Evolution of cooperation- and defection-networks in a multiplayer online game

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The analysis of high-frequency log-files of a massive multiplayer online game played by 300,000 users over a period of four years allows to assess socio-economical dynamics with extraordinary precision. We are able to relate social and economic behavior of the players to a series of stylized facts known to exist in the real world. We analyze the evolution of growing social networks of friends (cooperators) and communication networks. For the first time large-scale networks of enemies (defectors) are studied. We find profound differences between cooperator- and defector-networks. Our data display the recently observed phenomenon of network densification. A motif analysis confirms striking differences in topological structure between friend- and enemy-networks. Our findings are in good agreement with real-world data. With this setup we establish a ”laboratory” for socio-economical behaviour.

Introduction

The bottleneck in scientific approaches to quantification of human social dynamics is the availability and quality of data.

We have compiled a unique dataset of a self-developed multiplayer online game played by over 300,000 users. In this game every player has to generate virtual income through economic activities to 'survive' and is engaged in several social activities. We have tracked every action of all players in the past 4 years.

Aim

Establish a “laboratory” for socio-economical behavior.

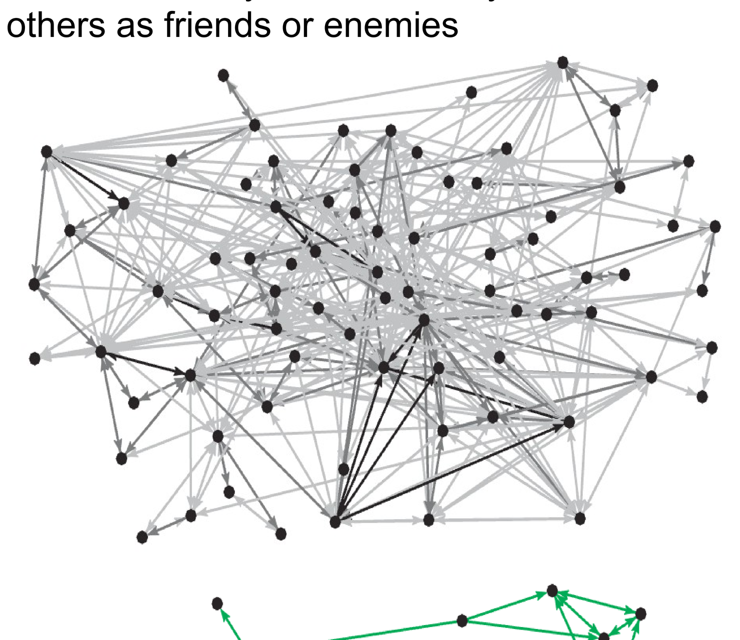
- Measure structure and dynamics of friend (cooperator), enemy (defector), and communication networks
- Test social-dynamics hypotheses
- Compare findings with real-world data

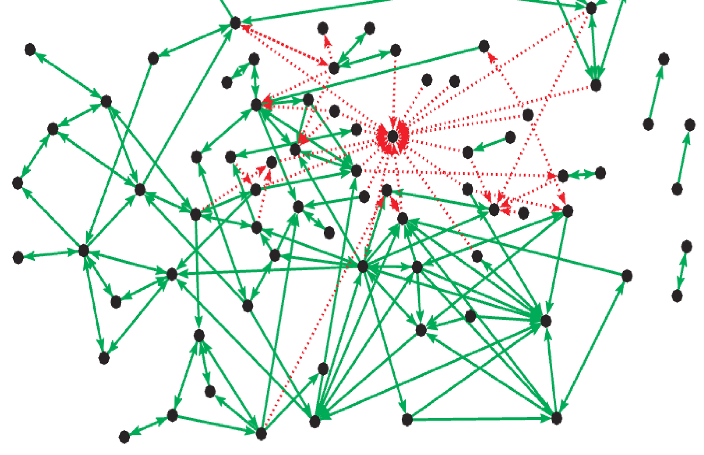
Dataset

1,000 GB of log-files containing *all* actions and properties of 300,000 players over 1,200 days. Data includes social and economical parameters (e.g. number of friends or income of game money).

Network extraction

- Communication networks: Players can send messages to others
- Friend/Enemy networks: Players can mark others as friends or enemies

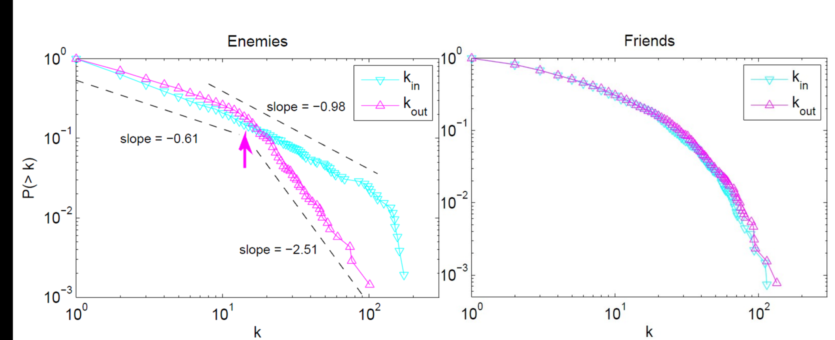




Snapshots of 78 randomly selected players (out of ~10,000) with their message communications (gray) and friend (green) and enemy (red) relations.

Result I: Degree distribution

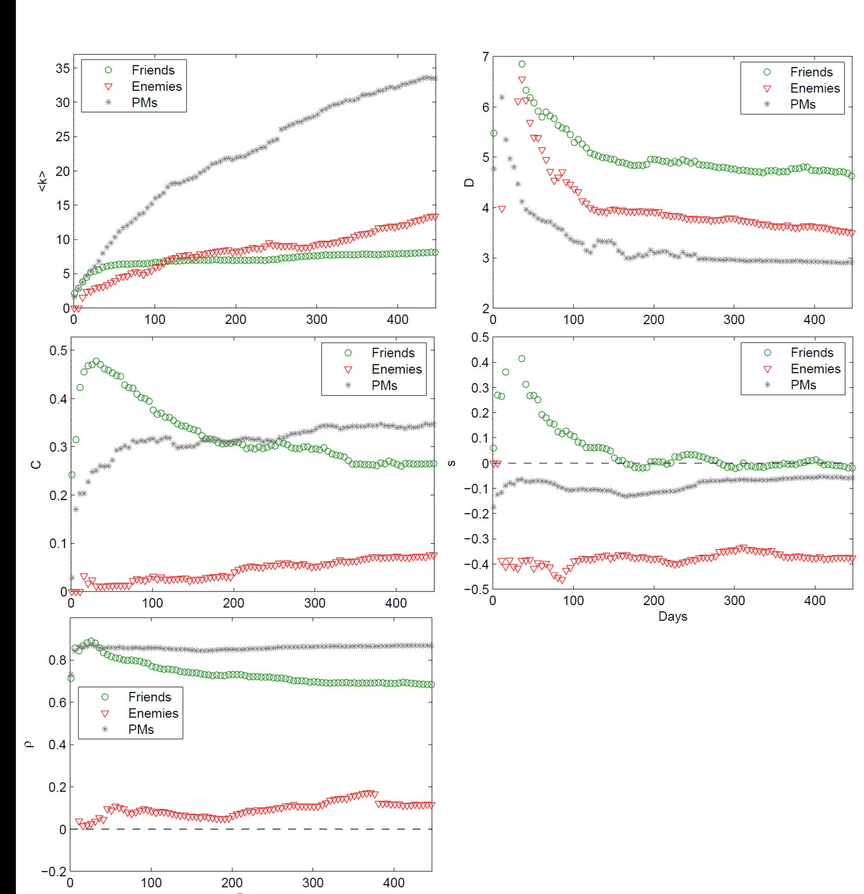
Degree distributions of enemy networks are well characterized by power-laws, not so for friend networks.



→ Note the differences of scaling exponents in the out-degree of enemy networks (separated by arrow).

Result II: Network densification

Daily evolution of standard network properties in communication networks and friend/enemy networks:



Measured properties:

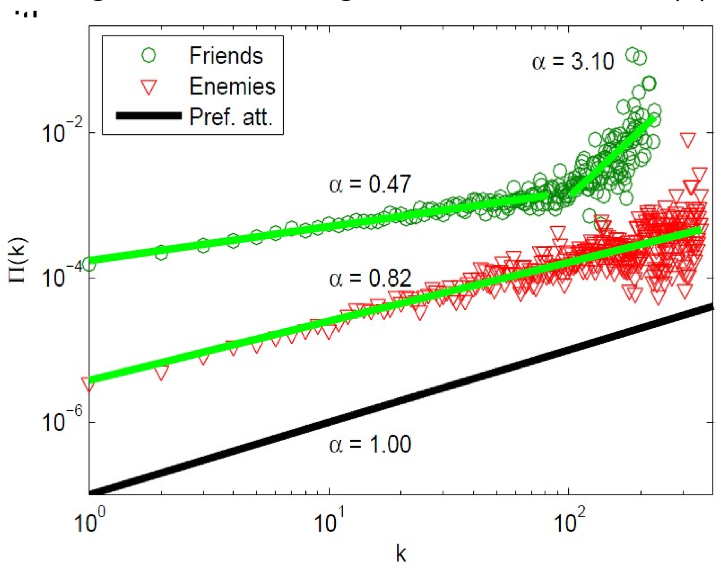
- Average degree <k>: Average number of friends/enemies/communication partners per player
- Diameter D: Longest shortest distance between all pairs of players
- Clustering coefficient C: “Cliquishness”
- Assortativity s: Correlation coeffi cients of the degrees at either ends of a link
- Reciprocity ρ: Tendency of players to reciprocate directed links

→ Decrease of diameters (after a “gelling point”) and increase of average degrees can be observed in all networks. This is *network densification* [1].

→ Note the significant differences between friend and enemy networks.

Result III: Preferential attachment

Preferential attachment is a model of network growth generating power-law degree distributions [2]. It assumes a preference of new nodes to link to popular existing nodes. The probability Π(k) that a new node connects to an existing node with degree k scales like $\Pi(k) \sim k^{\alpha}$, v … 1.

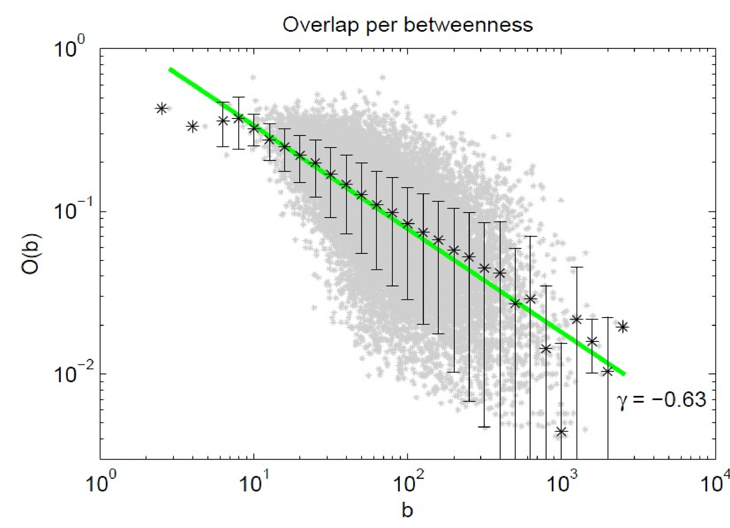


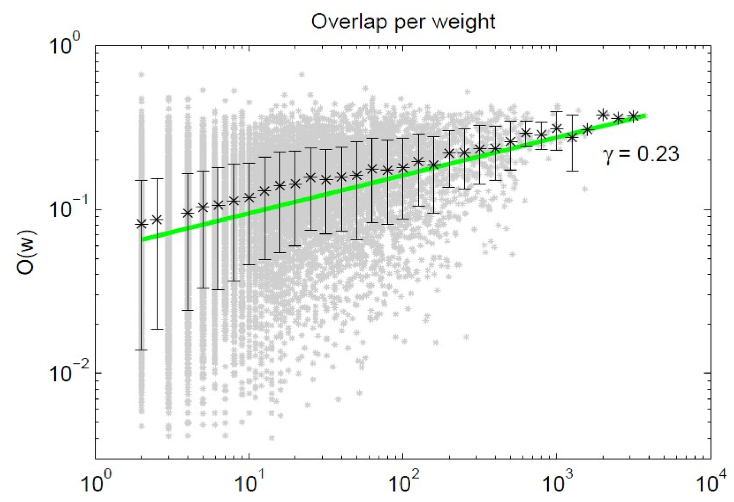
→ We observe an exponent of α = 0.47 for friends and α = 0.82 for enemies.

→ Note the super-preferential tendency for players with a high degree of friends (over 100).

Result IV: Weak-ties hypothesis

We confirm the famous Weak-Ties Hypothesis [3] in communication networks.





We correlate the following measures:

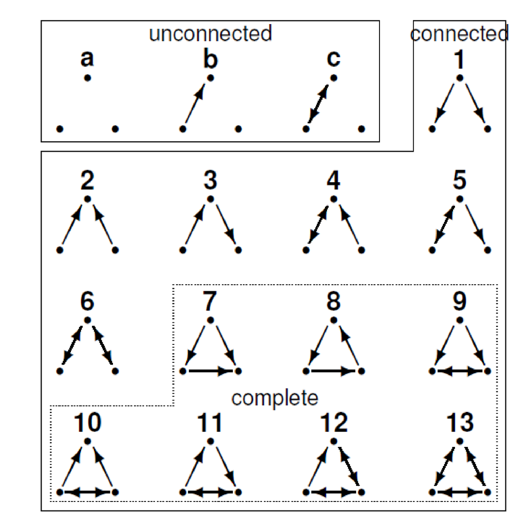
- Overlap O: Rel. number of neighbors common to two connected nodes
- Link betweenness centrality b: Number of shortest paths containing a link
- Link weight w: Amount of PMs sent

→ Correlations coincide with those in mobile phone call networks [4].

→ These dependencies are well fit by power-laws.

Result V: Triad significance profiles

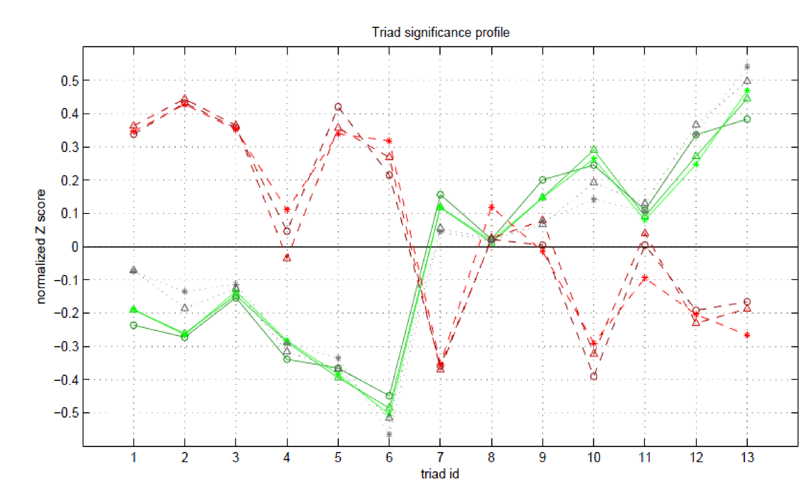
In directed networks there exist 16 isomorphism classes of 3-node subgraphs, called *Triad types:*



We calculate the statistical significance for each triad type in the networks relative to an appropriate null model. Due to combinatorial explosion ($\binom{10000}{3} \sim 10^{11}$) this is done via Monte-Carlo method. The resulting profile is called *Triad significance profile* (TSP) [5].

→ TSPs of friend and PM networks coincide with TSPs of social networks found in literature [5].

→ TSPs of all enemy networks deviate significantly. Note the almost mirror-inverted TSPs, featuring interesting deviations (such as triad id 4):



Triad significance profiles of friend networks (green), enemy networks (red) and communication networks (gray) in several game universes.

Conclusion

We measured properties of evolving social networks composed of interacting cooperators and defectors from a massive multiplayer online game. Significant differences between networks of cooperation and defection could be revealed.

Our results are in good agreement with real-world data. We are able to conduct social science with a precision usually only achieved in the natural sciences.

References

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