Influence Maximization for Informed Agents in Collective Behavior*

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Abstract. Control of collective behavior is an active topic in biology, social, and computer science. In this work we investigate how a minority of informed agents can influence and control the whole society through local interactions. The problem we specifically target is that a minority of people with a bounded budget for initiating new social relations attempt to control the collective behavior of a society and move the crowd toward a specific goal. Assuming that local interactions can only take place between friends, the minority has to initiate some new relations with the majority. The total cost of new relations is limited to a budget. The problem is then finding the optimal links in order to gain maximum impact on the society. We will model the problem as a diffusion process in a social network. The proof of NP-hardness of the problem for Local Interaction Game model of diffusion is presented. Simulations show that the proposed method surpasses the popular strategies based on degree and distance centrality in performance.

1 Introduction

Influencing society and changing the crowd behavior is one of the oldest ambitions of social science. Social and political sciences pursue strong impact on the society to change the attitude of people and prevail a desired behavior in the society. Socio-physics deals with such problems under the Opinion Formation topic [1]. In economical side this phenomena is known as Viral Marketing [2], [3].

The main problem that has been investigated extensively for attaining manipulation of crowd behavior is finding most influential persons of a society whom we

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call initiators from now on. Organizational theory calls such influential persons key players [4] and in political science they are called opinion leaders [5].

The idea is that influencing initiators would lead to the greatest possible diffusion of a behavior in a society. In Viral Marketing initiators are influential customers who are selected for direct marketing. Giving free samples or discounts are examples of marketing strategies for motivating initiators which would lead to stimulation of the others for buying the new product. Two-step flow theory in social and political sciences assumes initiators are well connected opinion leaders who channel media information to the masses [6].

All solutions of "K most influential persons" (K-MIP) problem suppose that changing initiators' opinions or behaviors is possible by costing a budget [7][8]. This simplification is not the case for real world problem, since opinion and behavior of people usually cannot be influenced by paying money.

On the other hand, studies in the field of Swarm Intelligence have more robust solutions to this problem. Couzin et al. [9] showed that among a group of foraging or migrating animals only a small fraction of them have proper information about the location of food source, or about the migration route. But these informed agents can guide the whole group through simple social interactions. The bigger the group is, the smaller the fraction of the required informed agents is. Halloy et al [10] showed in real experiments that informed robots in a mixed-society of animals (cockroaches) and robots can control the aggregation behavior of the mixed-society through microscopic interactions.

The strategy followed in this paper is similar. The minority is regarded as informed agents who want to have control on the opinion of the society. They should do this through social interactions that take place between local neighbors, i.e. agents that have direct friendship ties. So the minority has to have friendship relations with the majority or initiate new ties upon necessity. But in realistic situations, the total number of links that the minority can initiate is limited to a number, due to e.g. time or geographical distance. Now, the minority should choose which links to initiate in order to gain maximum impact on the society.

The rest of this paper organized as follow: in Section 2 related works are discussed. Section 3 presents the selected model of diffusion. In Section 4 we convert our problem to an optimization and solve it in Section 5. Finally Section 6 consists of simulations that compare our method with well-known heuristics.

2 Related Work

K-MIP tries to manipulate crowd behavior by directly targeting initiators. There are many models that describe diffusion phenomena by using methods from different domains. Based on the selected diffusion model, method of finding influential persons can vary. In this section different diffusion models are described and K-MIP solution for each of them is presented.

In all models, society is modeled by a directed graph $G = (V, E)$ whose vertices V and edges E are representing individuals and social relations respectively. In some models edges are weighted. Weights are usually interpreted as node v's trust on $N(v)$ which is the set of v's neighbors.