Using STERGMs to Model Tie Persistence in Students' Out-of-Class Networks

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Summary

Who: Students in an introductory physics for engineers course.

What: Modeling the factors that affect the structure and persistence of ties in a network of student collaboration outside of the classroom.

Where: A small liberal arts college.

When: Mostly first semester students, some second year students.

Why: Zwolak, et al. [1] have shown that integration into the out-of-class network is predictive of student persistence; it is crucial to understand how these networks form and change.

How: Students recorded who they worked with inside and outside of class each week, networks were created based on these data, then modeled using Separable Temporal Exponential Random Graph Models (STERGM) [2].

Conclusion:

1. Ties form mainly due to the common patterns of social relations: reciprocity and the formation of closed triads of interactions.
2. The persistence of ties is not well explained by this model, though there is some evidence that being in the same group in class makes ties more likely to persist.
3. In this particular section, a shared group membership and a heterogeneity of FCI score increased the probability of ties forming. The negative effect of activity indicates that most students in this section reported a similar number of interactions.

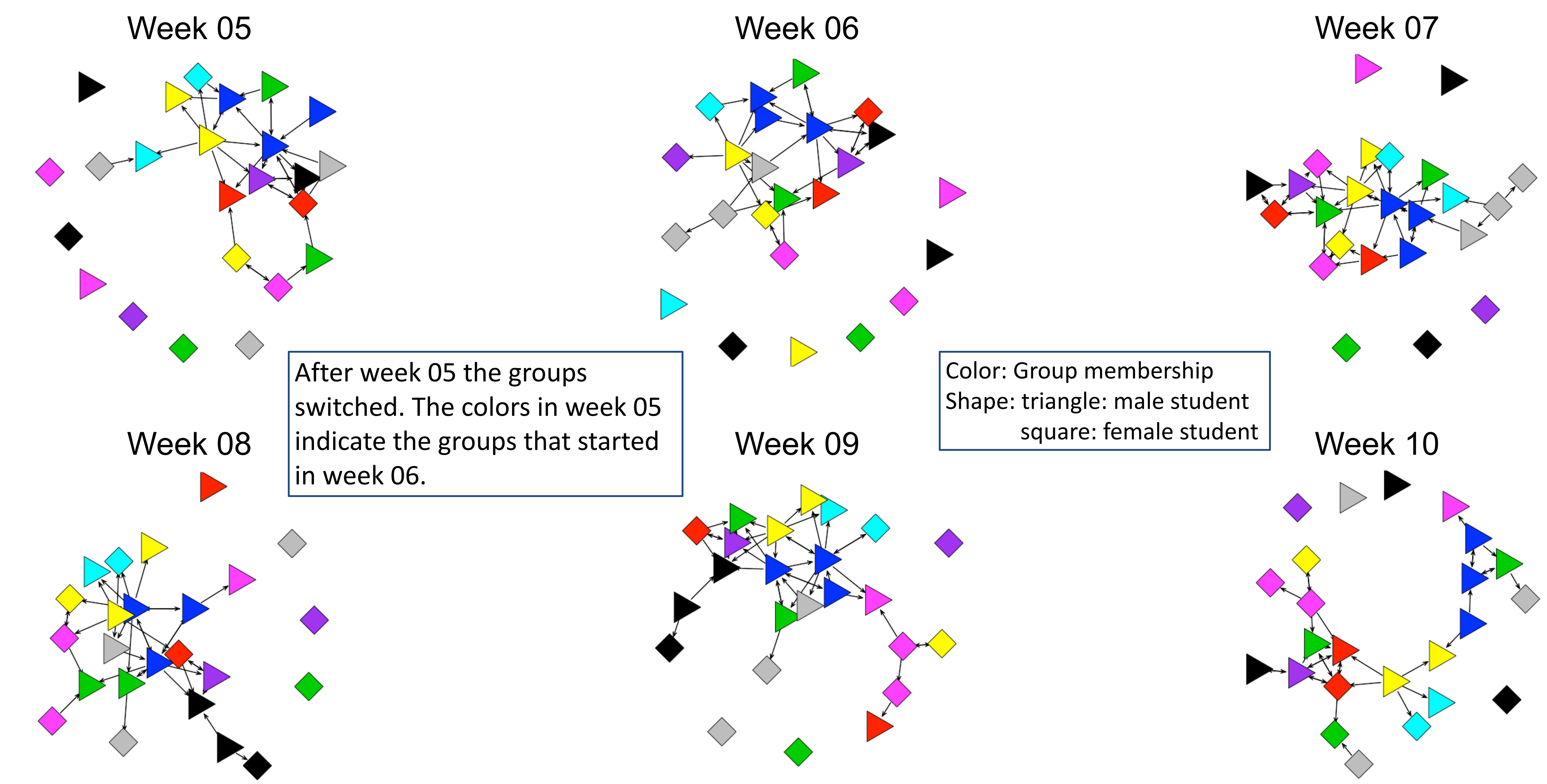
Separable Temporal Exponential Random Graph Models (STERGMs)

- Exponential Random Graph Models (ERGMs) are tie-based models of networks [3]. They give the probability of a tie existing, contingent on every other tie in the network.
- STERGMs extend ERGMs to model networks that vary in time. At each time step, they consist of two independent models: one that predicts the likelihood of a tie forming and one that predicts the likelihood of a tie persisting.
- Three main factors determine ties in networks:
  1. Structural: reciprocity, triangle formation, etc.
  2. Characteristics of the Actors: gender, grades, etc.
  3. Exogenous: group membership

Network Statistics

Network	Nodes	Edges	Density	Components	Diameter	Clustering
Week 05	24	35	.06	15	5	.36
Week 06	24	32	.06	19	3	.27
Week 07	24	42	.08	14	5	.29
Week 08	24	38	.07	16	3	.29
Week 09	24	41	.07	15	4	.29
Week 10	24	33	.06	17	3	.40

Results: Between the First and Second Exams



Model Terms [4]	Example	Exam 01 Formation	Exam 02 Formation	Exam 03 Formation	Exam 01 Persistence	Exam 02 Persistence	Exam 03 Persistence
Reciprocity		1.94(0.53)***	1.56 (0.48)**	1.12 (0.50)*	2.07 (0.78)**	0.90 (0.52)	0.84 (0.56)
Local Cycles		-0.28 (0.24)	0.20 (0.20)	0.10 (0.21)	-0.44 (0.41)	-0.29 (0.27)	-0.25 (0.24)
Local Hierarchy		0.19 (0.27)	0.12 (0.26)	0.69 (0.23)**	0.61 (0.51)	0.74 (0.79)	-0.56 (0.65)
Homophily in 1st Group		1.89 (0.43)***	0.80 (0.41)*	1.22 (0.39)**	0.27 (0.53)	0.27 (0.39)	-0.34 (0.46)
Homophily in 2nd Group			1.52 (0.37)***	1.07 (0.43)*		-0.46 (0.50)	1.40 (0.63)*
Homophily in 3rd Group				1.70 (0.35)***			0.05 (0.51)
Effect of FCI on Popularity		-0.01 (0.02)	$1.59{\times}10^{-4}$ ($3{\times}10^{-2}$)	$-3.09{\times}10^{-4}$ ($2{\times}10^{-2}$)	-0.08 (0.04).	-0.01 (0.03)	0.02 (0.04)
Effect of FCI on Activity		-0.01 (0.02)	$-3.40{\times}10^{-3}$ ($2{\times}10^{-2}$)	-0.01 (0.02)	-0.01 (0.04)	-0.01 (0.03)	0.03 (0.03)
Homophily in FCI Score		0.05 (0.02).	0.09 (0.02)***	0.05 (0.02)*	-0.09 (0.04)*	-0.03 (0.03)	0.02 (0.03)
Effect of Grade on Popularity		-0.01 (0.02)	0.04 (0.02).	-0.01 (0.02)	0.04 (0.04)	-0.05 (0.02)*	-0.12 (0.03)***
Effect of Grade on Activity		0.02 (0.02)	0.03 (0.02)	0.01 (0.02)	-0.01 (0.04)	-0.07 (0.02)**	-0.10 (0.0)***
Homophily in Grade		-0.02 (0.02)	-0.01 (0.02)	-0.07 (0.02)**	-0.02 (0.04)	-0.02 (0.03)	-0.24 (0.05)***
Female – Female Ties		-3.71 (0.48)***	-7.19 (3.35)*	-1.02 (2.64)	-2.97 (0.76)***	8.51 (0.89)***	18.74 (0.55)***
Male – Female Ties		-4.15 (0.40)***	-6.83 (3.20)*	-1.14 (2.55)	-2.82 (0.65)***	6.49 (0.52)***	16.72 (0.56)***
Female – Male Ties		-3.60 (0.41)***	-6.87 (3.16)*	-0.80 (2.50)	-0.91 (0.72)	6.78 (0.50)***	18.38 (0.60)***
Male – Male Ties		-3.17 (0.30)***	-6.07 (3.08)*	-0.68 (2.50)	-1.00 (0.59).	7.11 (0.47)***	18.05 (0.39)***
Triad Effect		0.38 (0.11)***	0.31 (0.16)*	0.36 (0.12)**	0.36 (0.27)	0.01 (0.73)	0.92 (0.55).
Multiple 2-paths		0.02 (0.08)	-0.31 (0.07)***	-0.29 (0.07)***	-0.42 (0.22).	0.04 (0.15)	$-4.41{\times}10^{-4}$ ($2{\times}10^{-1}$)
Popularity		0.13 (1.35)	-0.19 (1.11)	-1.50 (1.01)	0.91 (2.23)	3.03 (1.94)	1.24 (2.03)
Activity		-2.92 (0.81)***	-3.48 (0.68)***	-2.89 (0.73)***	1.34 (1.94)	0.28 (1.32)	-0.89 (1.33)

Significance

*** < 0.001

** < 0.01

* < 0.05

. <0.10 (indicated by gradient)

■ term increases the probability of a tie forming or persisting

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Use the QR Code

to download a copy of the poster and to see animated networks.

References

[1] Zwolak, Zwolak, Brewe. Phys. Rev. Phys. Educ. Res. 14, 010131 (2018)

[2] Krivitsky P and Handcock M (2017). *tergm: Fit, Simulate and Diagnose Models for Network Evolution Based on Exponential Family Random Graph Models*. The Statnet Project http://www.statnet.org. R package version 3.4.1, http://CRAN.R-project.org/package=tergm.

[3] Lusher, et al. *Exponential Random Graph Models for Social Networks: Theory Methods and Applications,* Cambridge (2013)

[4] Cranmer, et al. Am. J. Poli. Sci. 61(1) 237 (2016)
Kim, et al. PLoS ONE 10(4): e0125333 (2015)
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