Node Conversion Optimization in Multi-hop Influence Networks

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ABSTRACT

In this paper, we study scenarios such as diffusion of innovations in a social system and belief propagation in social choice decision-making, which can be captured by a social influence network. In such networks, nodes are distributed and are connected by links between them. Nodes have two different states, s and r. They can change from state s to state r, but not backward [24]. Nodes are interested in changing to state r only if a sufficient number of their neighbors change to state r. In many scenarios, it is desired to design *local decision algorithms* that guarantee this feature, termed as the *safety* of node conversion.

We design optimal algorithms that maximize the number of nodes that change to state r. In particular, we assume that each node can observe its neighbors up to a distance of k from itself, which introduces complexity to the setting that each node can only observe its immediate neighbors, i.e., $k = 1$. Moreover, we consider the models that nodes have the same threshold or different thresholds under which their conversion from s to r is safe. We first present the optimal algorithm for the uniform threshold model and establish its optimality by characterizing a monotonicity property. We then generalize the algorithm to maximize node conversion when they have different threshold values. The monotonicity properties and insights on nodes' recursive reasoning of their neighbors' status may be of independent interest.

KEYWORDS

Influence network; local decision; multi-hop; node conversion optimization.

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1 INTRODUCTION

In this paper, we follow the literature [4, 8, 18, 32] and consider the distributed decision-making multi-agent coordination problem. In daily life, most decisions people make, from which new products to buy to whom to vote for, are influenced by their friends' choices. Taking the diffusion of innovations, for example, often, individuals only wish to buy a new product if a sufficient fraction of their friends do. The purchase from their friends justifies the popularity and quality of the new product. For another example, when the shareholders of a company defend against a hostile takeover, an essential factor in their decision-making is how many other shareholders are resisting the acquisition. Naturally, the more shares have been acquired by the bidder, the more likely they would sell their shares. This empirical evidence on these peer effects motivates the theoretical study of Influence Networks.

On an influence network, agents are spatially separated but are linked by mutual relationships. Although communication is a powerful instrument to enable coordination, sometimes it is not as efficient as it is supposed to be [9, 10]. Thereafter, intelligent agents must be able to optimize their actions even without the benefit of communication. In many practical applications, indeed, communication may not be feasible. For instance, embedded platforms have strict energy constraints; communication channels are under electromagnetic interference; enemies can detect security risks of potential interception of messages in hostile territory. Therefore, it is natural to ask the question that can agents coordinate without communication? We tackle this question by considering situations where communication is impossible or forbidden, popularized by [3, 13, 16].

We consider a model in which agents have two possible statuses and can observe the network's local topology. Each agent can either keep its current status (not buying a new product and not attending a conference) or change to a different status (buying a new product and attending a conference). They would like to change their status if there are a sufficient number of their peers who do so; otherwise, they prefer to keep their original status. To prevent the system from being stuck in a suboptimal configuration, we are interested in protocols that change as many agents' statuses as possible.

Existing literature in studying influence networks has been implicitly assumed that not only does the individual's preferences depend on the status of their neighbors, but also that each individual only knows the information of their immediate neighbors. Therefore, agents do not mull over information beyond its 1-hop neighbors. This way, problems such as determining conditions under which it is safe to change status and maximizing node conversion is often tractable. However, in many scenarios, such as the aforementioned example in which academics decide to attend a conference, their decision is affected by their close colleagues and a wider range of friends who will attend the conference. In addition, each individual could have a different threshold on their neighbors' conversion beyond which they will decide to attend the conference. Hence, investigating the multi-hop information setting and generalizing the uniform threshold case to allow agents to have arbitrary thresholds is a natural extension in studying influence networks. In this case, on the one hand, the agents stand a better chance to make their decision if they view further on these networks; on the other hand, enabling agents to have distant views introduces extra complexity in their decision-making analysis.

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