Network Multiplexity in Online Chats

Vladimir Gligorijević, Milovan Šuvakov and Bosiljka Tadić

Department of Theoretical Physics, Jožef Stefan Institute, Ljubljana, Slovenia

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Outline

1. Chat Networks from Empirical Data
2. Multiplex Structure of Chat Networks
3. Agent-Based Model of Chats with Bots
4. Impact of Emotional Bots
5. Conclusions
Chat channel

- Data collected from **Ubuntu** chat channel
- **Details of user interaction**: $t, i \rightarrow j, \{v_i, a_i\}$, message type
- **User-to-user interaction** → directed, weighted network
- **Network properties**: hierarchical structure, disassortative mixing, power law distributions of topological quantities (degree, weight...), core of active users, moderators & Bot
- **Self-organized dynamics** of user activities

[V. Gligorijević et al., IEEE Computer Society (2012)]
[V. Gligorijević et al., Physica A 392, 538 (2012)]
Details of user interaction: Annotated data

- Speech act categories (13): Yes/No Question, Wh-Question, Yes/No Answer, Greet, Statement...
- Emotional content of messages: *valence* $v \in (-1, 1)$, *arousal* $a \in (-1, 1)$
- AB model: agent’s emotional state in a phase space

[J.A. Russel, A Circumplex Model of Affect (1980)]
Content-based linking \(\Rightarrow\) multiplex structure

- Emotional content of exchanged messages - positive and negative layers (*duplex network*)
- Message type (speech act categories) - 13 different layers
Hierarchical Structure Emerges from Multiplexity

- User participation among word layers vs. k-shell structure:
  \[ A_i = (A_i^{[1]}, ..., A_i^{[13]}) \quad A^R = (1, ..., 1) \]
- Measure of similarity: \( S_i = \frac{A_i A^R}{|A_i||A^R|} \)

\[ S_i \sim (k_{i}^{s})^\alpha \quad \alpha = 0.288 \pm 0.007 \]
Duplex networks: inter-layer correlations

- Which layer (emotion) drives the system?
- Conditional probability: \[ P(a_{ij}^\pm | W_{ij}^\mp = W) = \frac{N_{ij}^\pm}{N_{ij}^\mp(W)} \]
ABM of online chats

- Emotional agents (representing users and moderators) have "human" attributes: emotion, activity patterns, delay times,...

  \[ A[ID, \text{status}, (a, v); \text{activity.profile}; \text{connections}] \]
  \[ B[ID, \text{status}, (a^*, v^*); \text{activity.pattern}; \text{connections}] \]

- Emotion variables \( \{a(t), v(t)\} \): nonlinear maps,

- Activity profiles inferred from empirical data: \( P(N_C), P(\Delta t), g(N_C), T_0... \)

- Bots: predefined emotional states (posBot - "enthusiastic", negBot - "ashamed")

- Interaction rules (agent-agent, agent-wall, agent-wall-moderator-Bot) as in real chat channel

- Chat network grows by: addition of new agents (time series \( p(t) \)) and new links, reusing the existing links
Emotional dynamics: Local level $\rightarrow$ Collective state

- Agent’s emotional state vary in time:
  \[ a_i(t+1) = (1-\gamma_a)a_i(t) + \left[ \frac{h_i^a(t) + qh_{mf}^a(t)}{1+q} (d_1+d_2(a_i-a_{i2})) \right](1-a_i) \]  
  (1)

- Influenced by local activity on the network $h_i^a(t)$ and global fields $h_{mf}^a$; They depend on the active part of the network:
  \[ h_i^a(t) = \frac{\sum_{j\in lini} a_j^m (\theta(t_m - (t-1)) - \theta(t_m - (t-T_0)))}{\sum_{j\in lini} (\theta(t_m - (t-1)) - \theta(t_m - (t-T_0)))} \]  
  (2)

- Simulated data: $t, i \rightarrow j, \{a_i, v_i\}$
  Details in: [B. Tadić, M. Šuvakov, Arxiv:1305.2741, 2013]
Some results of AB Simulation

**Empirical Data**

![Empirical Data](image1)

**AB Simulation**

![AB Simulation](image2)


- Network heterogeneity: $P(q) = C(1 + \alpha \frac{q}{q_0})^{-1/\alpha}$; Data: $\tau_{q_{in}} \approx \tau_{q_{out}} = 1/\alpha = 2.2 \pm 0.1$; AMB: $\tau_{q_{in}} \approx \tau_{q_{out}} = 2.1 \pm 0.2$
- Disassortativity: $<q>_nn \sim q_i^{\mu}$; Data: $\mu \approx -0.5$; ABM: $\mu \approx -0.9$
Impact of Emotional Bots: Emotional Polarization

- Emotional polarity of a link: \( p_{ij}(t) = \text{sgn}(\sum_{t'=1}^{t} v_{ij}(t')) \)
Impact of Emotional Bots: Multiplex Structure

- Link overlap (Jaccard coefficient): $O^{p,n}$, degree correlation: $\rho(q^p, q^n)$, degree rank correlation: $\rho(rk(q^p), rk(q^n))$
Conclusions

- Multiplex representation $\Rightarrow$ detailed insight into user interaction and chat network organization
- Link and node participations through layers (local measures):
  - Hierarchical structure explained through multiplex representation
  - Positive emotional layer drives the system
- Measure of inter-layer interaction (global measures):
  - Multiplex structure changes in presence of Bots
  - Metrics for multiplex network characterize Bot’s efficiency
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