Network Multiplexity in Online Chats

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Exchange of emotional messages between users and between users and a Bot in online chats leads to the formation of a directed, weighted complex network. Such type of networks have been studied by mapping the high-resolution empirical data, which are collected from `Ubuntu` chat channel [1, 2]. In the data, additional information is available in association with the type and the emotional content of exchanged messages. Specifically, machine-learning methods of text analysis were used to classify online chat messages into 13 different dialog act classes, e.g., `yes-no question, why question, statement` etc. In addition, the exchanged messages were annotated by lexicon-based emotion classifier to extract the emotional *valence* and *arousal* from the text of messages [1]. Recently, our analysis of the chat network revealed that a new type of social structure emerges in the self-organized dynamics of chats, which differs significantly from previously studied social networks. Unlike most conventional social networks with community structure, user associations in online chats leads to a hierarchical network with a central core, consisting of the moderators and the Bot [1, 2].

Here, we study multiplexity structure of chat networks; we analyse the empirical data `Ubuntu` channel, as well as sets of data simulated by the agent-based model of chats with emotional Bots [3]. Specifically, multi-relational interactions between pairs of users are identified by distinguish the links according to the attributes of *message type* and *emotional valence* of messages exchanged along the links. Thus, we analyze two types of multiplex networks:

- *Duplex network*, consisting of positive and negative layer of emotional messages. In this case, message with positive (negative) emotional valence forms a link in positive (negative) layer.
- *Multiplex network with 13 layers*, where each layer contains the links which are carrying messages of a given type.

Introducing a suitable measures for user participation among 13 layers of the multiplex network, we are able to explain the origin of the hierarchical organization in the chat network. Namely, we find a positive correlation between user participation coefficient and its k-shell index. User participation in layers increases as one moves from the network periphery to the central core. In the case of emotion layers, we introduce conditional probability as a likelihood that a link with a particular weight in one layer of a duplex network will also be found in the opposite layer. Using the conditional probability we demonstrate how the positive emotion layer prevails in the chat system. Moreover, we find that the larger number of exchanged messages between two users (weight) increases the probability for them to be simultaneously active in both layers. We perform a similar analysis of duplex networks obtained from agent-based simulation of chats, when Bots with different emotional states are active [3]. Here, we consider positive, negative and neutral Bot with a fixed emotional state. In the simulation, agents with human attributes, inferred from the empirical data, interact by exchanging emotional messages and thus influencing each other's emotional state. The output file of the model is a stream of messages, that can be analysed in full analogy with the empirical data. By interacting with agents, the emotional Bot transfers its

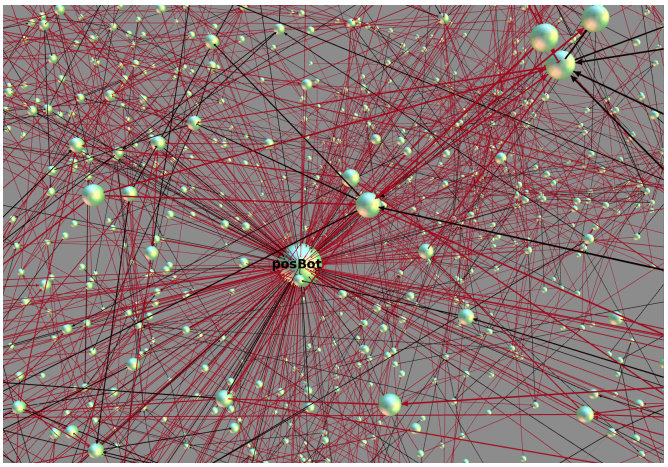

Figure 1: The polarization of links in a simulated chat network under the influence of positive emotional Bot. The color of the link represents the cumulative emotional valence of all messages transferred through that link as positive (red) and negative (black).

(fixed) emotion by each message. Consequently, these messages contribute to the emotional states of agents; hence, the presence of emotional Bots affects the interaction among agents, inducing a dominant mood as well as affecting growth of the network which propagates emotion [3]. An example of the network with link polarization in the presence of positive Bot is shown in figure 1. In order to quantify the impact of emotional Bots on a multiplex network topology, we determine various measures for interlayer interaction [4, 2]. Specifically, we compute *link overlap* between positive (+) and negative (-) layers $O^{\pm}$, as well as the *degree correlation* coefficient $R(q^+, q^-)$ between the degrees of nodes belonging simultaneously to the positive q^+ and to the negative q^- layer. According to these measures, the multiplex structure most similar to the one observed in the empirical data is found when the neutral Bot is active; in contrast, the two emotional Bots considerably influence the structure of the layers, i.e., by affecting the role of each agent within these layers.

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