The co-evolution of one-mode and two-mode networks

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One-mode and two-mode networks

The combined consideration of one-mode and two-mode networks
is very fruitful because it allows to consider
the mutual dependencies between (one-mode) relational networks
and (two-mode) activities and/or memberships and/or cognitions
and/or internal structure and/or details of behavioral tendencies and/or ....

These slides are about the co-evolution of one-mode and two-mode networks
according to the Stochastic Actor-oriented Model.

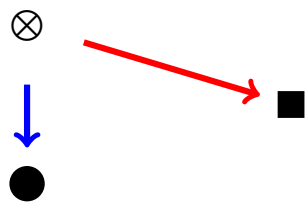
One-mode – two-mode dependencies

Two-mode networks have less structure, so that there are fewer effects.

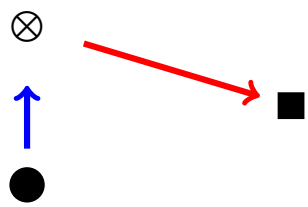
Within-dyad dependencies are undefined.

Actor-level dependencies are meaningful.

mixed activity



mixed popularity
⇒ activity

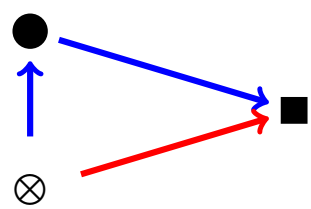


Closed triads are impossible in bipartite networks;
but they are possible as mixed patterns.

One-with-two-mode triads.

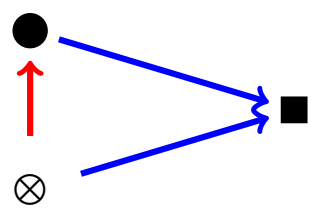
One-mode tie ⇒
two-mode agreement
'I go to places where my friends are'

association-based affiliation closure



Two-mode agreement ⇒ one-mode tie
'Those who go to the same places
become friends'

affiliation-based focal closure



The two different ways in which this mixed triadic closure can occur implies that, analogous to the distinction influence $\leftrightarrow$ selection in network-behavior co-evolution,
in the co-evolution of a one-mode and a two-mode network there is the distinction between
focal closure and *affiliation closure*,
also called *affiliation-based closure* and *association-based closure*.

(One-mode: *association*;
two-mode: *affiliation, focus*).

E.g., Easley and Kleinberg (2010, Section 4.3); Lomi and Stadtfeld (2014).

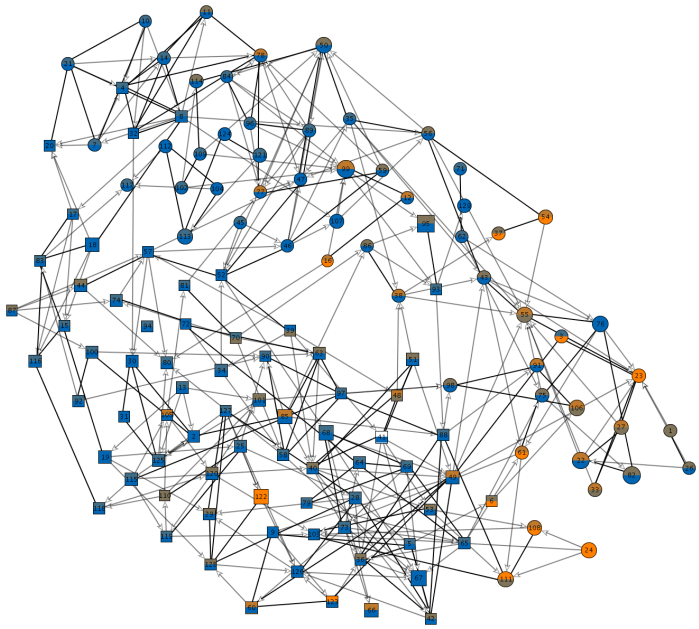
Example 1: Glasgow friends and pastimes

Example:
West of Scotland 11-16 Study; West et al. (1996 and later).

One school year group from a Scottish secondary school
starting at age 12-13 years, monitored over more than 2 years;
total of 160 pupils, sociometric & behavior questionnaires
at three moments, at appr. 1 year intervals.

First network: friendship;
second network (two-mode): activities.

covariates:
gender, smoking of parents and siblings (binary),
money available (range 0–40 pounds/week).

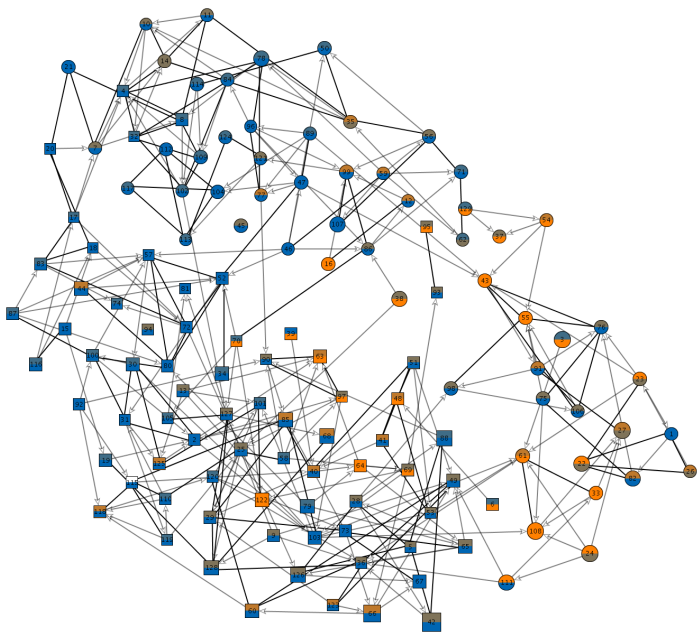


wave 1

girls: circles
boys: squares

node size: pocket money

color: top = drinking
bottom = smoking
(orange = high)



wave 2

girls: circles
boys: squares

node size: pocket money

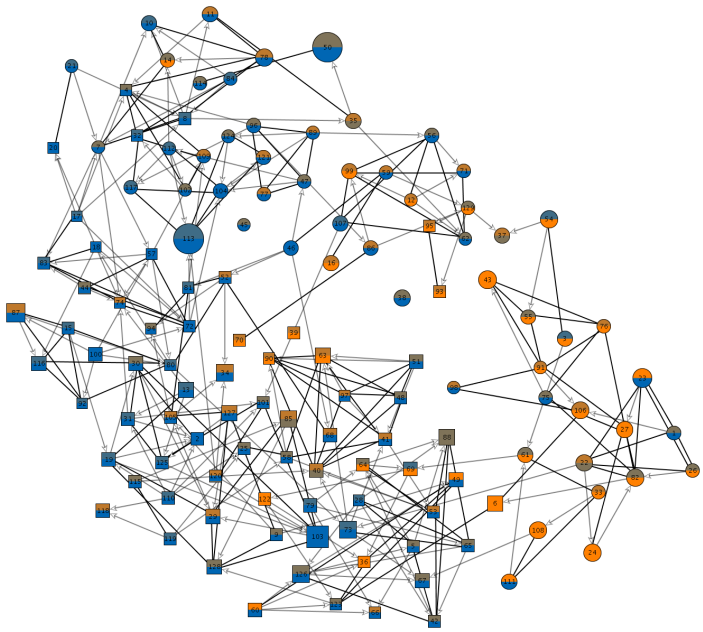
color: top = drinking
bottom = smoking
(orange = high)

wave 3

girls: circles
boys: squares

node size: pocket money

color: top = drinking
bottom = smoking
(orange = high)



Descriptives for friendship

Three waves $\sim$ two periods.

Average degrees 3.7; 3.5; 3.6.

Amount of stability in network ties measured by Jaccard coefficient

$$J = \frac{N_{11}}{N_{01} + N_{10} + N_{11}}$$

where $N_{hk} =$ number of tie variables
with value h at one wave and value k at the next.

J = 0.30; 0.35 for the two periods.

Descriptives for leisure activities

Three waves $\sim$ two periods.

Average degrees 4.7; 4.0; 3.9.

Amount of stability in activities also measured by Jaccard coefficient

$$J = \frac{N_{11}}{N_{01} + N_{10} + N_{11}}$$

where $N_{hk} =$ number of tie variables
with value h at one wave and value k at the next.

J = 0.51 for both periods.

Second mode: Leisure time activities

	daily	weekly	monthly	less
I listen to tapes or CDs	**388**	23	5	16
I look around in the shops	**65**	290	48	30
I read comics, mags or books	**186**	121	65	60
I go to sport matches	**30**	**113**	90	200
I take part in sports	**218**	117	30	68
I hang round in the streets	**216**	64	26	125
I play computer games	**157**	109	45	122
I spend time on hobby (e.g. art, instrument)	**114**	113	36	170
I go to something like B.B., Guides or Scouts	**36**	**81**	1	314
I go to cinema	**11**	**81**	269	71
I go to pop concerts, gigs	**7**	**6**	**92**	326
I go to church, mosque or temple	**2**	**52**	**10**	368
I look after a pet animal	**197**	25	6	203
I go to dance clubs or raves	**15**	**44**	**104**	266
I do nothing much (am bored)	37	39	24	331

Number of students participating in each of a list of activities, summed over three waves, for Glasgow data.
Bold-faced are categories counted as a tie.

Results

The table of results is distributed over 4 pages:

- friendship: the basis
- friendship: effects of leisure activities
- leisure: the basis
- leisure: sex-related specializations.

Friendship: basic

Effect	par.	(s.e.)
rate period 1	12.383	(1.217)
rate period 2	9.870	(1.132)
Friendship: endogenous effects		
outdegree (density)	–3.633***	(0.258)
reciprocity	3.337***	(0.311)
GWESPFF: creation ($\alpha = 0.69$)	3.350***	(0.301)
GWESPFF: maintenance ($\alpha = 0.69$)	0.273	(0.385)
indegree - popularity	–0.079***	(0.020)
outdegree - activity	0.121***	(0.036)
reciprocated degree - activity	–0.303***	(0.071)
indegree - activity	0.001	(0.056)
Covariate effects		
girls alter	–0.124	(0.085)
girls ego	0.032	(0.086)
same gender	0.446***	(0.082)

Friendship: effects of leisure activities

Effect	par.	(s.e.)
Friendship: effects of leisure		
leisure outdegree popularity	–0.046	(0.037)
leisure outdegree activity	–0.087*	(0.037)
affiliation-based closure	0.213**	(0.073)

Leisure: basic

Effect	par.	(s.e.)
Activities		
rate period 1	4.386	(0.293)
rate period 2	4.254	(0.313)
Endogenous effects of activities		
outdegree (density)	–2.149***	(0.333)
4-cycles	0.0272***	(0.0073)
indegree - popularity	0.0269**	(0.0084)
outdegree - activity	0.389***	(0.086)
out-in degree assortativity	–0.0128***	(0.0027)
Effects of friendship on activities		
friendship indegree activity	0.001	(0.039)
friendship outdegree activity	–0.148*	(0.073)
association-based closure	0.351***	(0.062)

Leisure: two-mode sex homophily

Homophily in two-mode networks is treated in
`https://www.stats.ox.ac.uk/~snijders/siena/Twomode_s.pdf`

Effect	par.	(s.e.)
Effects of sex on activities		
girls ego	–0.870**	(0.313)
4-cycles among girls	0.0027	(0.0065)
girls × outdegree - activity	0.066*	(0.029)
indegree - popularity within girls	0.0242*	(0.0098)
indegree - popularity within boys	0.0091	(0.0103)

Leisure homophily only for girls!

The leisure-only model did show leisure homophily also for boys.
This is 'explained away' here by association-based closure.

Example 2: American high school

Other example, based on Fujimoto, Snijders, & Valente (*NWS*, 2018).

US high school, X = friendship, Z = sport activities.

Descriptives

Two waves $\sim$ one period.

$n = 309$ students, $m = 16$ sports,
X = friendship, Z = sport participation in past 12 months.

Average friendship degrees 6.6, 6.2;
Jaccard similarity 0.25.

Average sport out-degrees 1.2, 1.1;
Jaccard similarity 0.44.

Again, four pages of results.

Results: friendship (1)

Effect	par.	(s.e.)
outdegree	–3.519***	(0.413)
reciprocity	2.775***	(0.171)
transitive triplets	0.398***	(0.032)
transitive reciprocated triplets	–0.293***	(0.071)
3-cycles	0.101	(0.064)
transitive ties	0.425***	(0.073)
indegree - popularity	0.022***	(0.005)
outdegree - popularity	–0.065***	(0.009)
outdegree - activity	0.011	(0.023)
outdegree - activity ($\sqrt{}$)	0.154	(0.187)
reciprocal degree - activity	–0.079***	(0.015)
outdegree positive	–0.776	(0.763)
gender (F) alter	–0.035	(0.041)
gender (F) ego	0.093*	(0.042)
same gender	0.363***	(0.047)
same gender $\times$ reciprocity	–0.442**	(0.136)

Results: friendship (2)

Effect	par.	(s.e.)
hispanic alter	0.013	(0.065)
hispanic ego	–0.045	(0.063)
same hispanic	0.144*	(0.064)
grade alter	–0.021	(0.022)
grade ego	–0.026	(0.023)
grade similarity	0.317***	(0.088)
same class	0.564***	(0.091)
same class × reciprocity	–0.210	(0.154)
same class × same gender	–0.041	(0.107)

Results: sports

Effect	par.	(s.e.)
outdegree	–2.369***	(0.613)
4-cycles	0.041	(0.030)
indegree - popularity	0.020**	(0.007)
outdegree - activity	–0.029	(0.102)
outdegree positive	–2.116***	(0.592)
gender ego (F)	0.023	(0.184)
two-mode gender similarity	1.750***	(0.416)
4-cycles same gender	–0.085*	(0.039)
hispanic ego	–0.599**	(0.222)
grade ego	0.299**	(0.115)

Strong evidence for homophily!

Results: cross-networks

Effect	par.	(s.e.)
Sports ⇒ *Friendship*		
outdegree ($\sqrt{}$) sports activity	–0.106**	(0.038)
affiliation-based closure	0.159**	(0.057)
Friendship ⇒ *Sports*		
friendship outdegree ($\sqrt{}$) activity (eval.)	0.171	(0.468)
friendship outdegree ($\sqrt{}$) activity (maint.)	–1.386	(1.063)
association-based closure (evaluation)	0.442*	(0.187)
association-based closure (maintenance)	0.646	(0.452)

Those mentioning more sports mention fewer friends;
shared sport activities lead to friendship;
friendship leads to shared sport activities
(not different for creating or maintaining activities).

Discussion

⇒ See Snijders, Lomi & Torlò in *Social Networks*, 2013
Fujimoto, Snijders & Valente (*Network Science*, 2018),
Lomi & Stadtfeld (*KZfSS*, 2014).

⇒ It's a multilevel issue (but not nested):
ties, dyads, actors, triads, subgroups, ...

⇒ Testing cross-network dependencies in
dynamics of multiple networks gives interesting
new possibilities for hypothesis testing.

⇒ Elaborated along the lines of actor-based modeling.

⇒ Compared to modeling dynamics of single networks,
this approach attenuates the Markov assumption
by extending the state space to a multiple network.

⇒ New perspectives possible
by combining one-mode and two-mode networks.

⇒ The method is available in RSiena.
This works for a small number (e.g., 2–6) of networks,
and a limited number of actors (up to a few hundred).

⇒ If there are implication relations between the networks,
e.g., two networks might be mutually exclusive,
or one might be a sub-network of the other,
then this constraint is observed, noted in the `print01Report`, and
respected in the simulations.
This gives possibilities for networks with valued ties
by using different dichotomies.