Physica A 466 (2017) 570–582

Contents lists available at ScienceDirect

Physica A

journal homepage: www.elsevier.com/locate/physa

A novel game theoretic approach for modeling competitive information diffusion in social networks with heterogeneous nodes

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HIGHLIGHTS

- A game theoretic approach is proposed to model competitive influence maximization.
- Network structure, nodes' heterogeneity and message content have been modeled.
- The solutions differ from well-known strategies in a non-competitive situation.

ARTICLE INFO

Article history:
Received 29 April 2016
Received in revised form 28 July 2016
Available online 27 September 2016

Keywords:
Social network
Influence maximization
Diffusion
Competition
Heterogenous nodes
Game theory

ABSTRACT

Influence maximization deals with identification of the most influential nodes in a social network given an influence model. In this paper, a game theoretic framework is developed that models a competitive influence maximization problem. A novel competitive influence model is additionally proposed that incorporates user heterogeneity, message content, and network structure. The proposed game-theoretic model is solved using Nash Equilibrium in a real-world dataset. It is shown that none of the well-known strategies are stable and at least one player has the incentive to deviate from the proposed strategy. Moreover, violation of Nash equilibrium strategy by each player leads to their reduced payoff. Contrary to previous works, our results demonstrate that graph topology, as well as the nodes' sociability and initial tendency measures have an effect on the determination of the influential node in the network.

1. Introduction

Influence maximization is an optimization problem that deals with the diffusion of information in social networks. It is thought that diffusion of messages is usually more effective and convincing if messages are received from a friend (Like viral marketing) rather than from a *social change agent* (e.g. Companies) [1,2]. The Social Change Agency works to support people and organizations with the aim of creating social impact. Universities are instances of social change agents [3]. Therefore, it is the interest of social change agents to identify and target a few "influential" seed nodes. These influential members are then expected to trigger a cascading influence, starting from their own friends who would consequently recommend the

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http://dx.doi.org/10.1016/j.physa.2016.09.038
0378-4371/

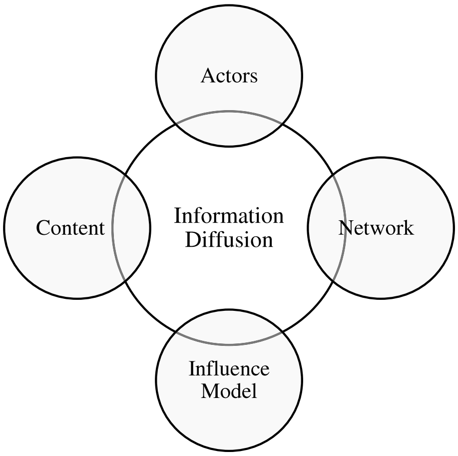

Fig. 1. Information diffusion components [16].

product to other friends so that many individuals are attracted [4]. Domingos and Richardson [5] initiated this research field which was later followed by Kempe et al. [6] who considered the linear threshold and independent cascade models. A wide array of research then focused on the identification of the most influential nodes in social networks so that the spread of information is maximized.

Influence maximization is generally classified into two major categories [7,8]: competitive and non-competitive influence maximization. In the competitive case, there are at least two players who strive to attract as many users as possible in a given social network. In the non-competitive case, however, only a single player is present. In this work, the focus is on the competitive case in which a conflict of interest exists between social change agents and diffusion of information that takes place via a communication platform, such as cell-phone text messaging services.

To date, several studies have attempted to model the competitive influence maximization problem by introducing algorithmic [8–11] and game theoretic models [7,12–15]. Alon et al. [12] used a game theory framework where two players compete to propagate their opinions on a topic over a social network with homogenous nodes. In their work, the effect of message content on information diffusion is ignored and their model fails to incorporate the situation in which a node is linked to two or more nodes with differing opinions. Fazeli and Jadbabaie [14] investigated a game between two firms who attempted to maximize the spread of their product in a network [14]. They considered a cost for infecting the initial nodes in their model and assumed that the choice of each node is a function of the respective choice of its friends. Here, the effect of individuals' characteristics and message content on diffusion of information was not considered and it was further assumed that all neighbors of a node equally effect its choice. Tzoumas et al. [7] studied issues of existence, computation and performance (social inefficiency) of pure strategy Nash equilibria. They used linear threshold model as the influence model to model a game between two firms who strive to maximize their diffusion in a social network. They utilized one of the well-known influence models, linear threshold model, which assumes homogeneous nodes and ignores the effect of message content on the diffusion process. In addition, they did not consider the cost of infecting the initial nodes.

To tackle the shortcomings of previous efforts in the field, the present work investigates the effect of individual characteristics and message content on the diffusion of information in a social network using a competitive influence model. Here, a strategic interaction is dealt with between the social change agents (e.g. sport clubs such as Real Madrid and FC Barcelona) who strive to maximize the diffusion of their product in the network. Following Weng [16], four components are incorporated into the model: *actors, content, underlying network structure*, and *influence model* (see Fig. 1) [16].

The rest of the paper is organized as follows: Section 2 introduces the game and its corresponding components (i.e. players, player strategies and player payoff). Section 3 presents the novel competitive influence model that determines the rules of the game. Section 4 demonstrates an implementation of the proposed game on a dataset. Finally, Section 5 concludes the paper.

2. The game

In this section, we describe our novel game theoretic framework which deals with competitive influence maximization problems. Notations hereby used are given below:

$i, j =$ Source and destination individuals (nodes).
$N = \{p_1, p_2, \ldots, p_{|N|}\} =$ The set of social change agents or players.
$V = \{1, 2, \ldots, n\} =$ The set of individuals (nodes) in the society (social network).
$IN_{p_k} =$ The set of initial nodes selected by the kth social change agent (or player) to which the message is sent.
$t =$ Discrete time step.