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Bridging online and offline social networks: Multiplex analysis

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HIGHLIGHTS

- Multiplex endogenous (structural) and exogenous factors are addressed.
- Common framework for reciprocity, three-cycles, and transitive triplets.
- In offline communication strong and weak ties are equally presented.
- In online communication weak ties are dominant.
- Weak ties are much less reciprocal than strong ties.
- Reciprocities are preserved across different layers of multiplex.
- Normalized three cycles and triplets are not significant in multiplex.

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ABSTRACT

We show that three basic actor characteristics, namely normalized reciprocity, three cycles, and triplets, can be expressed using an unified framework that is based on computing the similarity index between two sets associated with the actor: the set of her/his friends and the set of those considering her/him as a friend. These metrics are extended to multiplex networks and then computed for two friendship networks generated by collecting data from two groups of undergraduate students. We found that in offline communication strong and weak ties are (almost) equally presented, while in online communication weak ties are dominant. Moreover, weak ties are much less reciprocal than strong ties. However, across different layers of the multiplex network reciprocities are preserved, while triads (measured with normalized three cycles and triplets) are not significant.

1. Introduction

Intensity of involvement among actors in a social network and the types of actions and interactions that arise between them are a long active topic in sociological research. The analysis of group structures has started with the study of dyads and triads that was pioneered by German sociologist Georg Simmel at the end of the nineteenth century [1]. In network analysis, the importance of triads has long been emphasized in many research studies, including the highly influential work of Granovetter [2] and, more recently, the work of Watts and Strogatz [3], where the notion of clustering (formation of many triangles in networks) is an integral part of the analysis. Thus, both social and network analysis that represent

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actors as networks nodes and their interactions as (un)directed links have shown that the network structural properties like reciprocity and cycles are very important when trying to explain processes like information spreading and network evolution.

However, retaining the perspective on different connections, i.e. Granovetter's strong and weak ties, sheds additional light on the nature of connections between actors and provides deeper understanding of the triads formations and network clustering. Thus, deeper understanding of the network properties, and therefore the processes that run on top of it, can be gained if it is viewed as a collection of multiple types of links wherein each set of link types represents a separate layer of the network. This multilayered representation has led to the introduction of the concept of multiplex networks which refers to systems in which nodes are connected through more than one type of edges, and therefore, belong to multiple interacting and co-evolving networks. The importance of multiplex networks in sociology has been emphasized by many scholars. In the seminal treatment of multiple networks as the foundation of social structure, White, Boorman and Breiger [4] and Boorman and White [5] argued that the patterning and interweaving of different types of ties are needed to describe and characterize social structures. It has been demonstrated that multiplexity is critical to diverse phenomena, such as the mobilization of social movements [6], the consolidation of political power [7], the emergence of trust in economic relationships [8], the creation of social bonds within civic networks [9], and the organization of party coalitions [10]. Multiplexity has been studied to understand scientific collaboration [11], structural logic of intra-organizational networks [12], formation of ties featuring both an economic and a social component in inter-organizational networks [13], and formation of relationships among producers in the multiplex triads [14].

Multiplex networks have also been recently subject of particularly intense research by the network science and physics communities. Szell, Lambiotte, and Thurner [15] worked on correlations and overlap between different types of links and demonstrated the tendency of individuals to play different roles in different networks. Algorithmic detection of tightly connected groups of nodes known as communities in multiplex networks was studied in [16]. A framework for growing multiplexes where a node can belong to a different networks was developed by Nicosia et al. [17], while Kim and Goh [18] studied the possibility of growth of coevolving layers that can shape the network structure and showed analytically and numerically that the coevolution can induce strong degree correlations across layers, as well as modulate degree distributions. Evolutionary game dynamics on structured populations in which individuals take part in several layers of networks of interactions simultaneously which accounts for the different kind of social ties each individual has was studied by Gomez et al. [19].

Studying multiplex networks has attracted interest across decades (in sociology) and most recently in physics. A general framework for studying multiplex networks in terms of: (i) basic node and link properties such as the node degree, and the edge overlap and reinforcement, (ii) local properties such as the clustering coefficient and the transitivity, and (iii) global properties related to the navigability of the multiplex across the different layers, was presented in [20]. There have been several attempts to define multiplex clustering coefficients [20–22], some of their shortcomings along with the structure of triadic relations in multiplex networks are discussed in [23]. Here we develop a different framework for discussing various network characteristics which includes directed weighted graphs as well as exogenous characteristics that are of crucial importance for analyzing social (on- and off-line) networks.

In this paper we aim to study social relations among actors (strong and weak ties) as they appear in real life face-to face (offline) and virtual via social network sites (online) communications using the apparatus of multiplex network analysis/analytics. Real data was collected using an online survey/questionnaire given to two groups of students (two classroom based social networks). The students answers were used to map their own perception of strong vs. weak offline and online connections, thus constructing several offline and online directed friendship networks that constitute the layers of our multiplex network. The primary goal of this research is to study the interrelationship of different social structures represented as multiplex networks. For this reason, we develop normalized actor characteristics for multiplex networks, including metrics for dyads (such as reciprocity) and triads. We found that normalized reciprocity, three cycles, and triplets of an actor can be expressed using an unifying framework that is based on the comparison of two sets associated with the actor: the set of her/his friends – out links and the set of actors that consider her/him as a friend – in links. By extending these metrics for multiplex networks, we were able to observe the relationship of strong and weak ties in the offline and online space. Analyzing the collected data from two groups of undergraduate students we found that in offline communication strong and weak ties are (almost) equally presented, while in online communication weak ties are dominant. Moreover, weak ties are a lot less reciprocal than strong ties. However, while reciprocities are preserved across layers, the triads (measured using normalized three cycles and triplets) are not significant on the different layers of the multiplex network.

This is the outline of the paper. First, we describe the participants involved in the study and the procedure for collecting data. Next, we address the network endogenous (structural) and exogenous factors. Endogenous factors include graph characteristics such as reciprocity, three-cycles, transitive triplets, together with their normalized versions, as well as their generalizations for multiplex graphs. The section Results summarizes our findings regarding the offline and online multiplex networks generated by collecting the data described in the section Materials and Methods. We conclude the paper with the section Conclusions where we also discuss our future work.