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Impact of informal networks on opinion dynamics in hierarchically formal organization

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HIGHLIGHTS

- The fact that organization consists of formally hierarchical network and informal network is emphasized.
- The impact of informal network to formal organization is studied with opinion dynamics.
- Three main impact factors are agents' tolerances, informal network scale and number of links.

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ABSTRACT

Traditional opinion dynamics model focused mainly on the conditions under which a group of agents would reach a consensus. Conclusion has been gained that continuous opinion dynamics are subject to the constraint that convergent opinion adjustment only proceeds when opinion difference is below a given tolerance. This conclusion is useful but neglected the fact that an organization often consists of overlapped networks including formally hierarchical network and small-world/scale-free informal networks. To study the impact of different types of informal networks on converging speed or the number of opinion clusters, four typical types of informal networks (small-world, scale-free, tree and fully connected) are modeled and proposed as complements to formal communications. Experiments to compare formal network and hybrid networks are then carried out. It is observed that opinion dynamics with supplemented communications of informal networks can benefit convergence speed and reduce opinion clusters. More importantly, it is revealed that three key factors of informal networks affect their impact on formal network. These factors of informal network in descending orders are: agents' tolerances, scale and number of links.

1. Introduction

Agreement is one of the most important aspects of social group dynamics [1]. It is essential for an organization to reach shared decisions in many situations. Opinion dynamics is aimed at defining the opinion states of a population, and the elementary processes that determine transitions between such states. In the context of numerous information exchanges before decision-making, modeling adoption dynamics through methods inspired from information contagion is more appropriate than game theory in economics [2]. Research on public opinion dynamics has been gaining favor for several years, and many mathematical opinion dynamics models have been developed in social and political domains [3–6].

Opinion dynamics models can be classified as discrete and continuous, relying on the representation of opinion with discrete or continuous values. Well-known discrete models include Voter model [7], Sznajd model [8], Social Impact model [9],

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Axelrod Culture model [10], and Rumors model [11,12]. Continuous opinion dynamics models include Deffuant model [13], Hegselmann–Krause model [14], and CODA model [15]. The first two continuous models are bounded-confidence models [5], but they differ in the updating rule of opinions [1]. The CODA model is a hybrid approach, where agents hold continuous opinions, but make binary decisions. These classic models and their modified versions have been widely applied in exploring public opinion formation and social contagious behaviors.

Hierarchically formal organization is a structure where each entity in the organization is often subordinate to another entity [16]. This is the dominant mode of organization among large organizations like corporations, governments, military systems, organized religions etc. [17]. It is also typically visualized as a pyramid and depicted with a tree. Formal communications are those sanctioned by the organization itself and are organizationally oriented. Meanwhile, informal communications are socially sanctioned, and are oriented to the individual members.

Opinion exchange is ubiquitous among different units of any organization, both in formal and informal structure [18]. As an example, it is observed that direction of communication structures in military systems differentiates as formal and informal patterns [19]. Although the influence of informal network on formal organizations has been researched in the field of social science, it has not been researched with respect to quantified opinion dynamics in the form of hybrid network yet. For instance, Song et al. [20,31] built a military network to study the hierarchical relationships among agents, but the impact of informal network on the formal tree network was neglected. Weisbuch et al. [21] presented a model of opinion dynamics in which agents adjust continuous opinions as a result of random binary encounters whenever their difference in opinion is below a given threshold. This work did not take into account the communications of agents' informal network either. Therefore we propose to study communication impact of informal organization on hierarchically formal network in the domain of opinion dynamics. In this paper, the organizational structure will be modeled as a network consists of both formal and informal interactions and their interplay is modeled as round by round communications.

The remainder of this paper is divided into the following sections. Basic opinion dynamics model is built in Section 2. In Section 3, formal organization is modeled using an example network of armored division. Informal organization is modeled as four typical network types. Then interactions of the two networks are modeled as sequential communication rounds. Section 4 illustrates experiment results of opinion dynamics and corresponding analysis is given. Finally, conclusions are drawn in Section 5.

2. Basic opinion dynamics model

In organizations, agents are assumed to interact with their connected agents whose opinions do not differ too much from their own opinions. The difference is called tolerance in Ref. [20], or threshold in Ref. [21].

Core aspect of opinion dynamics model is tolerance and influence of agents [20,21]. Each agent has its own initial opinion. As prerequisite, we set floating initial opinion value for each agent, distributed uniformly between 0 and 1. Suppose that at time t, the opinion value of agent i is $z_i(t) \in [0, 1]$. When agent i communicates with another agent j, it keeps its initial opinion if the difference of their opinions is higher than its tolerance ($|z_i(t) - z_j(t)| > d_{ij}$), where $d_{ij}(0 < d_{ij} < 1)$ is the tolerance of agent i to j. Otherwise, agent i adjusts its opinion according to the opinion dynamics model, i.e., Eq. (1).

$$z_i(t+1) = z_i(t) - u_{ij} * [z_i(t) - z_j(t)] \tag{1}$$

where, $z_i(t)$ and $z_j(t)$ are opinion values of agent i and agent j at time t, u_{ij} is defined as influence of agent j on agent i. The larger tolerance means the node can compromise with more opinions, and the larger influence gives the node more opportunities for opinion adjustment in every communication. Based on Eq. (1), we can derive the more general algorithm for each agent i in every communication process, which is as follows.

$$z_i(t+1) = z_i(t) - \frac{\sum_j u_{ij} * (z_i(t) - z_j(t))}{N(j)} \tag{2}$$

where, $N(j)$ means the number of agent j that meets the communication conditions (where, agent i and agent j are connected as well as $|z_i(t) - z_j(t)| < d_{ij}$).

3. Modeling of formal and informal networks

3.1. Formal network model and its opinion dynamics

As known, hierarchical organization is a typical formal network widely applied in corporations, governments, military systems and organized religions [22,32,33].

Normally, the definition of formal organization is based on the concept of process organization and comprises vertical and horizontal structural aspects [16]. With respect to network organizations, Baker [23] suggests that formal network structures are based on two key principles of organizational design: (1) vertical and horizontal differentiation referring to the formal division of an organization into ranks, functions, departments, work teams, etc. and (2) informal integration refers to the degree of coordination and interaction among organizational units.