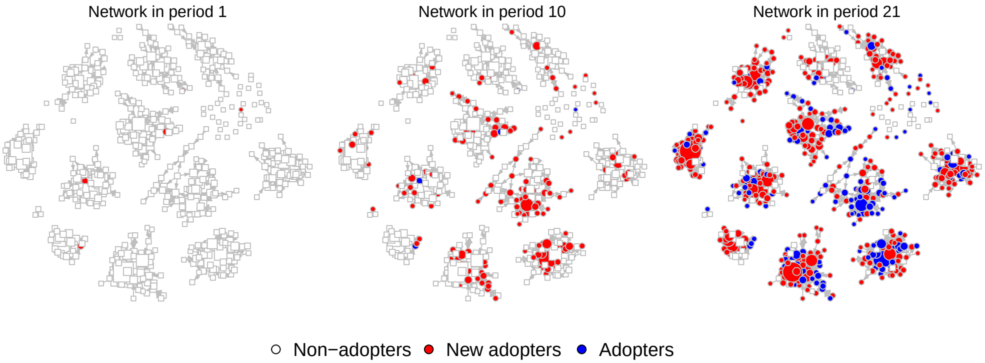
So, what can we do with `diffnet` objects?

Visualizing Diffusion: `plot_diffnet`



Network in period 1

Network in period 10

Network in period 21

Figure: Diffusion of Hybrid Corn Seed (Brazilian Farmers) - 11 communities/20 years.

Visualizing Diffusion: `plot_diffnet2`

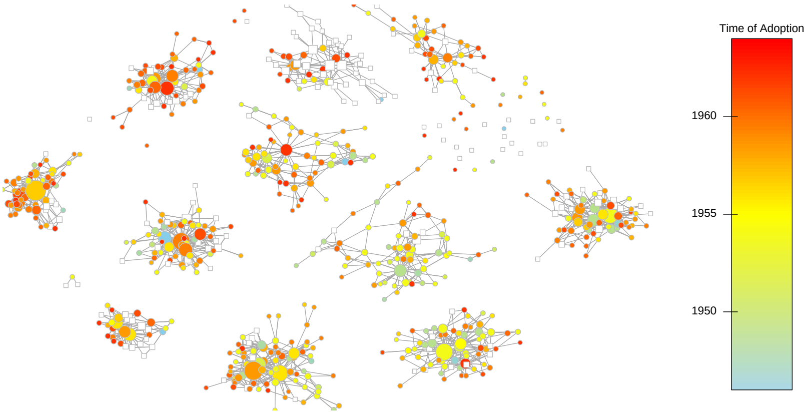


Figure: Diffusion of Hybrid Corn Seed (Brazilian Farmers) - 11 communities/20 years.

Visualizing Diffusion: `plot_infectsuscept`

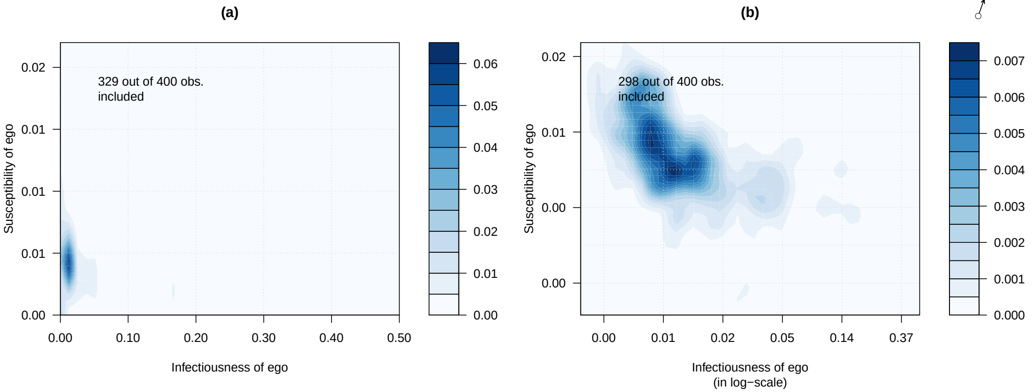


Figure: Joint distribution of Infectiousness and Susceptibility in a random bernoulli diffusion network: (b) shows (a) with log-scale.

Visualizing Diffusion: `plot_threshold` (a classic)

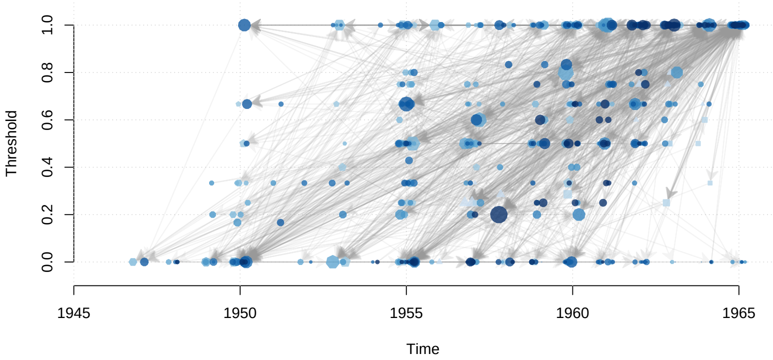


Figure: Adoption thresholds and times of adoption for the Brazilian Farmers: Colors and shapes represent villages. Size is scaled accordingly to each vertex degree.

Visualizing Diffusion: `classify_adopters` (also a classic)

	Very Low Thresh.	Low Thresh.	High Thresh.	Very High Thresh.
Early Adopters	14.04	8.40	0.57	0.29
Early Majority	5.64	11.65	5.54	2.58
Late Majority	1.34	5.06	6.21	2.96
Laggards	1.53	0.00	0.00	34.19

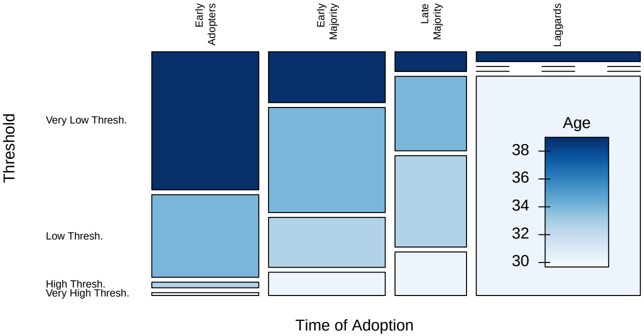


Figure: Adopters classification in the Korean Family data: From the mosaic we can see that in general low threshold levels and early adoption seems to be positively correlated with age.

What about **netdiffuseR** being big??

Visualizing Diffusion: `plot_diffnet2` w/ big graph

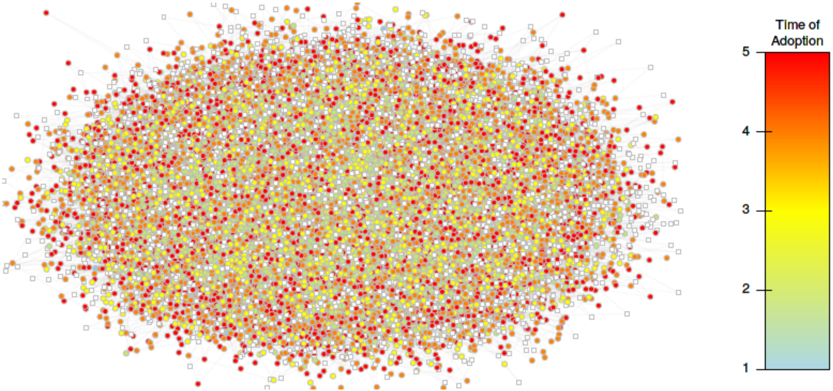
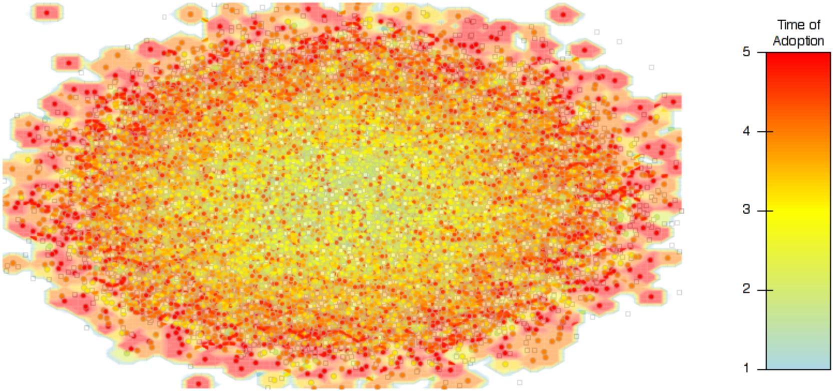


Figure: Random scale-free diffusion network: With 5e4 vertices, diffusion started at the central nodes.

Visualizing Diffusion: `plot_diffnet2 + diffmap` w/ big graph



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But. . . be careful with this!

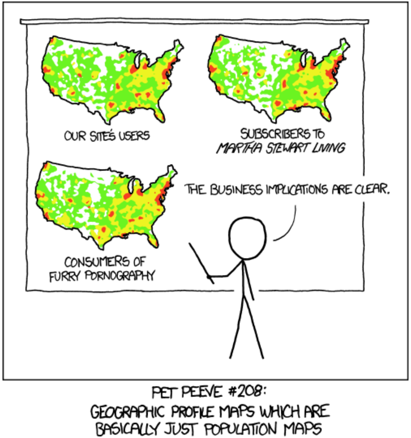

OUR SITE'S USERS
SUBSCRIBERS TO MARTHA STEWART LIVING
CONSUMERS OF FURRY PORNOGRAPHY
THE BUSINESS IMPLICATIONS ARE CLEAR.
PET PEEVE #208:
GEOGRAPHIC PROFILE MAPS WHICH ARE BASICALLY JUST POPULATION MAPS

Figure: The heatmaps pitfall (source `xkcd.com/1138`)

Simulating Diffusion Process: `rdiffnet`

Simulations are a big thing in **netdiffuseR**. The `rdiffnet` function features:

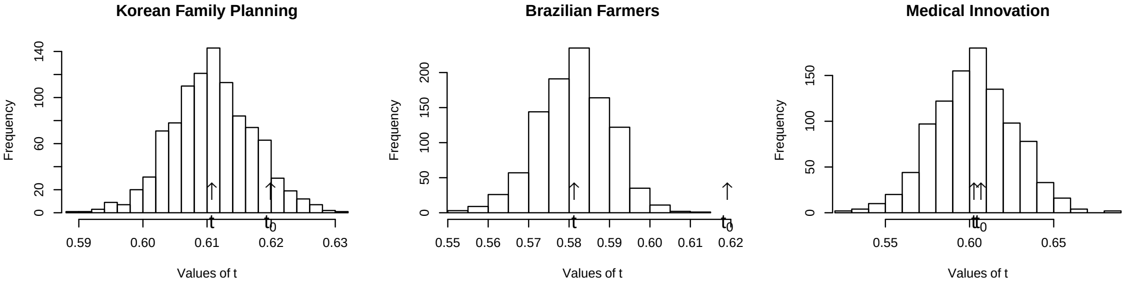
```r
set.seed(887)
mydn <- rdiffnet(
  n=1e3, t=5, # Number of vertices and time points
  seed.nodes     = "random", # Set of initial adopters
  seed.p.adopt   = .15, # Proportion of initial adopters
  seed.graph     = "small-world", # Baseline graph
  rgraph.args    = list(p=4), # Arguments for the rgraph call
  rewire.args    = list(algorithm="swap", p=5), # Rewiring args after time 1
  threshold.dist = function(x) runif(1, .4, .8), # Distribution of thresholds
  exposure.args  = list(normalized=TRUE) # Args for computing exposures
)
```

Statistical inference: `struct_test`

$$H_0 : \mathcal{G} \perp \text{Time of Adoption (random time of adoption)}$$

$$H_a : \mathcal{G} \not\perp \text{Time of Adoption (not random time of adoption)}$$

	Korean Family	Brazilian Farmers	Medical Innovation
p-val	0.1440	0.0000	0.8440
Obs. Avg. threshold t_0	0.6199	0.6191	0.6067
Sim Avg. threshold $\bar{t}$	0.6107	0.5813	0.6026


Korean Family Planning

Brazilian Farmers

Medical Innovation

Concluding remarks

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    - Health behavior diffusion (tobacco, drinking, etc.),
    - Memes on social media,
    - Country-level spill over effects (FCTC)
    - ... social contagion (human or not) in general.[1]

[1] Social learning in animals, see Franz and Nunn (2009)

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- Provides out-of-the-box tools for network diffusion analysis (both classic and new),
- Complements your favorite SNA R package–**igraph**, **statnet**, **RSiena**, etc. (and further, work is been done to extend it to others *s.a.* **spdep**, **spatialprobit**)

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  - ... social contagion (human or not) in general.[1]
- Provides out-of-the-box tools for network diffusion analysis (both classic and new),
- Complements your favorite SNA R package–**igraph**, **statnet**, **RSiena**, etc. (and further, work is been done to extend it to others *s.a.* **spdep**, **spatialprobit**)
- Is on active development, so stay tuned for more to come!

[1] Social learning in animals, see Franz and Nunn (2009)

Thank you!

More info

https://github.com/USCCANA/netdiffuseR

http://cana.usc.edu

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Sesssion Info

version	R version 3.3.1 (2016-06-21)
system	x86_64, darwin15.5.0
ui	unknown
language	(EN)
collate	en_US.UTF-8
tz	America/Los_Angeles
date	2016-06-29

package	*	version	date	source
boot		1.3-18	2016-02-23	CRAN (R 3.3.1)
devtools		1.12.0	2016-06-24	CRAN (R 3.3.1)
digest		0.6.9	2016-01-08	CRAN (R 3.3.1)
evaluate		0.9	2016-04-29	CRAN (R 3.3.1)
formatR		1.4	2016-05-09	CRAN (R 3.3.1)
highr		0.6	2016-05-09	CRAN (R 3.3.1)
igraph		1.0.1	2015-06-26	CRAN (R 3.3.1)
knitr	*	1.13	2016-05-09	CRAN (R 3.3.1)
lattice		0.20-33	2015-07-14	CRAN (R 3.3.1)
magrittr		1.5	2014-11-22	CRAN (R 3.3.1)
MASS		7.3-45	2016-04-21	CRAN (R 3.3.1)
Matrix		1.2-6	2016-05-02	CRAN (R 3.3.1)
memoise		1.0.0	2016-01-29	CRAN (R 3.3.1)
netdiffuseR	*	1.16.6	2016-06-27	local
Rcpp		0.12.5	2016-05-14	CRAN (R 3.3.1)
rstudioapi		0.5	2016-01-24	CRAN (R 3.3.1)
sna		2.3-2	2014-01-14	CRAN (R 3.3.1)
SparseM		1.7	2015-08-15	CRAN (R 3.3.1)
stringi		1.1.1	2016-05-27	CRAN (R 3.3.1)
stringr		1.0.0	2015-04-30	CRAN (R 3.3.1)
withr		1.0.2	2016-06-20	CRAN (R 3.3.1)
xtable	*	1.8-2	2016-02-05	CRAN (R 3.3.1)