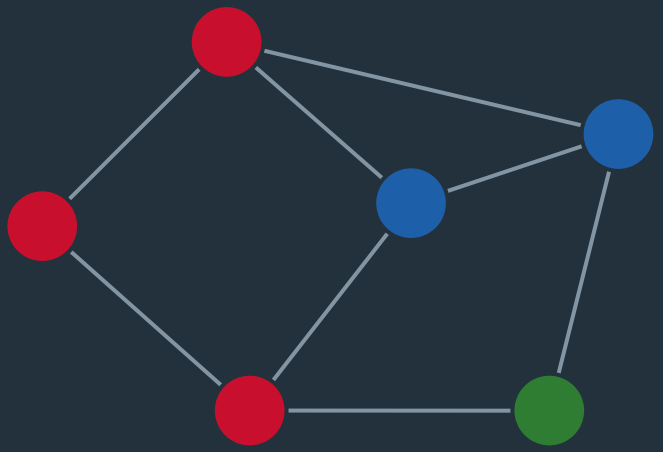
Change between waves

Course B · Week 8

Chapter 14 and the first part of Chapter 25 of Network Analysis with Stata (Stata Press) · one lecture and one lab, about 90 minutes each

Instructors are free to use, adapt and share these slides.



Today: a lecture, a break and a lab

0:00	**1 A network seen twice**	20 min
0:20	**2 How much changed, and where**	35 min
0:55	**3 From two snapshots to the process**	35 min
1:30	Break	10 min
1:40	**4 Lab: turnover and pictures of change**	45 min
2:25	**5 Lab: the first look at a panel model**	45 min

A network observed once cannot show how it changes

A snapshot

A still photograph of something that moves. Ties are made and lost through choices, meetings and events, and none of that is visible in one picture.

Two or more waves

How much of the network persists, how much is new, how fast it is changing. The same relation observed on the same actors, again.

A directional question

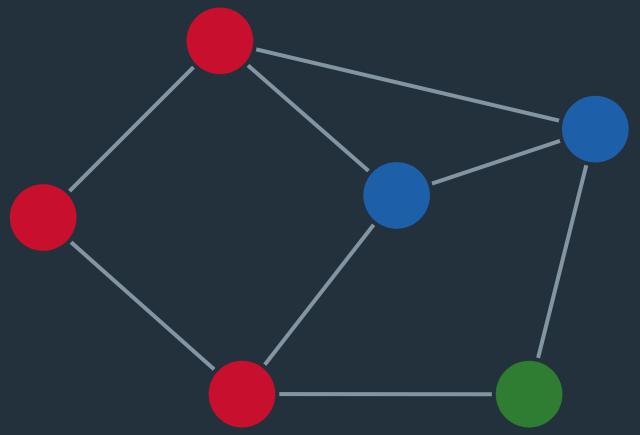
Did friends come to drink alike because they were friends, or did they become friends because they drank alike? Only repeated observation can start to tell.

The question of the week: how much did the network change between observations, and what can two snapshots support?

1

A network seen twice

20 min · Chapter 14: waves, a panel, stable, formed and dissolved ties, the Glasgow data



Waves are fixed observation points; what happens between them is invisible

Wave

One round of data collection. On its own, a wave is a static network.

Panel

Three or more waves on the same set of actors: what makes the networks a panel is the shared node set.

Interval

A longer interval shows more change. A friendship formed and ended within the year leaves no trace.

Design, not computation: choose the interval to fit how fast the relation moves, or collect timestamped ties.

Between two waves, every possible tie is stable, formed, dissolved or absent

	present in wave 2	absent in wave 2
present in wave 1	**stable**	dissolved
absent in wave 1	formed	no tie in either wave

```
Jaccard     = stable / (stable + formed + dissolved)
persistence = stable / (stable + dissolved)
```

Formed and dissolved are differences between two recorded states, not counts of the events in between.

Jaccard index

Stable ties over the ties present in either wave. 1 when nothing changes, 0 when nothing persists.

Persistence

The share of the first wave's ties still present in the second wave. A different denominator: the ties of wave 1.

The Glasgow panel: 50 girls, three waves about a year apart

```
. nwwebuse glasgow, nwclear
. nwsummarize glasgow1
   Nodes: 50
   Arcs: 113
   Density: .0461
   Mean outdegree:  2.26
```

Wave	Ties	Density
glasgow1	113	.0461
glasgow2	116	.0473
glasgow3	122	.0498

50 girls, three nomination lists

Directed friendship nominations at three waves about a year apart: glasgow1, glasgow2, glasgow3.

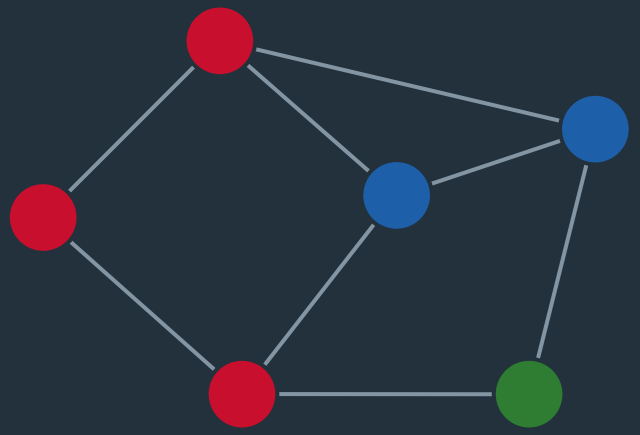
Attributes

smoke1 and sport1 at wave 1; alcohol1, alcohol2 and alcohol3 at the three waves. Week 9 uses the drinking.

2

How much changed, and where

35 min · Chapter 14: nwturnover, who changed, nodexy() and nwmovie, formed ties, what description cannot say



Between waves 1 and 2, 57 ties stayed, 59 formed and 56 dissolved

```
. nwturnover glasgow1 glasgow2, generate(_turnover)
------------------------------------------
  Networks: glasgow1 -> glasgow2
  Stable: 57  Formed: 59  Dissolved: 56
  Jaccard index: .331
  Persistence: .504
```

Stable: present in both waves. Formed: absent, then present. Dissolved: present, then absent.

generate() is required

_turnover holds each girl's own Jaccard index, computed from her own ties alone.

0.33

Jaccard index: 57 stable ties of the 172 present in either wave

0.50

persistence: 57 of the 113 ties of wave 1

The second year is somewhat more stable, and the tie counts hide the turnover

```
. nwturnover glasgow2 glasgow3, generate(_turnover) ///
>     replace
  Networks: glasgow2 -> glasgow3
  Stable: 66  Formed: 56  Dissolved: 50
  Jaccard index: .384
  Persistence: .569
```

Waves	Stable	Formed	Dissolved	Jaccard	Persist.
1 to 2	57	59	56	0.331	0.504
2 to 3	66	56	50	0.384	0.569

- **The tie counts hide the turnover**

  113, 116 and 122 ties: formed minus dissolved is only 3 and 6, and the density stays near .05. Yet about half of the ties of one wave are not present in the next. Formation and dissolution roughly cancel.

Twelve girls replaced every friend they had; eight kept every one

```
. nwturnover glasgow1 glasgow2, generate(_turnover) replace
. summarize _turnover
    _turnover |         48    .3944444    .3421413          0          1
. count if _turnover == 0
  12
. count if _turnover == 1
  8
. count if missing(_turnover)
  2
```

12

girls kept none of their ties

8

girls kept every tie

Missing for two girls

n13 and n20 have no ties in either wave, so their own Jaccard index is undefined.

Same total, different change

Ten girls who replace all friends and fifty who each replace one give the same counts. The girl-level index tells them apart.

What a Jaccard index of 0.33 says, and three ways to misread it

It says

About a third of all friendship nominations present at either wave were present at both.

It does not say

That two thirds of the friendships were lost or that the data are unreliable. Some turnover is error and some is change, and the index cannot tell which. Nor is it the speed of change: ties formed and dissolved within the interval are never seen.

Different instruments

A different ceiling on the number of friends named produces turnover that is measurement.

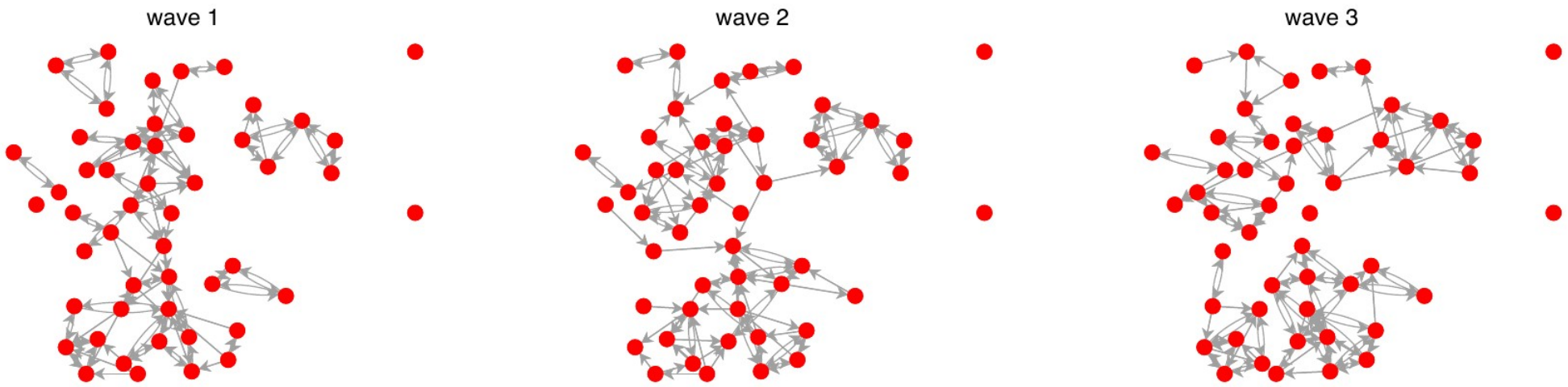
Different intervals

An index after one month and one after two years are not comparable.

A movie instead of statistics

An animation shows where change happened, not how much; a lively one makes a stable network look volatile.

Every girl at the same position: each panel difference is a real tie change



Layout computed once on the union of the waves; every change from panel to panel is a real tie change (Chapter 14, Figure 14.1).

```
. nwplot glasgowall, generate(x y)
. nwplot glasgow1, nodexy(x y) title("wave 1") name(g1, replace)
```

A movie shows where the changes happened, not how many

```
. nwmovie glasgow1 glasgow2 glasgow3, ///
>     fname(glasgow_movie) noopen
Resolving network glasgow1 (1/3)...
...
Wrote glasgow_movie.html
```

```
. nwmovie glasgow1 glasgow2 glasgow3, duration(2000) ///
>     fixedlayout export(glasgow.mp4) replace
Wrote glasgow.mp4
```

export() writes .mp4, .webm or .gif; duration() sets the milliseconds per change.

One page, three waves

The page plays the waves in turn. By default the layout drifts; fixedlayout keeps the first wave's positions.

Intuition, not measurement

Use it to see where the changes are. Report the turnover statistics for how much.

Formed ties return a received tie or close a two-path far more often than chance

```
. nwturnover glasgow1 glasgow2, generate(_turnover) ///
>     replace formation
  Formed ties, compared with all pairs without a tie in glasgow1:
                            Formed    No tie
    Pairs                       59      2337
    Return a tie             0.186     0.015
    Close a two-path         0.153     0.053
```

Share of	1 to 2 formed	no tie	2 to 3 formed	no tie
Return a tie	0.186	0.015	0.268	0.020
Close a two-path	0.153	0.053	0.446	0.057

Second output: 56 formed ties among 2,334 pairs (waves 2 to 3).

Two mechanisms, descriptively

A formed tie from i to j returns a tie if j had named i in the first wave, and closes a two-path if i had named someone who named j. The comparison group is every pair without a tie in the first wave: 2,337 and 2,334 pairs. In the first interval, 11 of 59 formed ties returned a tie and 9 closed a two-path.

These shares are descriptions; the models of the next weeks add what they cannot

It says
New ties are many times likelier than a random pair without a tie to return a tie or to close a two-path, in both intervals.

It does not say
That reciprocity or transitivity drives friendship formation. Girls in one class nominate each other and share friends, the two shares overlap, and 59 and 56 ties in one cohort leave room for chance.

Data	Model	Chapter
A few waves of the same actors	SAOM	23, 24
Timestamped events	relational event model	25
Events that actors initiate	dynamic network actor model	26
One observation	ERGM	21, 22

The data structure decides the model

This week and next: the first row.

When ties carry timestamps, nwattime gives a static network at any time

```
. nwset ego alter, edgelist undirected time(wave) name(evolving)
. nwsummarize evolving
   Edges: 6
   Temporal: true
      Temporal type: snapshot
. nwattime evolving, at(1) name(snap1)
  Static graph view: snap1   At: 1   Ties: 3
. nwattime evolving, at(2) name(snap2)
  Static graph view: snap2   At: 2   Ties: 2
```

Input: the six ties of the chapter, Anna-Sophie, Sophie-Gwen, Gwen-Anna at wave 1, Gwen-Leh and Anna-Leh at wave 2, Leh-Sophie at wave 3.

Snapshot type

at(t) returns the ties tagged with exactly that wave. It does not accumulate earlier ties or carry a tie forward.

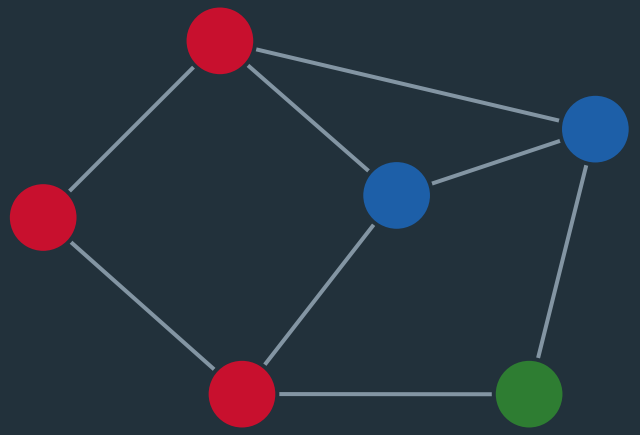
Say what a timestamp means

First appearance, an event, or an interval of activity: a reader cannot recover it from the numbers.

3

From two snapshots to the process

35 min · Chapter 25: the ministep process, rate and objective function, a first model, nwsaom describe



A panel records the net result of an unseen sequence of small changes

Many paths, one result

A friendship that formed in October and ended in March leaves no trace in a panel observed in September and June.

Changes are linked

Whether a pupil befriends a classmate may depend on a shared friend that was itself formed earlier in the same interval.

Not wave 2 given wave 1

A QAP regression of wave 2 on wave 1 compresses the sequence into one step and cannot show how one change creates the conditions for the next.

The remedy: model the process between the waves, and treat each wave as an observation of it.

Four assumptions turn the unseen process into a model

Small steps in continuous time

At any moment at most one tie changes; a larger difference between waves is the accumulation of many ministeps.

Markov

The next ministep depends on the current network and attributes, not on how the network got there.

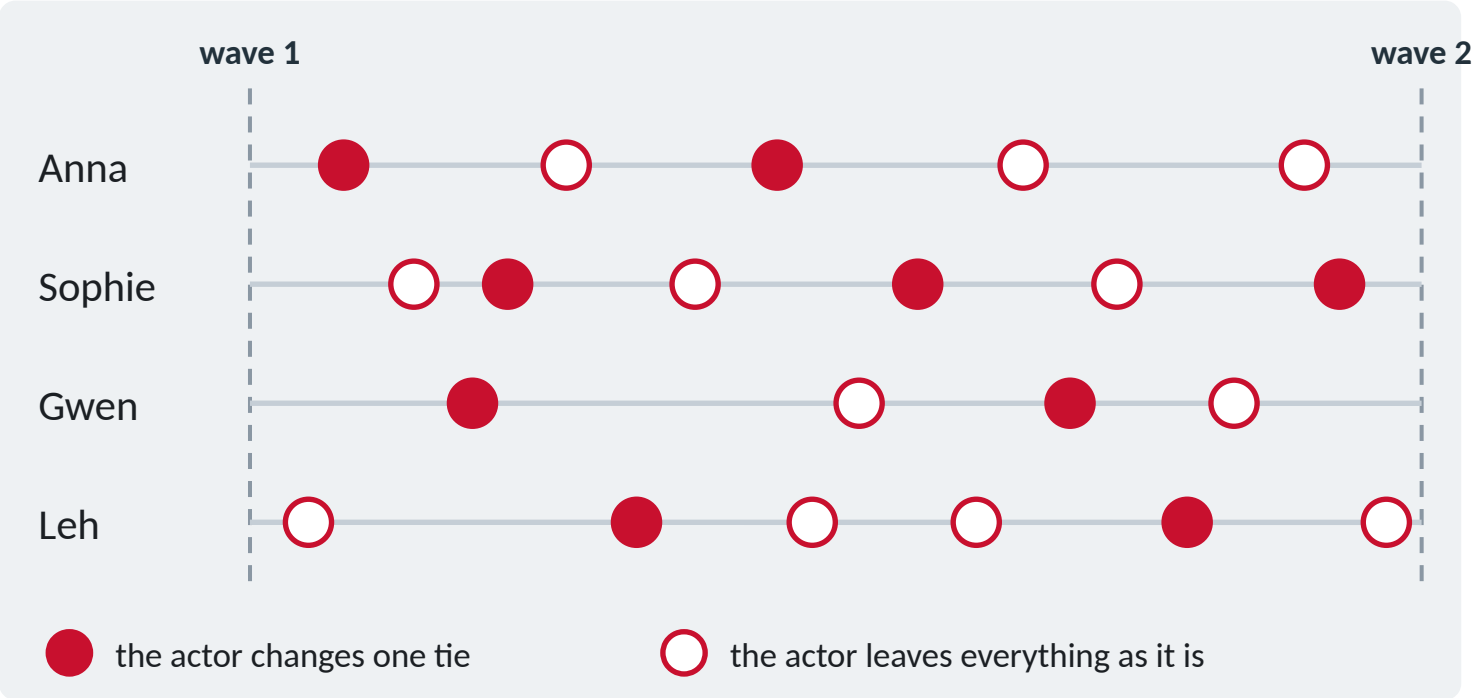
Actors control outgoing ties

Each ministep is a choice by one actor about one of its own ties: create one, dissolve one, or leave everything as it is.

Myopic choice

An actor compares the networks its options would produce, with an objective function, and does not plan ahead.

Each actor's clock ticks at a rate; a tick is one chance to change one tie



Schematic, not data: the tick times are invented.

Rate

The expected number of opportunities per actor between two waves. It says how often, not what.

A tick is a chance

The actor may create a tie, dissolve one or change nothing. The panel never shows the ticks.

The objective function decides what an activated actor does with the chance

```
objective function:  f_i(x) = theta_1 s_i1(x) + theta_2 s_i2(x) + ...
choice (one multinomial logit):  P(i chooses x') = exp{f_i(x')} / sum of exp{f_i(x'')}
```

The choice set

Every network one tie-change away from the current one under i's control, and the current network itself: add a tie, drop a tie, or leave things as they are.

Reading a coefficient

Of two alternatives that differ by one unit of a statistic, the one with the higher f_i is more likely by a log-ratio equal to the coefficient. Preferences at the moment of choosing; nothing about how often.

An SAOM models one actor's choice; an ERGM models the whole graph

	ERGM (Weeks 5 to 7)	SAOM (Weeks 8 to 10)
Outcome	the whole network, one joint distribution	the change of one actor's outgoing ties, a step at a time
Data	one observed network (standard form)	panel waves of the same actors (standard form)
Statistics	counted across the whole graph	nested in the actor's own ties
Estimation	Monte Carlo maximum likelihood	Method of Moments, by simulation

Effects with the same name are different statistics: adding the tie i to j raises an ERGM's count of transitive triads for every triad it completes; in a SAOM, i counts only the triads in which i sends two of the ties.

The picture needs a bounded group: every actor can plausibly see the whole network.

A first model: the rate is 5.55, reciprocity is strongly positive

```
. nwsaom, wave1(glasgow1) wave2(glasgow2) outdegree reciprocity seed(1)
SAOM (Method of Moments, conditional), waves: glasgow1 -> glasgow2
Actors: 50                          Estimated rate:  5.552 (0.856)

        SAOM | Coefficient  Std. err.      z    P>|z|
-------------+----------------------------------------
   outdegree |   -2.26413    .127996   -17.69   0.000
 reciprocity |    2.50883   .2328995    10.77   0.000
Overall maximum convergence ratio: 0.178 (criterion: below 0.25; met)
Convergence t-ratios (criterion: all below 0.1 in absolute value): met
```

5.55

estimated rate: opportunities for change per pupil between the waves

12

exp(2.51): how much likelier a reciprocated tie is to be chosen

Outdegree (-2.26) works like an intercept: a further friendship is evaluated unfavorably unless other effects make up for it. The last two lines say whether the search has settled; Week 9 reads them.

Before any model, look at how much change there is to explain

```
. nwsaom describe, waves(glasgow1 glasgow2 glasgow3)
       Wave |       Ties     Density   Avg. degree
          1 |        113      0.0461         2.260
          2 |        116      0.0473         2.320
          3 |        122      0.0498         2.440

     Period |    Kept   Created  Dissolved   Jaccard   Hamming
       1->2 |      57        59         56     0.331       115
       2->3 |      66        56         50     0.384       106
```

Glasgow's two periods are on the lower, but acceptable, side. Too little change leaves nothing to explain; too much makes one continuous process doubtful.

Rule of thumb

A Jaccard index of at least about 0.3. Below that, estimation tends to be unstable.

Hamming distance

Ties created plus ties dissolved: 59 + 56 = 115 and 56 + 50 = 106.

What to take away from the first half of the week

Two waves allow change

How much persisted, how much is new: questions a snapshot cannot answer.

Turnover is not speed or cause

Counts of changed ties. Level tie counts hide that about half of the ties were replaced.

Shares are not effects

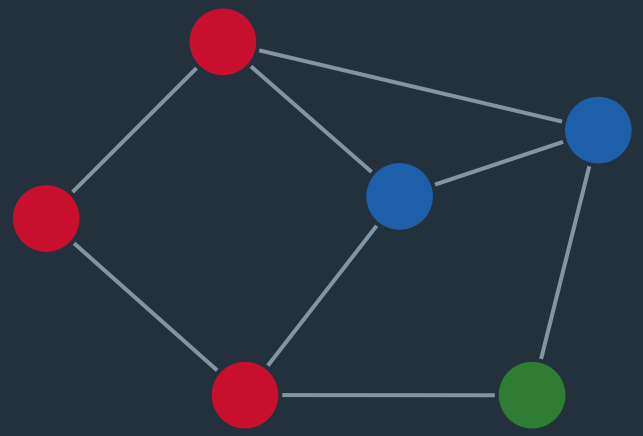
Formed ties return a tie or close a two-path far more often than chance. That is a description.

Rate and objective function

An SAOM separates how often an actor may change a tie from which change it makes.

Break

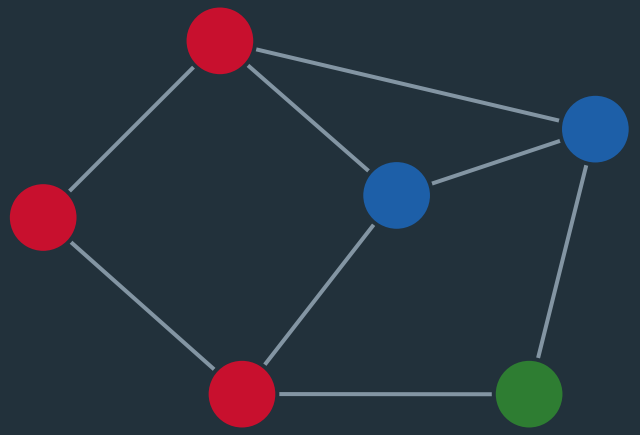
10 minutes



4

Lab: turnover and pictures of change

45 min · Run along: nwturnover, formation, a layout fixed across waves, nwmovie; Ch. 14, Ex. 2 and 7



Run along 1: turnover for both periods, with the formed-tie shares

```
. nwwebuse glasgow, nwclear
. nwturnover glasgow1 glasgow2, generate(_turnover)
. nwturnover glasgow2 glasgow3, generate(_turnover) replace
. nwturnover glasgow1 glasgow2, generate(_turnover) ///
>     replace formation
. nwturnover glasgow2 glasgow3, generate(_turnover) ///
>     replace formation
```

Checkpoint	1 to 2	2 to 3
stable, formed, dissolved	57, 59, 56	66, 56, 50
Jaccard, persistence	.331, .504	.384, .569
pairs without a tie	2337	2334
return a tie, formed ties	0.186	0.268
close a two-path, formed ties	0.153	0.446

Predict first. Will the second period have more or fewer stable ties than the first?

A second call needs replace: generate() will not overwrite _turnover.

Run along 2: one layout for all three waves, and the movie

```
. nwgen glasgowall = (glasgow1 + glasgow2 + glasgow3) > 0
. nwplot glasgowall, generate(x y)
. nwplot glasgow1, nodexy(x y) title("wave 1") name(g1, replace)
. nwplot glasgow2, nodexy(x y) title("wave 2") name(g2, replace)
. nwplot glasgow3, nodexy(x y) title("wave 3") name(g3, replace)
. graph combine g1 g2 g3, rows(1) xsize(9) ysize(3.3)
. nwmovie glasgow1 glasgow2 glasgow3, fname(glasgow_movie) noopen
```

Checkpoint	Value
arcs of glasgowall	214
density of glasgowall	.0873
file written	glasgow_movie.html

Look at the picture. Which parts of the layout gain ties from wave to wave, and which lose?

Open glasgow_movie.html in a browser and step through the waves.

Hands-on (20 min)

Ch. 14, Ex. 2

Check by hand the Jaccard index (0.384) and the persistence rate (0.569) for waves 2 to 3 from the counts of 66 stable, 56 formed and 50 dissolved ties.

Hint The Jaccard index is stable divided by stable + formed + dissolved, the ties present in either wave. Persistence is stable divided by stable + dissolved, the ties of wave 2.

Ch. 14, Ex. 7

From the table of the option formation, compute for each interval the ratio of the share of formed ties that return a tie to the same share among all pairs without a tie, and do the same for closing a two-path. Name one explanation other than reciprocity that could produce the first ratio, and say which variable, not in the Glasgow data, would let you check it.

Hint Each ratio divides a share in the column "Formed" by the share in the same row of the column "No tie", in each of the two nwturnover tables. For the rival explanation, ask what two girls could share that makes each likely to name the other, whoever named first.

Debrief Ex. 2: the Jaccard index divides by all ties, persistence by wave 2

```
Jaccard     = 66 / (66 + 56 + 50) = 66 / 172 = 0.384
persistence = 66 / (66 + 50)      = 66 / 116 = 0.569
```

Jaccard

Denominator: the ties present in either wave (172). Symmetric in the two waves.

Persistence

Denominator: the ties of the first wave of the pair (116). Not symmetric.

The common slip

Dividing stable ties by the ties of the later wave or by the total of all waves. Say which wave the denominator belongs to, and say in the report which index you use.

Debrief Ex. 7: closing a two-path is 3 to 8 times likelier than for a pair without a tie

Ratio: formed / no tie	1 to 2	2 to 3
Return a tie	12.4	13.4
Close a two-path	2.9	7.8

From the printed shares: .186/.015, .268/.020, .153/.053, .446/.057. The unrounded shares give 13.6 for the second return ratio.

It says

Formed ties were 3 to 14 times likelier than a random pair without a tie to return a tie or close a two-path.

It does not say

That reciprocity or transitivity caused them. The closure ratio rests on 9 and 25 ties, and the two intervals differ a great deal.

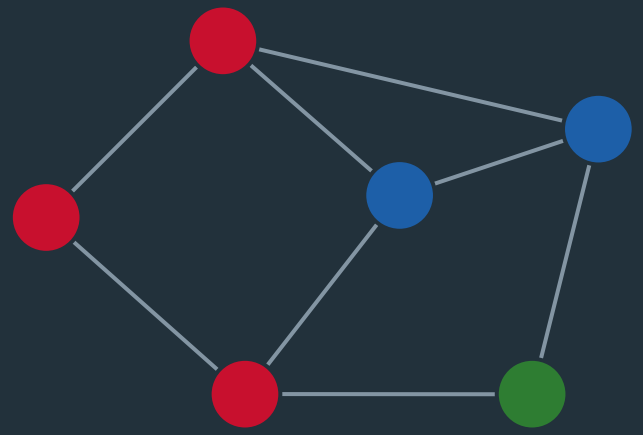
Rival explanation

Girls in the same class nominate each other whoever names first. Class membership or seating, not in the data, would let you compare ratios within and across classes.

5

Lab: the first look at a panel model

45 min · Run along: nwsaom describe and the first model; Ch. 25, Ex. 1 and 7



Run along 3: how much change is there, and a first model

```
. nwwebuse glasgow, nwclear
. nwsaom describe, waves(glasgow1 glasgow2 glasgow3)
. nwsaom, wave1(glasgow1) wave2(glasgow2) ///
>     outdegree reciprocity seed(1)
```

Predict first. Is the Jaccard index of the second period higher or lower than .331?

Checkpoint	Value
ties in waves 1, 2, 3	113, 116, 122
period 1: kept, created, dissolved	57, 59, 56
Jaccard, Hamming (period 1)	0.331, 115
estimated rate (se)	5.552 (0.856)
outdegree, reciprocity	-2.264, 2.509
overall convergence ratio	0.178 (met)

Always seed(): the fit is a simulation, and the seed makes it repeat.

Hands-on (20 min)

Ch. 25, Ex. 1

nwsaom describe reports that between the first two Glasgow waves 57 ties stay, 59 are created and 56 dissolve. From these counts compute (a) the share of the wave-1 ties still present in wave 2, (b) the share of the wave-2 ties that are new, and (c) the Jaccard index. Check (c) against the printed 0.331.

Hint Wave 1 has the kept and the dissolved ties (57+56=113), wave 2 the kept and the created ones (57+59=116). The Jaccard index divides the ties present in both waves by the ties present in at least one of them.

Ch. 25, Ex. 7

The rate in the first Glasgow model is 5.55. (a) Say in one sentence what this number counts. (b) For each of two classes, say whether the rate or the objective function would differ from Glasgow's: in the first, pupils get more opportunities to change friends; in the second, pupils are just as often activated but more reluctant to add a friend.

Hint The reading of the first model describes the rate as the estimated number of opportunities for change each pupil gets between two waves. The objective function decides what an actor does with an opportunity; its baseline for adding a tie is the outdegree coefficient.

Debrief Ex. 1: half of wave 1 persists, and half of wave 2 is new

Share	Calculation	Value
(a) wave-1 ties still present	57 / (57 + 56) = 57 / 113	**0.504**
(b) wave-2 ties that are new	59 / (57 + 59) = 59 / 116	**0.509**
(c) Jaccard index	57 / (57 + 59 + 56) = 57 / 172	**0.331**

Same counts, other denominators

(a) is the persistence rate of Chapter 14. (b) divides by the later wave. (c) divides by the union of the two waves.

Tie counts hide the change

113 and 116 differ by 3, yet only 57 ties are common to both waves.

Debrief Ex. 7: the rate counts opportunities; the objective function sets the choice

(a) What the rate counts

The estimated number of opportunities for change each pupil gets, on average, between two waves: a count of chances, not of changes.

How often versus which

The rate answers how often an actor may change a tie. The objective function answers which change it makes.

Class of pupils	Rate	Objective function
more opportunities to change friends	**differs: larger**	need not differ
as often activated, more reluctant to add a friend	same	**differs: outdegree more negative**

A larger rate is not a more consequential action: it means more opportunities to act.

To read after the session

Before next week: the rest of Chapter 25

Left over: Ch. 14, Ex. 1, 3 to 6 and 8; Ch. 25, Ex. 6

Rerun the first model, then try nwsaom refit

Do-files and teaching material: nwcommands.org/book

Instructors are free to use, adapt and share these slides.

