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Managing social networks: Applying the percolation theory methodology to understand individuals' attitudes and moods

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ABSTRACT

A disruptive technology is an unexpected technological breakthrough which destroys existing markets, shakes up an industry and induces organisations to radically change their business models. Digital technologies, and in particular social media are, without a doubt, the most disruptive innovations to have emerged over the past few decades. Social media virtually rule society: people's moods and opinions, spreading openly and rapidly within networks, can affect almost any business or brand in a positive or negative way.

This conceptual study aims to search for ways in which to describe and manage the states of groups of individuals by researching percolation processes in social networks, and identifying percolation thresholds at which negative moods and undesirable ideas will be freely distributed within the network. The methodology proposed for describing the state and dynamics of individuals' moods implements percolation models. Percolation processes are modelled using specially designed software. Within the chosen model framework, percolation theory generates answers to the following questions: a) how does society become clustered into groups of individuals united by certain views according to the average number of connections per node? and b) what proportion of negatively-tuned individuals can bring the network into such a state wherein harmful information can be transmitted between two randomly chosen individuals? Focus is placed on discussing practical implications of the results in order to both predict people's behaviours, and to manage groups of people in networks. This work may be of interest to scientists, specialists in consumer behaviour, sociologists and politicians.

1. Introduction

It is widely accepted that the internet is the most disruptive social and technological innovation to date, having provoked deep changes in every sphere of society. Social networks have revolutionised the ways in which people communicate with each other: now anyone owning a mobile phone can broadcast ideas and views without restrictions, to huge audiences within their network. This can significantly affect politics and businesses, and people's attitudes and moods in general. Therefore, researching the processes of dynamics of states of society is a highly relevant and has significant implications for today's world. Take brands, for example: today, when social networks virtually rule society, brands are impacted and can potentially be harmed due to the huge volume of their clients who use these social networks. If no effort is made to manage consumer behaviour, the consequences for companies can be very unfortunate indeed. Therefore, monitoring and managing the moods of individuals is important for ensuring the success of brand marketing strategy, the safety of the customer groups and, more widely, the national security of any state, especially in times of growing international instability and serious economic downturn. As for national security, assessing and monitoring so called "crowd behaviour" and the moods and views manifested by users of social networks can serve to purposely influence a situation when it becomes alarming. For business purposes, the benefits are also evident: digital marketing, monitoring and managing customer moods, advertising in social networks, etc. can all benefit from "crowd behaviour" research.

A social network can be understood as being a unity of individuals with various motivations, abilities, goals, etc. connected by a set of more or less random mutually-influential connections such as personal acquaintances, business partners and colleagues, family circles, mass media, etc. In such a structure, it is possible to tentatively reveal two mutually connected and reciprocally influencing subsystems: the information system and the social system. The information system comprises various mass media, the choice of which is defined by the personal characteristics of an individual, such as their level of education, professional qualifications, etc. In other words, a social network is a

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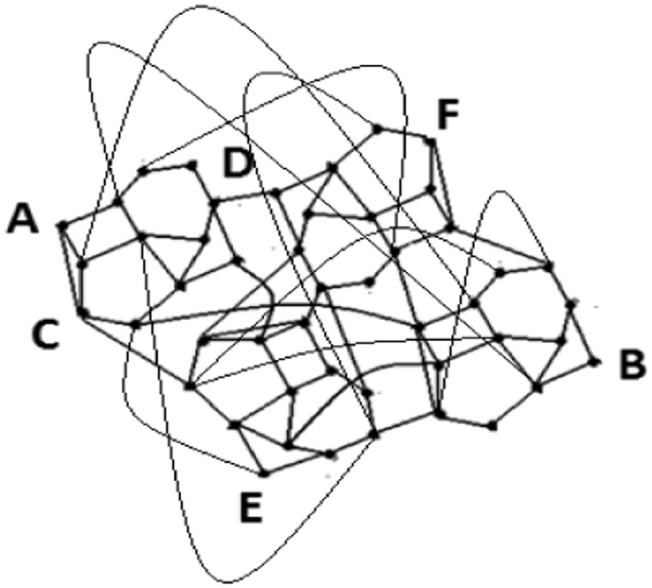

Fig. 1. The structure of the social network of individuals A, B, C, D, E (Block et al., 2015).

network located within an information environment including the internet, books, newspapers, etc. Mass media have a significant impact on the condition of certain nodes in a social network, encouraging individuals to make choices and to choose certain behavioural reactions. As such, the condition of nodes (individuals) can change over time under the influence of both the information environment and internal interactions within the network.

As the information environment is mainly the object of direct management, managing the state of social networks in the interpersonal (social) environment in terms of loyalty and manipulation inspires the greatest aspect of research interest. Hence, a number of questions arise. Firstly, it would be important to know how, and how fast, the proportion of nodes with a certain condition in a network can be modified, i.e. how the massive influence of TV, the internet, etc., can cause the proportion of people with certain views to increase or decrease, and what the "ideal" proportion of such people should be. The second thought-provoking question is how these people (nodes) become grouped into subgroups or clusters.

In Fig. 1 the structure of the social network is illustrated, wherein people are nodes and channels of communication are edges or bonds, the number of which can be random.

In this network, information distribution can occur through various trajectories and nodes, so the number of potential routes can be very large. Information is transferred or blocked in the following way: a given node (individual A, B, C, D, E, etc.) receives certain information, i.e. a number of ideas, political and professional views, opinions, and so on, and transfers this to other nodes (individuals) if s/he internally agrees with the received information, making him/her an active transporter. If s/he disagrees with the incoming ideas and information flows as a result of his/her internal beliefs or for any other reasons, such further spread of information is blocked.

The important issue of social security criteria, which directly or indirectly influence negative moods and threaten social stability, must also be addressed. Such criteria can be represented by a) the probability of free negative information spread or "percolation" and b) the probability that individuals with negative moods will unite with direct connections: this is called a clusterisation process.

The percolation processes model was initially developed in the field of Physics and represents a universal mathematical tool for researching clustered and non-clustered environments. Percolation refers to regular movement of media (whether this is information, liquid, epidemic, etc.) within a random environment (Tarasevich, 2002; Zhukov and Aleshkin, 2008). Percolation takes place if the neighbouring active cells (nodes) of a network, having a certain probability, group together and form a cluster which becomes gradually large enough to connect two sides of the net or two chosen nodes. This probability is called the "percolation threshold" (PT): the proportion of transmitting (non-blocked) nodes when conductivity between two randomly chosen nodes in a network takes place.

The most common modelling proposed by percolation theory are those of nodes and of bonds (Tarasevich, 2002). In the field of bond modelling, researchers attempt to discover the proportion of bonds which must be removed in order to prevent percolation. For node modelling, researchers investigate how many nodes must be blocked in order to break the network (Block et al., 2015). Studying the characteristics of the percolating cluster is another preoccupation of percolation theory. In Physics, percolation is often investigated in regular networks (rectangular, square, cubic). However, networks of people usually have a random structure, as in Fig. 1. Therefore, only computer modelling can provide solutions to accurately represent these structures.

Percolation theory can be applied to numerous physical processes such as electrical conduction (Last and Thouless, 1971), fracture mechanics (Robinson, 1983), spread of epidemics (Newman, 2002), information flow between Internet servers (Zhao et al., 2005), personal relationships in a telephone network (Onnela et al., 2007), financial flows among banks (De Masi et al., 2006; Ueno et al., 2007), intra-organisational knowledge sharing (Khvatova et al., 2016), etc.

In this research, solutions for the two key models which emerge when describing and managing society states, i.e. percolation and clusterisation within social networks, are presented.

a) *Percolation in a social network*. As mentioned before, the proportion of unblocked (active) nodes allowing information transfer between two distinct randomly chosen nodes is called *the percolation threshold*. Exploring social moods in terms of percolation theory, free spread (percolation) of negative information from one random person to another in a social network can be considered in our model as the threat criterion.
b) *Clusterisation of a social network*. The transition of any social network node (an individual) from a state of loyalty to a state of negativity (opposition) is a random process, characterised by the probability of this transition being influenced by a number of factors, including mass media. This probability inevitably influences the average size of a cluster as a group of directly connected nodes, as well as influencing their negative (oppositional) or loyal moods.

Percolation theory enables us to explore the following concrete questions:

1. What is the proportion of negatively-tuned individuals (nodes) creating the condition for the free distribution of negative influences from one randomly chosen node of a network to another?
2. How does clusterisation of society into groups of individuals united by negative views happen, according to the average number of connections per node?

The proportion of negatively (oppositionally, criminally, etc.) tuned individuals can be calculated using sociological surveys, enabling us to assess how close the network is to the PT (i.e. how close society is to a social explosion, for example). To assess this, the average number of connections per node is also required. This can be defined by monitoring existing social moods.

The aim of this conceptual study is to provide the foundations for percolation-based approaches which give insight into how information spreads through social media and, in particular, to find a way in which to consistently describe and manage the state of groups of individuals using computer modelling: a) researching percolation processes in

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