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The Analysis and Modelling of Social Networks: Leader Identification and Information Dissemination

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***Abstract* – Individuals, who have more connections with others in the social network, can have more chances to influence others. Therefore, this study aims to identify groups of users with maximum joint influential power in order to help companies to conduct online marketing and reputation management. The method proposed in this study can be used to identify influential groups, on the basis of data from SNS. The proposed method will allow building a social network model, which will be used to simulate different scenarios in order to predict the speed of information dissemination.**

***Keywords* – social network, modelling, social network visualization, pretopology, leader identification**

I. Introduction

Recently, the emerging industry of social networking sites (SNS), such as Facebook, Twitter, and Draugiem, has attracted the attention of researchers and marketing specialists. These sites not only allow users to comment and express their opinions about the products, people, organizations, events, and many other objects (entities), but also allow users to build a variety of social relationships.

In the last few years, this problem becomes more acute. Marketing experts have assessed the role of social networks, in particular, by promoting new products. Companies are increasingly interested in social networking sites to promote their products and to get feedback from their customers.

Many companies are trying to identify groups of users with maximum joint influential power in order to help them to conduct online marketing and reputation management.

Using these social relations, opinions will have a greater impact on people rather than other sources (such as shopping sites), because people always more easily believe or trust the opinions of those with whom they have social relationships [7]. In addition, the opinions expressed in SNS have a wide and rapid effect on users, i.e., some opinions can strongly influence other users' decisions regarding purchases or their opinions about the company.

The goal of the study is to develop an approach for influential group identification. To achieve this goal it is necessary to study the spread of influence in social networking sites and dissemination of information, different approaches to social network modelling, as well as different methods and techniques for social network visualization.

The study will be developed within a social network model for one of the industrial representatives. Within this model, different scenarios will be simulated, such as new product promotion or extreme incidents that are associated with competitors' negative advertising, with the aim to predict the speed of information dissemination in a social network and improve response time due to incidents.

In this study, a mathematical framework proposed by Vincent Levorato [1] is used to solve the social networking group modelling problem using pretopology as a generalization of graph theory. The paper also provides a simulation example using the Levorato's formalism.

Network simulation is used in several research fields (physics, biology, computer science, etc.), and it is mainly based on graph theory. In particular, in social network modelling, the graph is used to describe the links that represent relationships or flows between the entities. Usually individuals are listed as separate elements, but the groups are formed of the interaction of several individuals.

The method proposed in this study can be used to identify influential groups, on the basis of data from SNS. Overall process of this method consists of three steps: Data Collection, Influence Network, and Target Group Identification.

Social network visualization field is very extensive, with various methods and approaches. Social network visualization can be based on two main areas of research [2], [3], information visualization of networks and graph drawing. In other words, visualization design is responsible for information visualization, navigation and interactivity, whereas properties and construction of geometric representations are more central to graph drawing.

II. Influence in Social Networking Sites

In the existence of enormous competition, the company's dialogue with the customer is extremely important. Companies are increasingly interested in social networking sites to promote their products and to get feedback from their customers. It is therefore necessary to evaluate and rank the users according to different purposes. This study aims to identify groups of users with maximum joint influential power in order to help companies to conduct online marketing and reputation management. The concept is based on Twitter social network features, where the particular attention is devoted to the determination of leaders.

Spread of influence and information dissemination in social networks is very closely related to each other. Opinions have a greater impact on people rather than other sources (such as shopping sites), because people always more easily believe or trust the opinions of those with whom they have social relationships [7]. In addition, the opinions expressed in SNS have a wide and rapid effect on users, i.e., some opinions can

strongly influence other users' decisions regarding purchases or their opinions about the company.

With the commercialization of the Internet in 1993, a considerable number of online social networking sites have achieved international fame [4]. Online social groups have become extremely important in the social environment, as they "provide sociability, support, information, a sense of belonging, and social identity" [5].

People can position themselves as independent entities with unique attributes and goals (individual identity), as partners communicating with each other (relational identity) or as members of the group, conforming to social norms (collective identity).

In this research, the hypothesis of homogeneity is important because it is related to the personality and value profiles of online social networking groups. When members of the group have similar values and personal qualities, we can expect greater cooperation and solidarity in the group and, consequently, greater group functionality and effectiveness [22]. One of the objectives of this study is to identify the leaders. It is necessary to separate standard users from leaders of these groups.

Leadership is one of the most widely researched topics in organizational science. Thus, leaders and members develop exchange expectations, based on their characteristics and their exchange partners. Finally, the relationship either weakens or strengthens by dyadic partner's evaluation of the exchange, such as met expectations and efforts perceived by the other party [6].

According to the attraction–selection–attrition (ASA) method [6], leaders influence and are influenced by the group modal characteristics, which are shown as a comparison between personalities and values of the leaders and members. Prior research has found that leaders influence collectively and use cultural artifacts in virtual groups [23].

Using these social relations, opinions will have a greater impact on people rather than other sources (such as shopping sites), because people always more easily believe or trust the opinions of those with whom they have social relationships [7]. In addition, the opinions expressed in SNS have a wide and rapid effect on users, i.e., some opinions can strongly influence other users' decisions regarding purchases or their opinions about the company.

Many business entities have recently come to understand this phenomenon, and some companies have been attempting to identify certain users of SNS for online marketing and reputation management in the field of e-commerce and e-business [8]. If companies are willing to use benefits of SNS for cost-effective, targeted marketing, and reputation management, they should give serious consideration to this issue, because of a large number of users of social networks and limited budgets of companies. This brings us to the question of what opinions are more important and which users have a greater impact on the actions of others. If the most influential groups of users can be identified, companies will have a minimum of resources to improve sales and enhance the reputation of the company.

Recent results of marketing research suggest that if the customers are provided with positive information about the products or the company by all related users in online communities, the probability of purchase of such products or improving the general opinion about the company is higher [9], [10]. This is known as the joint influential power of a group of users. Therefore, the marketing specialists must identify users, who have large joint influential power in SNS, and find ways to encourage these people to express a positive opinion about the company and its products in the strategy of target marketing. As a result, companies can maximize their sales and enhance the reputation of enterprises through the joint influential power of the specific group of users.

III. General Mathematical Framework

In several studies of social networks, it is considered that the group behaviour is equivalent to a single individual's behaviour "sum" [1], [6]. However, groups need to be seen as a complex system, which could lead to new phenomena.

There may be various types of relationships different in nature: for example, we can simulate the social network, which contains colleagues and geographical relations. It is possible to create pseudo-closure, solving the problem of modelling, for example, people are close to each other, if they are friends, colleagues, and neighbours (using a given distance threshold). This concept has allowed using a general mathematical framework, which is proposed by Vincent Levorato [1], to simulate groups in social networks, using pretopology formalism, in generalization of graph theory.

Network theory was invented by Swiss mathematician and physicist Leonhard Euler in 1730s. The network consists of nodes and links where the nodes are connectors and links are connections between nodes [13]. For example, the social network of nodes and links is represented by the people who are tied together by friendship. Basically, the social network is an online community of people united by a common interest. Social networks are focused on the people. Classical social services, such as Twitter, Facebook and Draugiem, provide people with a place in the global online community to create their own websites and provide communication tools and other basic tools to perform a variety of activities in the social network [14].

Network simulation is used in several research fields (physics, biology, computer science, etc.), and it is mainly based on graph theory. In particular, in social network modelling, the graph is used to describe the links that represent relationships or flows between the entities. Usually individuals are listed as separate elements, but the groups are formed of the interaction of several individuals.

Since social networks are complex networks, it is possible that new phenomena emerge and behaviour of groups of individuals, behaviour "sum", can vary from each individual in a group. Thus, graph theory is insufficient to model all complex interactions that occur in social networks. This is the

reason why the mathematical framework proposed by Vincent Levorato is very useful for modelling groups of entities in the network. Levorato proposed the mathematical structure of the group entity modelling social networks from the topological point of view.

In this section, it is displayed how a social network can be modelled by complex interactions using Levorato's general mathematical structure. This example is based on a "toy" dataset, which reflects the relationship between the monks in the monastery. This example is often used in various studies of sociology. It is based on large amount of social interaction data. Many relationships are encoded, but the reader's attention is focused on just two: esteem and disesteem. The relationships are not symmetric and have three integer values – from 1 to 3 (3 represents the highest or first choice and 1 is the last option). The model was constructed based on the following assumptions: the individual y is close to another individual x if:

- there is **esteem** from y to x, according to the selected threshold;
- there is no **disesteem** from x to y, according to the selected threshold.

This model is based on the following hypothesis: if an individual asks other people "who would like to join my group?", most people with a sense of esteem to him will approve this offer more than other people. However, this individual will not take in his group individuals, against whom he has feelings of disesteem, even if they respect him. This model evaluates two asymmetrical relationships with E, which contains individuals:

$$E \times E \to \mathbb{N}$$

$$(x, y) \to est(x, y)$$

$$(x, y) \to disest(x, y). \qquad (1)$$

where ***est*** is esteem relationship and ***disest*** – disesteem relationship.

Pseudo-closure is built, using Levorato's mathematical framework:

$$\forall A \in P(E), a(A) = \left\{ y \in E - A / \sum\downarrow (x \in A) \cong est(y, x) \geq \right. \qquad (2)$$

$$\left. \geq a \wedge \sum\downarrow (x \in A) \cong disest(x, y) < \beta \right\} \cup A$$

Where $\alpha, \beta \in \mathbb{N}$

In this example, strong restrictions on the neighbors is made $\alpha = 3$ and $\beta = 1$: if the pseudo-closure is applied on the set of people, then people will be in $\alpha(A)$ pseudo-closure, if they feel the esteem to one or more individuals from A (according to α), and if A not contains people who feel disesteem for them (Fig. 2).

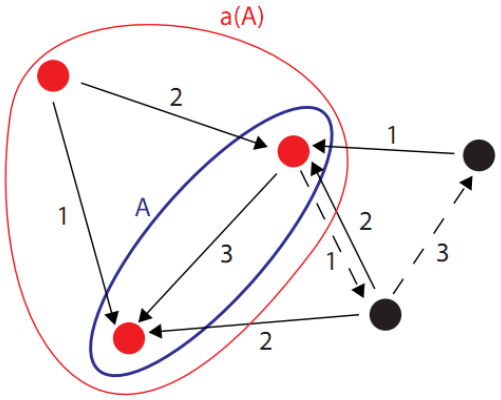

Fig. 1. Pseudo-closure of of A with $\alpha = 3$; $\beta = 1$. Esteem relation is represented by a straight line and disesteem relation – by a dashed line

Levorato's mathematical framework can be used to discover the largest group in a social network, using the author's technique of neighbours, building $\mathcal{F}_e$ household of all closed elementary subgroups from E sets. When the closure is applied to each of the sets E consistently, it reveals that there is an $VICTOR\_8$ individual, who can gather around himself the most people in social networks (Fig. 3).

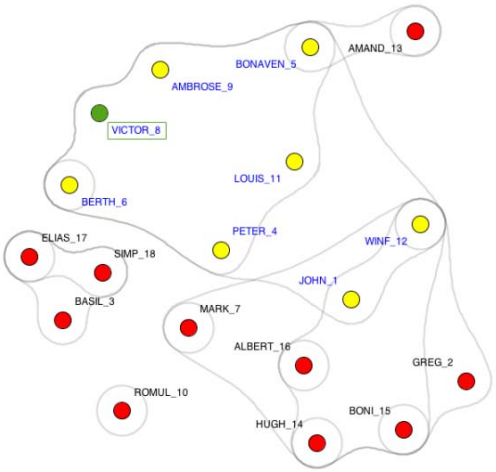

Fig. 2. Simulation of model to find the most influential person according to a given neighbourhood definition

Using Levorato's mathematical model, a social network was modelled with the Java language using PretopoLib library that can implement all pretopology concepts.

IV. Social Network Visualization and Modelling

Social network visualization is a field of growing interest per se, as well as partly because of the variety of available methods suitable for specific use cases.

Visualization methods that are used in this study help to promote the visual exploration of data and models. Obviously, experimentation and further clarification will be necessary to better assess their utility.

The inherent flexibility of the basic layout engine, stress reduction may carry over related visualization problems, and it is planned to look at the exponential random graph models.

Most of the studies in the field of network visualization are in the social network using the node-link format to describe social concepts. It is based on the assumption that clearly drawn network representation will automatically deliver the topological features described by social network concepts. However, visualization based on node-link format usually does not present data in terms of standard network concepts. Therefore, it can be challenging to understand their concepts. For the most part, they just assume the network visualization of concepts that are included in their reference values. To interpret them, users need to integrate different visual cues presented in the visualization and then infer the network concepts of interest [13].

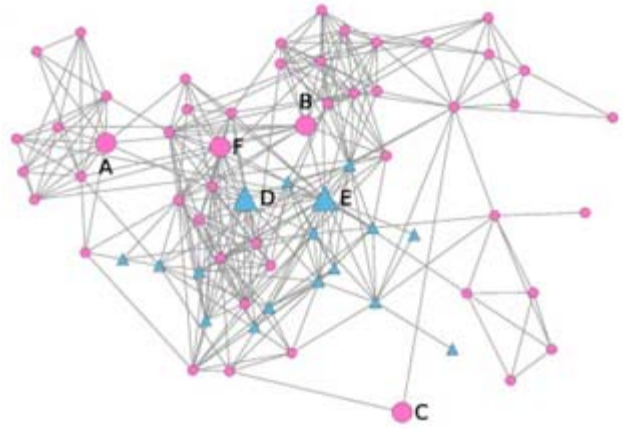

Fig. 3. Social network visualization

Social network visualization can be based on two main areas of research: information visualization of networks and graph drawing. [2], [3] In other words, visualization design is responsible for information visualization, navigation and interactivity, whereas the properties and construction of geometric representations are more central to graph drawing.

The central task of creating node–link diagrams is to determine the position of its elements. This is because the differences in position are the most accurately perceived graphical attributes, and the position of complex dependencies raises most complex problems algorithmically. If layout quality is low, even the best graphic design (in terms of using other image attributes, such as shape, colour, size, etc.) may not lead us to the desired result. Interaction mechanisms can worsen the correct interpretation of objects in these situations. This is the reason, why determination of the position of social network elements is a crucial problem.

Most network visualization researchers to date have focused on issues related to clarity and scalability of automatic network visualization methods [2]. According to [2], the previous studies of these two issues are based on three aspects: the first is about the layout algorithm, the second focuses on the navigation and interaction with the network graph displayed, and the third works to reduce visual complexity. The development of visualization systems typically combines the technology of these three aspects.

More recent studies have sought to render better support for the exploration of network data by adding additional views or more advanced user interface techniques to a conventional force-directed node–link network visualization. For instance, the Social Action System [16] enables users to rank and filter network nodes based on the values of network concepts. The MatrixExplorer system [17] complements the node-link view of a social network with a matrix view of the same network.

Social network visualization field is very extensive, with various methods and approaches. Therefore, it has been decided to concentrate in this research mainly on the analysis of the social network and the evaluation of the results.

V. Approach for Influential Group Identification

The first part of this research focuses on studying the spread of influence in social networking sites and dissemination of information, different approaches for social networks modelling, as well as different methods and techniques for social networks visualization.

After all the necessary information and knowledge has been gathered, it is possible to develop an approach for influential group identification.

A. Influential Target Groups

To detect influential target groups, users are classified according to the number of their written feedbacks or comments, and then users and trust relationships are added to the target group, while clustering coefficient of the target group is less than a threshold [11].

Individuals, who have more connections with others in the social network, can have more chances to influence others. In an undirected social network, centrality value is the number of connections one person has. This study aims to identify groups of users with maximum joint influential power in order to help companies to conduct online marketing and reputation management.

One of the tasks of this research is to study the spread of influence in social networks, as well as identify influential users, who activate other users to buy products. Recent studies have proposed different methods for the identification and simulation of the spread of influence. Domingos and Richardson proposed the method [12] used to simulate the spread of influence, which is based on Markov random field. In some others studies, the spread of influence is described by a linear model of the threshold, independent of the cascade model, and the voter model [6].

These marketing studies usually assume the condition of the spread of influence (such as certain probability), and based on these assumptions, their methods identify influential users to make as much effect as possible [11].

However, by applying certain mathematical methods, you can significantly increase the accuracy of these assumptions.

In contrast to main research conducted in this area, our study focuses on the identification of target groups with maximum joint influential power, which has a large impact on the SNS users' opinions.

B. General Process

As it is known, there are many SNS, such as Draugiem, Twitter, Facebook, etc. The proposed method can be used to identify influential groups, on the basis of data from SNS. Fig. 1 shows the overall process of this method:

- Data Collection;
- Influence Network;
- Target Group Identification.

Data Collection. At this stage certain information about user profiles and relationships between users is collected from SNS. This information may include the following:

- General information;
- Social relationships;
- User activity rating;
- Interaction information.

1) General information – user profile information such as user ID, user role (standard user profile, company profile, public person's profile), etc.

2) Social relationships. Social relationships between users, such as friendship relationships on Facebook and Draugiem, followers' relationships on Twitter and Draugiem indicate influence relationships between users, because users always trust or accept the opinions of those with whom they have social relationships [7]. Due to the fact that in this study it is planned to use Twitter as a data source, the following data are gathered: the number of followers and the number of followed users.

3) User activity rating. In some SNS, users can rate other users' opinions. These ratings also show the relationship between users to some degree. However, in this study the user activity will be understood by the number of tweets in the past six months. Such period of time has been chosen, because people's influence decreases with time.

4) Interaction information. In SNS, there are many interactions between users – comments, reviews, ratings. However, in this study, the interaction is assessed by the number of retweets (repost another user's opinion) and comments on users' opinions.

Influence Network. The influence network can be constructed from the analysis of the collected data: users are represented by a set of nodes; the influence relationships are based on the analysis of social relations, ratings, and interaction information.

Social network visualization field is very extensive, with various methods and approaches. Therefore, it has been decided to concentrate in this research mainly on the analysis of the social network and the evaluation of the results.

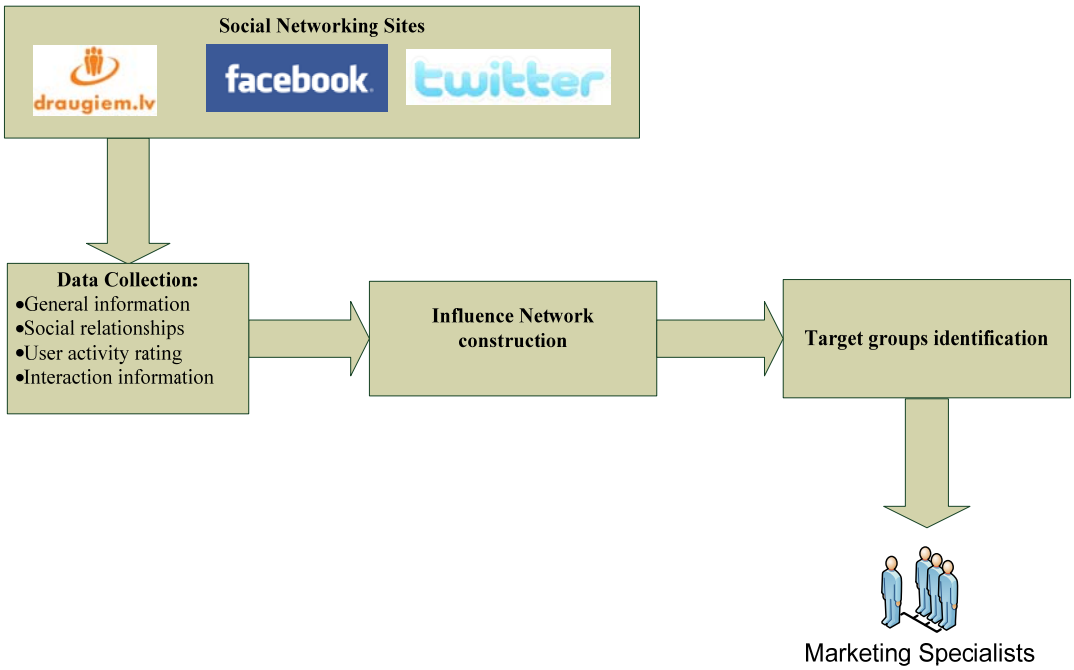

Fig. 4. General process of influential target group identification

Target Group Identification. If the most influential groups of users can be identified, companies will have a minimum of resources to improve sales and enhance the reputation of the company.

Based on the constructed network of influence, the target groups are discovered by an improved version of the mathematical method presented in the next section.

Since social networks are complex networks, it is possible that new phenomena emerge and behaviour of groups of individuals, behaviour "sum", can vary from each individual in a group. Thus, graph theory is insufficient to model all complex interactions that occur in social networks. This is the reason why the mathematical framework proposed by Vincent Levorato is very useful for modelling groups of entities in the network.

The method proposed in this study can be used to identify groups of users with maximum joint influential power in order to help companies to conduct online marketing and reputation management. Overall process of this method consists of three steps: Data Collection, Influence Network, and Target Group Identification. This method can help marketing specialist to find ways to encourage these people to express a positive opinion about the company and its products in the strategy of target marketing.

VI. Conclusions

The result of this study is the proposed method that can be used to identify influential groups on the basis of data from social networking sites. The method includes three steps: Data Collection, Influence Network and Target Group Identification. The authors have proposed a general mathematical framework and methods of social network visualization to develop a social network model for one of the industrial representatives. This model will be used to simulate different scenarios, such as new product promotion or extreme incidents from competitors' negative advertising; with the aim to predict the speed of information dissemination and to improve response time due to incidents. For modelling, the author's proposed concept of leader determination will be used.

Typical issues of social networks are an individual who has the capability to gather a group around him; the most influential persons; knowledge about the formation of groups, dissemination of information, methods of group manipulating, certain group behaviour leading to total control of people's behaviour and desires. These methods and knowledge can be used to reduce people's time wasted on social network sites. This becomes an alarming problem.

Pseudo-closure map building depends on the nature of the networks, and it is sometimes necessary to combine a number of pseudo-closure to obtain certain results. In several previous studies, complex systems modelled with pretopology were observed and they showed some interesting results by modelling the proximity effect on scientific cooperation, clustering and structuring of data, modelling of pollution phenomena or by analyzing the online communities. Ideas and concepts of Vincent Levorato allowed proposing a general mathematical framework for modelling groups in social networks, generalizing graph theory.

Future work will focus on some interesting new methods using generalized measures to find groups, which maximize a given centrality (degree, betweenness and closeness), optimize the "efficiency" of a group or identify emergent groups in a network. Moreover, it is necessary to continue work on the spread of influence in a social network.

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Aleksejs Čumiks, Andrejs Romānovs. Sociālo tīklu analīze un modelēšana: līderu identifikācija un informācijas izplatīšana
Autoru pētījums koncentrējas uz sociālo tīklu analīzi, līderu noteikšanu un grupu izveidošanu ap tiem. Pievērsta uzmanība arī vispārējām matemātiskajām sistēmām, lai modelētu grupu, un izpētītas sociālā tīkla vizualizācijas metodes. Sociālo tīklu modelēšanā tiek izmantotas diagrammas, lai aprakstītu saites, kas pārstāv attiecības vai plūsmas starp entītijām. Dažādos pētījumos indivīdi pārsvarā ir uzskatīti kā atsevišķi elementi, bet grupas tiek izveidotas vairāku indivīdu mijiedarbības procesā. Šī pētījuma mērķis ir identificēt lietotāju grupas ar maksimālu kopējo ietekmes spēku, lai palīdzētu uzņēmumiem veiksmīgi īstenot tiešsaistes mārketingu un reputācijas vadību. Šā pētījuma laikā tika izstrādāta metode, kuru var izmantot, lai noteiktu ietekmīgākās grupas, pamatojoties uz datiem no sociālajiem tīkliem. Metode sastāv no trīs posmiem: datu vākšana, ietekmes tīkla izveidošana, mērķa grupu identificēšana. Autori plāno izstrādāt sociālo tīkla modeli vienam no finanšu nozares pārstāvjiem, izmantojot piedāvāto metodi. Izmantojot šo modeli, tiks modelēti dažādi scenāriji, piemēram, veicinot jaunu produktu vai konkurentu negatīvu reklāmu, lai prognozētu informācijas izplatīšanas ātrumu un samazinātu reakcijas laiku. Turpmākie pētījumi tiks vērsti uz dažām interesantām jaunām metodēm, izmantojot vispārinātus pasākumus grupu identificēšanai, kas maksimizē attiecīgo centralitāti (grāds, tuvība utt.), lai optimizētu grupas "efektivitāti", vai lai identificētu grupu parādīšanos tīklā. Turklāt ir nepieciešams turpināt darbu, kas ir saistīts ar ietekmes izplatīšanos sociālajā tīklā.

Алексей Чумик, Андрей Романов. Анализ и моделирование социальных сетей: выявление лидеров и распространение информации
Исследование авторов сосредоточено на анализе социальных сетей, выявлении лидеров и создании групп вокруг них. Также уделено внимание общим математическим системам для моделирования групп, и рассмотрены методы визуализации социальных сетей. В частности, в моделировании социальной сети диаграммы используются для описания связей, которые представляют собой отношения между субъектами. В различных исследованиях индивиды в основном указаны в качестве отдельных элементов, а группы формируются из нескольких индивидов в процессе взаимодействия. Это исследование направлено на выявление групп пользователей с максимальной совместной силой влияния с целью помочь компаниям успешно проводить онлайн-маркетинг и управление репутацией. Во время данного исследования был разработан метод, который может быть использован для идентификации влиятельных групп на основе данных из социальных сетей. Метод состоит из трех этапов: сбор данных, создание сети влияния, выявление целевых групп. Авторы планируют разработать модель социальной сети для одного из представителей финансовой индустрии, используя разработанный в этом исследовании метод. Используя эту модель, будут промоделированы различные сценарии, такие как продвижение нового продукта или негативная реклама конкурентов с целью предсказать скорость распространения информации и сократить время реакции на возникшие инциденты. Дальнейшие исследования будут направлены на интересные новые методы с использованием обобщенных для поиска групп, которые максимизируют данную централизованность (степень, близость и т.д.), чтобы оптимизировать "эффективность" группы, или для выявления возникающих в сети групп. Кроме того, необходимо продолжить работу, которая связана с распространением влияния в социальных сетях.