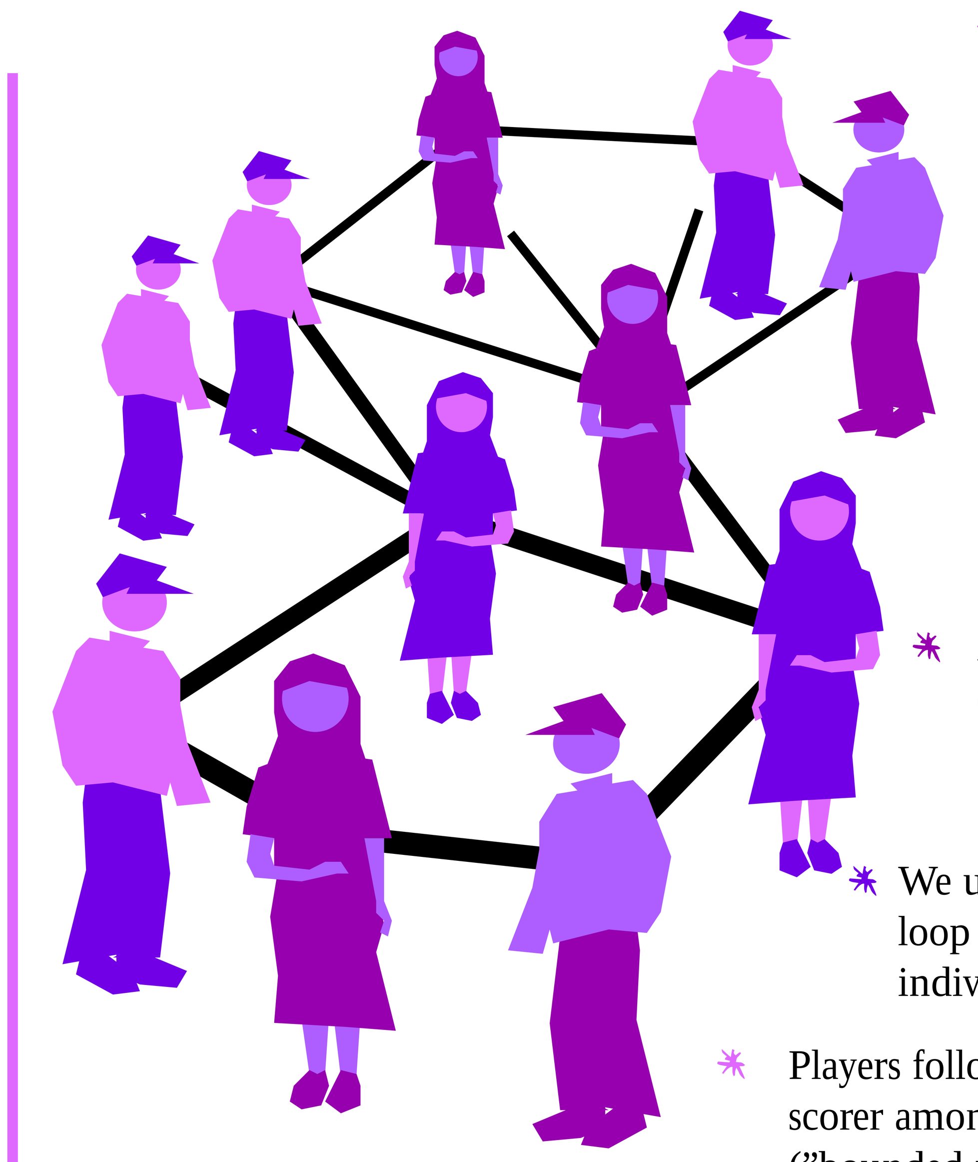
Prisoners' dilemma in real-world acquaintance networks

by Petter Holme
with Ala Trusina, Beom Jun Kim, and Petter Minnhagen

The rules



- Two strategies: cooperate *C* or defect *D*
- The gain of a player is the sum of the gain over his/her ties
- A *C-C* encounter gives both players unity gain
- A *D-D* encounter gives both players zero gain
- A *D-C* encounter gives the cooperator zero gain and the defector the gain *b*, $1 < b < 2$
- We use synchronous updating, i.e. loop over: 1. Calculation of individual gain. 2. Choice of
- Players follows the strategy of the high-scorer among the neighbors and his/herself ("bounded rationality paradigm").

The reason

The prisoners' dilemma is a metaphor for situations where egoism is profitable in a short perspective but cooperation is best in the long run.

Such situations are everywhere in all levels of society . . . from household disputes to global politics.

To study the cooperation in social space Nowak & May let embedded the players in a geometry and let them interact only with their local surrounding.

The interaction pattern among people is highly complex . . . so we put the prisoners' dilemma dynamics in its most natural setting: in a empirically acquired social network

The networks

pussokram.com

pussokram.com digitala relationer

pussokram.com is Swedish Internet community intended for romantic interaction

N = 29 314, M = 115 684

P. Holme, C. R. Edling and F. Liljeros, cond-mat/0210514

nioki.com

NIOKI www.nioki.com

nioki.com is a French Internet community with a younger audience than pussokram.com

N = 50 259
M = 239 452

R. Smith, cond-mat/0206378

email

These contacts are emails logged from a server serving student at Kiel University.

Both external and internal (fully mapped) actors contributed to the network.

N = 40 346
M = 58 224

H. Ebel *et al.*, PRE 66, 035103 (2002).

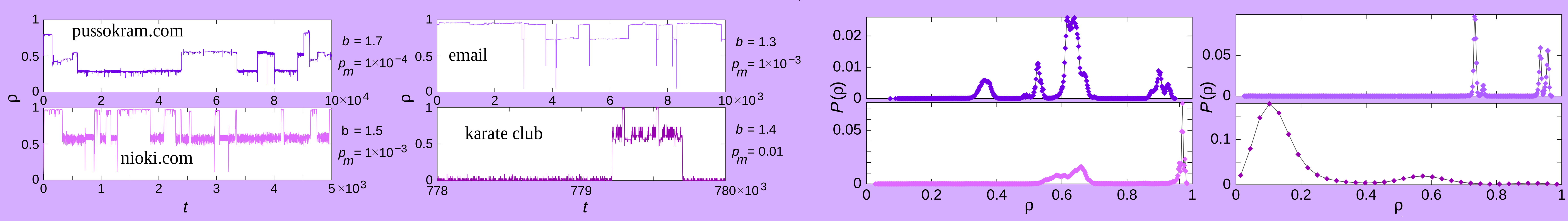
karate club

This network was obtained from a field survey.

N = 34
M = 78

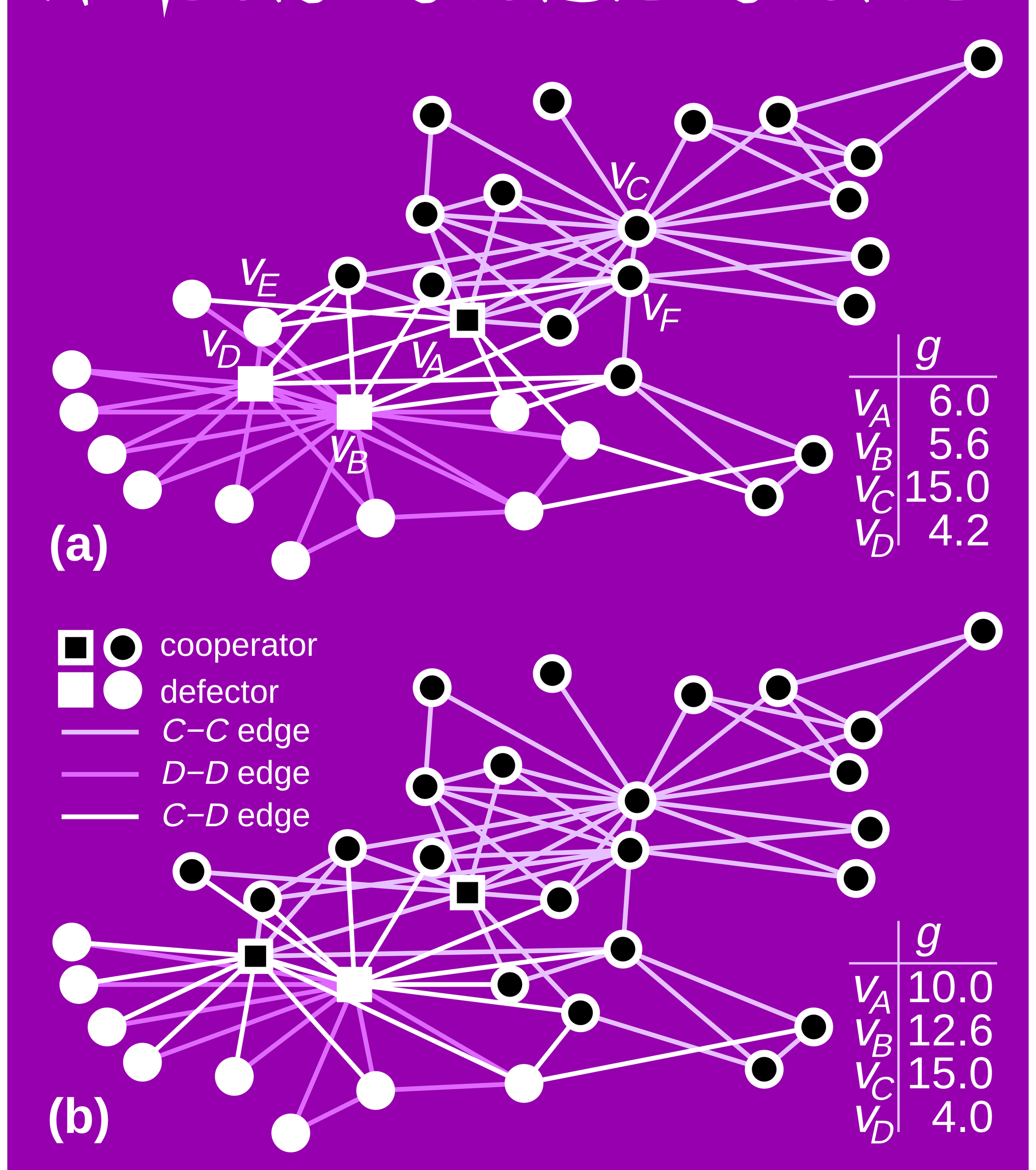
W. Zachary, J. Antropol. Res. 33, 452 (1977).

Time evolution of cooperator density



- Complex time series over a large parameter range
- Spikes and transitions between quasi-stable states (and noise + high frequency oscillations, as on regular networks)
- The distribution of cooperator density (for a specific *b* value) is independent of the mutation rate and forms a fingerprint of the network.

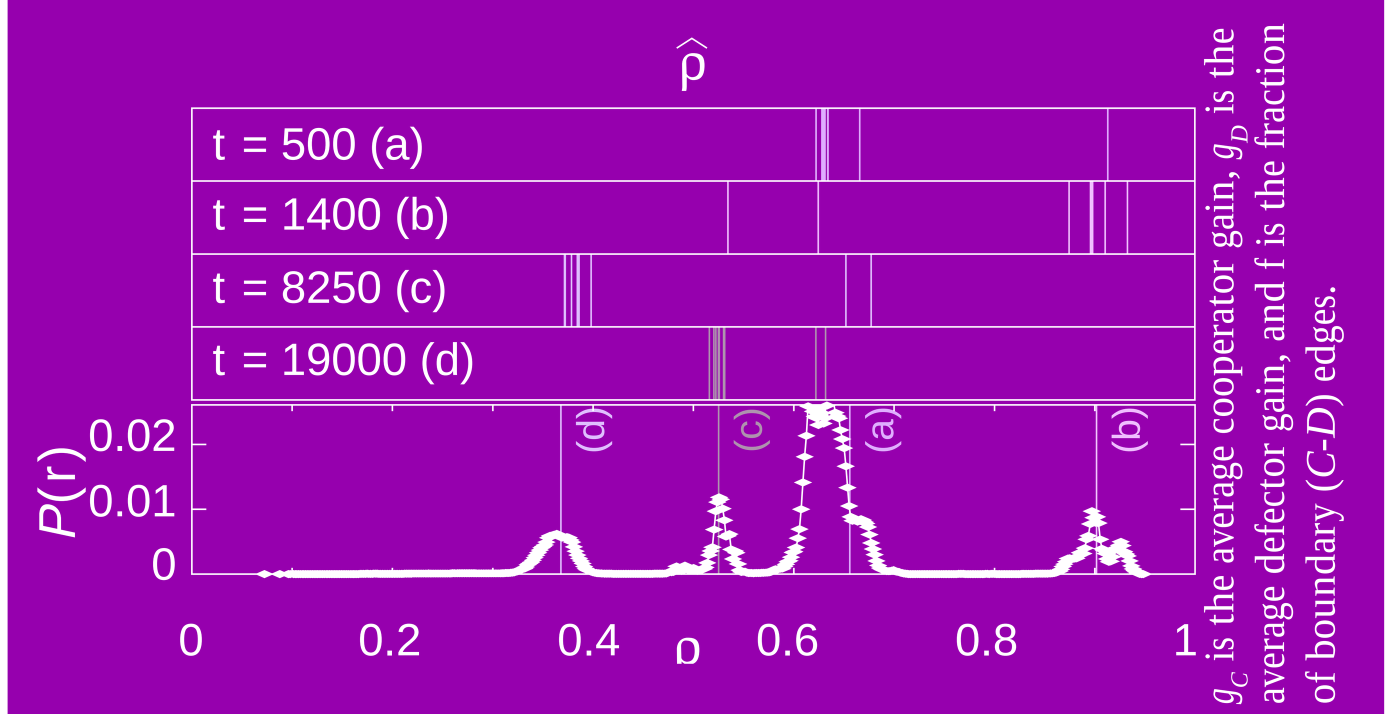
A quasi-stable state



A cyclic quasi-stable state of the karate club time series above. That v_A and v_B is not connected is a crucial feature sustaining the quasi-stable state.

We note that if v_E is mutated in the (a) configuration the system looses the cyclic behavior. Thus, the quasi-stable levels of the ρ time series is a collection of quasi-stable states, close in Hamming distance.

Statistics of the C/D clusters



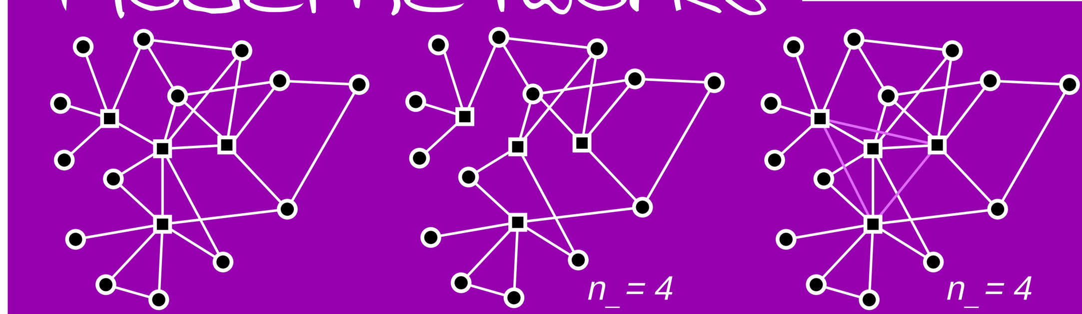
Correlations within high-degree vertices

We test the correlations within the set of highest degree vertices we measure the average degree within the maximal subgraph of the *n* vertices of highest degree, k_n.

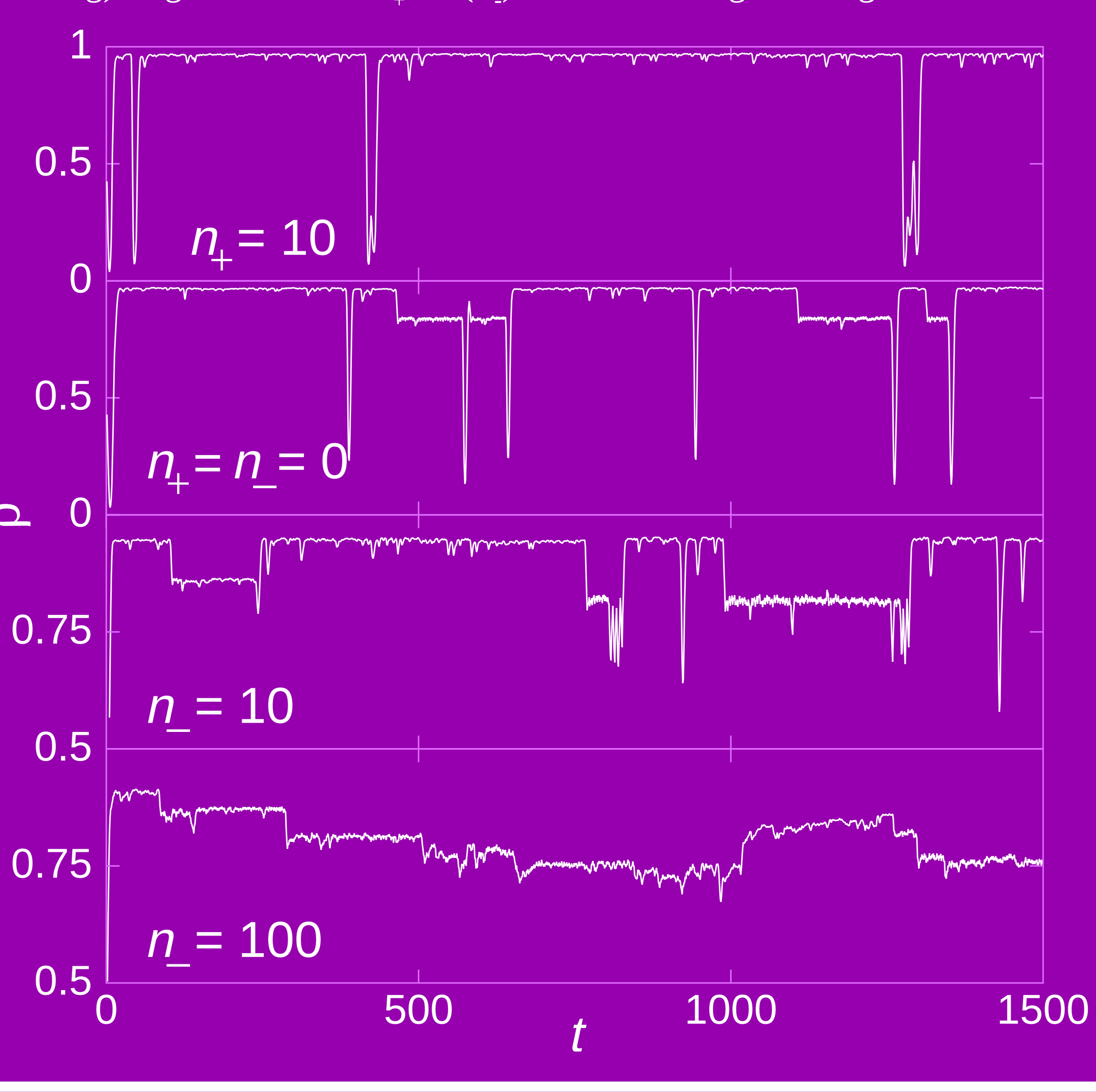
This is compared with the corresponding values of random graphs with the same degree sequence K_n.

	k_n	K_n
pussokram.com	1.6	6.0(1)
nioki.com	1.2	1.9(1)
email	1.8	4.9(1)

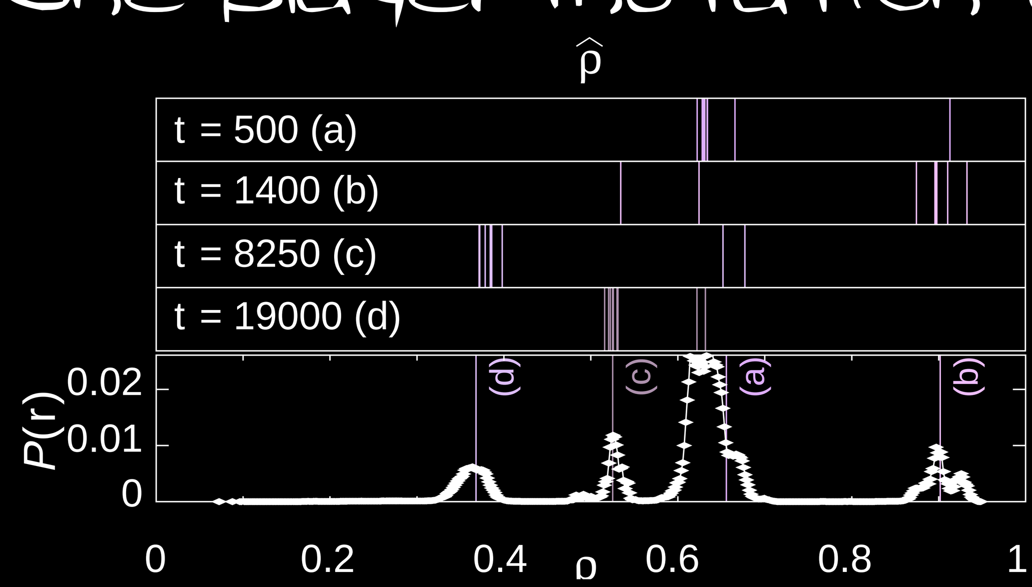
Model networks



To get a broad degree-distribution we start by creating $M = 3N$ BA model networks. We tune the number of edges within the highest-degree vertices by adding the missing (or deleting the existing) edges from the n_+ or (n_-) vertices of highest degree.



One player mutation impact



To test how much a single player mutation can affect the system we plot ρ after a mutation (if we let the system evolves without mutations). The figure shows the ten most different ρ values for four times.

Conclusions

- We find a complex ρ behavior with steps & spikes
- High-ρ states are characterized by high cooperator gain and small boundaries, low-ρ states vice versa.
- The transitions are likely caused by single-player mutations on high degree vertices.
- Important ingredients for the emergence and sustentation of the quasi-stable states are: 1. A broad degree distribution. 2. That the vertices of highest degree and not mutually well-connected.

Based on: P. Holme, A. Trusina, B. J. Kim, and P. Minnhagen, Nonstationary social stability induced by the structure of acquaintance networks, submitted to Phys. Rev. E (RC).

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