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Characteristics of successful opinion leaders in a bounded confidence model

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HIGHLIGHTS

- We study the HK model with competing opinion leaders.
- We define four characteristics: reputation, stubbornness, appeal and extremeness.
- We study how the four characteristics affect opinion leaders attracting followers.
- We show how successful opinion leaders perform in terms of the four characteristics.

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ABSTRACT

This paper analyses the impact of competing opinion leaders on attracting followers in a social group based on a bounded confidence model in terms of four characteristics: reputation, stubbornness, appeal and extremeness. In the model, reputation differs among leaders and normal agents based on the weights assigned to them, stubbornness of leaders is reflected by their confidence towards normal agents, appeal of the leaders is represented by the confidence of followers towards them, and extremeness is captured by the opinion values of leaders. Simulations show that increasing reputation, stubbornness or extremeness makes it more difficult for the group to achieve consensus, but increasing the appeal will make it easier. The results demonstrate that successful opinion leaders should generally be less stubborn, have greater appeal and be less extreme in order to attract more followers in a competing environment. Furthermore, the number of followers can be very sensitive to small changes in these characteristics. On the other hand, reputation has a more complicated impact: higher reputation helps the leader to attract more followers when the group bound of confidence is high, but can hinder the leader from attracting followers when the group bound of confidence is low.

1. Introduction

Opinion dynamics in a group of interacting agents (individuals) has been studied for a long time from a wide range of perspectives, e.g., sociology, physics, politics, economics and philosophy [1–6]. In these models of opinion dynamics, a group of agents who hold beliefs and opinions about a given topic interact with each other to seek truth or reach consensus [7]. In many real situations, there are some agents, called *opinion leaders*, in a society who have more power on influencing the other agents' opinions because of their expertise or positions [8–10]. In some cases, there are usually two or more (groups of)

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opinion leaders holding competing opinions, e.g., political parties in elections, experts in scientific research, opinion leaders in science and religion [11,12]. In a society with competing opinion leaders, questions such as, under what circumstances (a) agents follow one of the opinion leaders but reject the other, (b) opinion followers switch from following one leader to another, (c) a sub-group of agents emerge that do not follow any opinion leader, immediately suggest themselves.

The original definition of opinion leaders in social opinion dynamics was provided by Katz and Lazarsfeld [13] as "the individuals who were likely to influence other persons in their immediate environment". Although intuitively clear, this definition does not provide a specific mechanism through which the opinion leaders influence the others. The well-known two-step flow model described a process of the information influence "flowing" from the media through opinion leaders to their respective followers [14], where the mechanics of the process itself remain unspecified. Based on the two-step flow model, using different opinion update rules, a significant number of opinion dynamics models have been built to analyse the function of opinion leaders in the context of party elections, marketing, and diffusion of innovations [8,13,15].

Despite the merits of these models, it is worth considering in more detail how to model the mechanism and measure the power of opinion leaders to influence their followers. In reality, the ways opinion leaders utilize their powers to affect the opinions of others are quite diverse due to different scenarios, their personalities and backgrounds [1,16]. It is hardly possible to consider all of the real characteristics in one mathematical model, but key characteristics can be included. Kurmyshev and Juárez [17] suggested *reputation* as a key characteristic reflecting the power of opinion leaders, which is usually realized through higher weights assigned to leaders. Interestingly, however, Douven and Riegler [18] reported that applying higher reputation to some elite agents does not produce a discernible difference compared to the situation where all the agents are equally weighted. It was also suggested [17] that opinion leaders should maintain invariable opinions in the process of opinion dynamics, which is sometimes called *stubbornness* [19,20]. More recently, Zhao and Kou [21] proposed an opinion leader–follower model which divides the whole group into two sub-groups, i.e., a leader sub-group and a follower sub-group, and the information/influence transition is based on the principle of a two-step flow model where the opinion update is based on a bounded confidence model, the Hegselmann–Krause (HK) model [22,23]. Their results showed that the opinion followers are strongly influenced by the leaders if they have higher confidence levels and trust degrees in the leaders. The trust degree introduced in their model is defined by the weights of leaders, and so is actually a kind of reputation, while the higher confidence levels of followers towards opinion leaders can be thought of as the *appeal* of the opinion leaders.

Most of the existing models on opinion dynamics with opinion leaders discuss only one leader or a sub-group of opinion leaders who normally achieve consensus, while the phenomenon that two or more (groups of) opinion leaders hold competing opinions in a social group is very common in reality [11,12], and therefore it is important to explore how competing opinion leaders can attract more followers. For potentially competing opinion leaders, their opinions usually go in polarized directions due to the competing environment [24]. Therefore, the opinion *extremeness* should also be considered as an important characteristic of opinion leaders, especially in a competing environment. Summing up, we conclude that the influential power of competing opinion leaders on their followers in a social group can be measured by four characteristics: reputation, stubbornness, appeal and extremeness. However, there are few studies that have analysed the impact of such characteristics on opinion dynamics in a social group with competing opinion leaders systematically, and therefore this will be the focus of the current paper.

As for opinion update mechanisms, there are generally two types of opinion dynamics models: continuous opinion dynamics and discrete opinion dynamics [5,6]. In continuous opinion dynamics models, the opinion is usually modelled as a real variable in the interval [0, 1], and the agents interact with each other to update their opinions. The bounded confidence model is a representative continuous opinion dynamics model, where agents only interact with neighbours whose opinions are similar to theirs, and the similarity is decided by the bound of confidence or tolerance [25]. Among these models, the Deffuant–Weisbuch (DW) model and HK model have recently received considerable attention [26–33]. It has already been well established that these models have consensus thresholds for the bound of confidence, above which a consensus in the group is always achieved while the whole group may split into two or more non-interacting sub-groups with the same opinion in each of them when below the consensus thresholds [5]. Furthermore, several interesting modifications or extensions to these models have been introduced recently. Some of the modifications introduce heterogeneous bounded confidence such that the assumption that all individuals in a given society have the same level of confidence is no longer necessary [32]. The impact of external factors, e.g., mass media, on dynamics of opinions in real societies has also been analysed recently [34,35]. In this paper we adopt the HK model as the basic opinion update mechanism for the group opinion dynamics with competing opinion leaders, and use it to investigate the impact of the four characteristics of opinion leaders identified above.

2. The HK model with opinion leaders

The HK model is based on a complete network consisting of n vertices, representing agents, i.e., all the agents are linked to each other. Each agent holds an opinion about a given topic. The opinion $x_i(t)$ that agent i has at time-step t is a real variable in the interval [0, 1], and it may change along a set of discrete time points according to the given update mechanism. We adopt the extended HK model proposed in Ref. [18] as the basic opinion update mechanism, which is

$$x_i(t+1) = (g(i,t)) \quad {}^{-1} \sum\nolimits_{j \in I(i,t)} r_j x_j(t). \tag{1}$$