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© A. Imanberdi*, R. Moldasheva[2], 2023
Eurasian National University named after L.N. Gumilyov, Astana, Kazakhstan;
[2]S. Seifullin Kazakh Agrotechnical University, Astana, Kazakhstan.
E-mail: asel_khas@list.ru

REVIEW OF MODELS OF DISSEMINATION OF INFORMATION IN SOCIAL NETWORKS

Imanberdi Assel Alibekovna — Doctoral student of the Department of Information Systems LN Gumilyov Eurasian National University. 010000. Astana, Kazakhstan.
E-mail: asel_khas@list.ru, https://orcid.org/0009-0007-8935-4954;
Moldasheva Raushan Nurkozhaevna — Doctoral student of the Department of «Iformation Systems» S. Seifullin Kazakh Agrotechnical University. 010000, Astana, Kazakhstan.
E-mail: raushan85_07@mail.ru, https://orcid.org/0000-0002-4570-0487.

Abstract. This article provides an overview of information dissemination models in social networks. The authors discuss various approaches to modeling the processes of information dissemination in social networks, including stochastic models, graph-based models, and models based on user behavior. The article describes the main components of the models, such as nodes (users) and the links between them, as well as the characteristics of the disseminated information, such as its format, content and target audience. Next, the authors discuss examples of specific models, such as the SIR (Susceptible-Infected-Recovered) model, which is used to model the spread of infectious diseases, as well as the IC (Independent Cascade) model, which is used to model the spread of information in social networks. In conclusion, the authors note that social media dissemination models can be used for various purposes such as identifying key social media users, predicting trends in dissemination of information, and improving marketing strategies.

Key words: Information dissemination models, social networks, social network analysis, user influence, content rebroadcasting (repost), viral marketing, behavioral models, statistical models, social media analytics, recommender systems, network dynamics

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Л.Н. Гумилев атындағы Еуразия ұлттық университеті, Астана, Қазақстан;
[2]С. Сейфуллин атындағы Қазақ агротехникалық университеті,
Астана, Қазақстан.
E-mail: asel_khas@list.ru

ӘЛЕУМЕТТІК МЕДИА ТАРАТУ ҮЛГІЛЕРІНЕ ШОЛУ

Иманберді Асель Алибековна — докторант. Ақпараттық жүйелер кафедрасы. Л.Н. Гумилев атындағы Еуразия ұлттық университеті. 010000. Астана, Қазақстан.
E-mail: asel_khas@list.ru, https://orcid.org/0009-0007-8935-4954;
Молдашева Раушан Нуркожаевна — докторант. Ақпараттық жүйелер кафедрасы. С. Сейфуллин атындағы Қазақ агротехникалық университеті. 010000. Астана, Қазақстан.
E-mail: raushan85_07@mail.ru, https://orcid.org/0000-0002-4570-0487.

Аннотация. Бұл мақалада әлеуметтік желілердегі ақпаратты тарату үлгілеріне шолу жасалады. Авторлар әлеуметтік желілерде ақпаратты тарату процестерін модельдеудің әртүрлі тәсілдерін, соның ішінде стохастикалық модельдерді, графикалық модельдерді және пайдаланушы мінез-құлқына негізделген модельдерді талқылайды. Мақалада түйіндер (пайдаланушылар) және олардың арасындағы байланыстар сияқты модельдердің негізгі құрамдас бөліктері, сондай-ақ оның форматы, мазмұны және мақсатты аудиториясы сияқты таратылатын ақпараттың сипаттамалары сипатталған. Әрі қарай, авторлар жұқпалы аурулардың таралуын модельдеу үшін қолданылатын SIR (Sesceptible-Infected-Recovered) моделі, сондай-ақ модельдеу үшін пайдаланылатын IC (Тәуелсіз каскад) үлгісі сияқты нақты үлгілердің мысалдарын талқылайды. әлеуметтік желілерде ақпараттың таралуы. Қорытындылай келе, авторлар әлеуметтік желілерді тарату модельдерін әлеуметтік медианың негізгі пайдаланушыларын анықтау, ақпаратты тарату тенденцияларын болжау және маркетингтік стратегияларды жетілдіру сияқты әртүрлі мақсаттарда қолдануға болатынын атап өтеді.Түйін сөздер: әлеуметтік желі, әлеуметтік желі мониторингі, әлеуметтік әл-ауқат, пайдаланушы қабылдауын бағалау, бағдарламалық қамтамасыз ету жүйесі.

Түйін сөздер: Ақпаратты тарату модельдері, әлеуметтік желілер, әлеуметтік желіні талдау, пайдаланушының әсері, вирустық маркетинг, мінез-құлық үлгілері, статистикалық модельдер, әлеуметтік медиа аналитикасы

© А.А. Иманберді*, Р.Н. Молдашева[2], 2023
[1]Евразийский национальный университет им. Л.Н. Гумилева, Астана, Казахстан;
[2]Казахский агротехнический университет им. С. Сейфуллина, Астана, Казахстан.
E-mail: asel_khas@list.ru

ОБЗОР МОДЕЛЕЙ РАСПРОСТРАНЕНИЯ ИНФОРМАЦИИ В СОЦИАЛЬНЫХ СЕТЯХ

Иманберди Асель Алибековна — докторант кафедры Информационных систем Евразийского национального университета имени Л.Н. Гумилева. 010000. Астана, Казахстан.
E-mail: asel_khas@list.ru, https://orcid.org/0009-0007-8935-4954;
Молдашева Раушан Нуркожаевна — докторант кафедры Информационных систем Казахского агротехнического университета им. С. Сейфуллина. 010000. Астана, Казахстан.
E-mail: raushan85_07@mail.ru, https://orcid.org/0000-0002-4570-0487.

Аннотация. Данная статья представляет обзор моделей распространения информации в социальных сетях. Авторы обсуждают различные подходы к моделированию процессов распространения информации в социальных сетях, включая стохастические модели, модели на основе графов и модели, основанные на поведении пользователей. В статье описываются основные компоненты моделей, такие как узлы (пользователи) и связи между ними, а также характеристики распространяемой информации, такие как ее формат, содержание и целевая аудитория. Далее авторы обсуждают примеры конкретных моделей, таких как модель SIR (Susceptible-Infected-Recovered), которая используется для моделирования распространения инфекционных заболеваний, а также модель IC (Independent Cascade), которая используется для моделирования распространения информации в социальных сетях. В заключение авторы отмечают, что модели распространения информации в социальных сетях могут использоваться для различных целей, таких как определение ключевых пользователей в социальных сетях, предсказание тенденций в распространении информации и улучшения маркетинговых стратегий.

Ключевые слова: модели распространения информации, социальные сети, анализ социальных сетей, влияние пользователей, вирусный маркетинг, поведенческие модели, статистические модели, аналитика социальных медиа

Introduction

In the modern world, social networks are an integral part of our lives. Millions of people around the world use social networks to communicate, get information, business contacts and much more. However, in addition to simple communication, social networks are a huge source of information that can spread with great speed among users.

Studying the processes of dissemination of information in social networks is essential to understand how information is distributed in society, how it affects the opinions and behavior of people, and how it can be used in various fields such as marketing, politics, etc (Timofeev et al., 2019: 119; Gribanova, 2018: 66).

To understand the processes of information dissemination in social networks, various mathematical models have been developed that allow us to analyze the processes of information transmission in networks. One such model is the SIR model, which is used to study the spread of infectious diseases, but can also be applied to analyze the processes of information transmission in social networks. Another model is the IC model, which describes the process of dissemination of information in social networks, based on the influence of users on each other.

In this article, we will consider the main models of information dissemination in social networks, as well as methods for analyzing the processes of information transmission, such as centrality analysis, clustering and community detection, which can be used to study and optimize the processes of information dissemination in social networks.

Research materials and methods

Models of information dissemination in social networks: basic approaches. There are two main approaches to modeling the dissemination of information in social networks: network and non-linear models.

1. Network models. This approach is based on graph theory and considers a social network as a collection of nodes (people or organizations) and connections between them. Network models can be used to study how information propagates through these links, how resources are distributed within a network, and which nodes are central in that network. One of the most common examples of the network model is the social media influence model, which is used to study how messages can be distributed across various social media platforms (Newman, 2010).

2. Nonlinear models. This approach is based on the theory of dynamical systems and is used to study how changes in one node of the network can affect other nodes. Nonlinear models can be useful for predicting how changes in one node might affect the entire network. An example of a non-linear model would be the virus spread model, which is used to study how an infectious disease can spread through a population (Hethcote, 2000).

Both approaches have their advantages and disadvantages, and they are often used in combination to gain a more complete understanding of the processes taking place in social networks.

Network models of information dissemination. Network models are used to study the dissemination of information in social networks and include various approaches. Let’s consider three main types of network models.

1. *Distributed models*. These models are based on the fact that each node in the network decides whether to propagate information further or not, based on some decision rule. An example of a distributed model is a linear threshold model, in

which each node has some threshold level of influence, and only if the number of its neighbors that have already propagated information exceeds this threshold, it also begins to propagate information.

The IC (Information Cascade) model is a model that describes the process of dissemination of information in a group of people. In this model, each person makes a decision based on their own observations and other people's previous actions. Each node has an activation probability, which can be represented as a number from 0 to 1. When a node becomes active, it can activate its neighbors with some probability. Propagation occurs in stages: at each stage, all nodes that were activated in the previous stage are activated, as well as all their neighbors that were activated in the previous stage with a probability equal to their activation probability (Bikhchandani et al., 2000:49).

The formulas for the IC model can be written as follows:

Decision Probability:

$$P = f(I, S), \tag{1}$$

where P is the probability of making a decision, I is the personal information that the person has, and S is the information that comes from other people.

Personal information:

$$I = i + \alpha \sum pj, \tag{2}$$

where I is personal information, i is the initial information that a person has, α is the coefficient of influence of the initial information, is the sum of decisions made by other people.

Information that comes from other people:

$$S = \beta \sum pk, \tag{3}$$

where S is information that comes from other people, β is the coefficient of influence of information coming from other people, is the sum of decisions made by other people.

Other people's solution:

$$pj = f(Ij, Sj), \tag{4}$$

where is other people's decision, is other people's personal information, is information that comes to other people.

These formulas can be used to describe the IC process and understand how people make decisions based on the information they get from other people (Toropov, 2016).

The LT model is a more complex model that takes into account the influence of not only the activation probability of each node, but also the weight of links between nodes. Each node has a weight, which can be represented as a number from 0 to 1. When a node becomes active, it can activate its neighbors if the link weights between the node and its neighbor exceed a certain threshold. Distribution occurs in stages, similar to the IC model (Goyal et al., 2010: 241).

The IC model is simpler and faster than the LT model, but it does not take into account the influence of link weights between nodes. The LT model is more realistic, but may be more time and resource intensive. Both models can be used to analyze the distribution of information in social networks, marketing campaigns and other areas.

2. *Models of influence*. These models consider the process of information dissemination as a result of interaction between network nodes. In these models, each node can influence its neighbors by changing their probability of making decisions about the dissemination of information. An example of an influence model is the Cascade model, in which each node can influence its neighbors by changing their decision probability (Gorkovenko, 2019: 55).

3. *Models of random walks*. In these models, information propagation is treated as a random walk through the network. The node that propagates information moves to a random neighbor node with some probability. An example of a random walk model is the PageRank model, which is used to rank web pages in search engines (Algazinov et al., 2010: 241).

Each of these approaches has its advantages and disadvantages, and the choice of model depends on the purpose of the study. It is important to understand that network models are used not only to study the distribution of information in social networks, but also to study other processes that occur in networks, such as the distribution of resources and interaction between nodes.

Nonlinear models of information dissemination. Nonlinear dissemination models are used to study the dissemination of information in social networks, marketing campaigns, political campaigns, and other areas. These models take into account non-linear relationships between various factors such as the number of people who see certain information and the number of people who actually respond to it.

One of the most well-known non-linear information dissemination models is the viral distribution model, also known as the Susceptible-Infected-Recovered (SIR) model, which describes how information is distributed through social networks. In this model, each participant has a certain probability of infecting another participant, and this probability may depend on factors such as the number of connections between participants and the degree of their interaction.

The virus dissemination model is a mathematical model that describes the process of information dissemination in a society, as the spread of an infection in a population. In this model, each person can become infected and transmit information to other people, who in turn can become «carriers» and continue to spread (Gorkovenko, 2017: 103).

The formulas for the viral information dissemination model can be written as follows:

Basic distribution model:

$$\frac{dS}{dt} = -\beta SI$$
$$\frac{dI}{dt} = \beta SI - \gamma I, \quad (5)$$

where S is the number of exposed people, I is the number of infected people, β is the infection rate, γ is the recovery rate, t is the time.

Dissemination of information taking into account the influence of the environment:

$$\frac{dS}{dt} = -\beta SI - \lambda S$$
$$\frac{dI}{dt} = \beta SI - \gamma I, \quad (6)$$

where λ is the coefficient of environmental influence.

Immunization Model:

$$\frac{dS}{dt} = -\beta SI - \mu S$$
$$\frac{dI}{dt} = \beta SI - \gamma I$$
$$\frac{dR}{dt} = \gamma I + \mu S, \quad (7)$$

where R is the number of people with immunity, μ is a coefficient characterizing the immunization process.

Model taking into account the changing degree of protection of the population:

$$\frac{dS}{dt} = -\beta S\alpha I - \lambda S$$
$$\frac{dI}{dt} = \beta S\alpha I - \gamma I$$
$$\frac{dR}{dt} = \gamma I + \mu S, \quad (8)$$

,

where α is the coefficient of the degree of protection of the population, which may change over time.

These formulas can be used to describe the process of viral dissemination of information in society, and to understand how changes in various parameters can affect the dissemination of information and the control of this process (Khrapov et al., 2019: 225).

Another non-linear information dissemination model is the «contagion» model, which describes how information can be disseminated through marketing campaigns or other forms of advertising. In this model, the advertiser can choose a specific strategy that can have more or less impact on the target audience depending on their characteristics and preferences.

Non-linear dissemination models can help improve the effectiveness of marketing campaigns, political campaigns, and other dissemination processes. However, like any model, they must be carefully tested against real data and used with care when making decisions based on their results.

Threshold models and *competition models* are two examples of non-linear information dissemination models used in econometrics and other fields to describe non-linear relationships between variables (Avetisyan et al., 2018: 199).

Two of the best-known threshold models are the Sharma-Tamas model and the Granovetter model.

The Sharma-Tamas model is based on the assumption that each person has a certain threshold, which determines how many people with a certain opinion must be in his environment in order for him to accept this opinion. If the number of people supporting an opinion exceeds a threshold, the person accepts that opinion. If the number does not reach the threshold, he remains in his opinion. The Sharma-Tamas model was developed to explain the dynamics of the spread of opinions in social networks.

Granovetter's model is based on the idea that people have two types of connections in their social network: strong and weak. Strong ties are those that connect people who know each other very well, while weak ties are those that connect people who don't know each other very well. Granovetter's model assumes that people are more affected by their weak ties than their strong ties. This is because people with strong ties often have very similar opinions, while people with weak ties can represent diverse points of view.

Both models — Sharma-Tamas and Granovetter - are useful tools for studying the dynamics of influence and distribution of opinions in social networks. They can help in understanding how people form their opinions and make decisions in the context of a social network, which can have important practical applications in fields such as marketing, politics, and social psychology (Wiedermann et al., 2020).

Competition models describe relationships between multiple variables that compete with each other for limited resources.

Two of the more well-known competition models are the Lotka-Volterra model and the takeover model.

The Lotka-Volterra model is a mathematical model developed to study the interaction between two species in an ecosystem: predators and prey. The model assumes that the number of prey and predators changes over time depending on their interaction. The number of prey increases when the number of predators is small, and decreases when there are many. Likewise, predators increase when there are many prey and decrease when there are few. The Lotka-Volterra model can be used to analyze various ecosystems such as marine and forest ecosystems (Trubetskov, 2011:66).

The engulfing model, also known as the Gompertz model or the life cycle model, is a mathematical model that describes the change in population size over time. The model takes into account births, deaths and competition for resources. Each individual in a population has a probability of dying or producing offspring. When the population reaches its maximum size, it begins to absorb its own individuals, which leads to a decrease in the population size. This model can be applied to the analysis of animal and plant populations (Delitsyn, 2015).

Both the Lotka-Volterra and engulfing models are useful tools for studying interactions between species and competition for resources in ecosystems. They can help predict population dynamics and understand how changes in one population can affect another population in an ecosystem.

Results and discussion

Methods for analyzing information transfer processes in networks are necessary to understand how information propagates in a network and how it is influenced by various factors, such as node properties, types of connections, and other network parameters. They help identify important nodes, groups of nodes, and information paths in the network.

Thus, methods for analyzing the processes of information transfer in networks can be used to:

- understanding of the structure and properties of information transmission networks;
- optimization of information transfer processes in networks;
- identification of key nodes that may be vulnerable in case of attacks on the network;
- identification of groups of nodes that can work together to achieve a specific goal;
- search for optimal ways of information transfer in the network;
- determining the degree of influence of nodes on the processes of information transfer in the network.

Let us consider some methods for analyzing the processes of information transfer, such as the analysis of centrality, clustering and detection of communities (Tabassum et al., 2018).

Centrality analysis:

Centrality analysis is a method for evaluating the importance of nodes in a network. There are several measures of centrality, including:

Betweenness centrality:

$$BC(v) = \sum(s,t) \in S(v)\delta\,(s,t|v)/\delta(s,t) \qquad (9)$$

where is the set of shortest paths between all pairs of nodes passing through node v; σ(s, t) is the number of shortest paths between nodes *s* and *t*; and is the number of shortest paths between nodes *s* and *t* that pass through node *v*.

Closeness centrality:

$$CC(v) = 1/\sum d(v,u) \quad (10)$$

where is the shortest distance between nodes v and u.

Degree centrality:

$$DC(v) = k(v)/(n-1) \quad (11)$$

where is the number of links linking node *v* and *n* is the total number of nodes in the network.

Clustering:

Clustering is a method of dividing nodes in a network into groups that have similar properties or structure. There are several clustering methods including:

Method of K-means (K-means):

The K-means algorithm consists of the following steps:

Select K random cluster centers.

Assign each node to the nearest cluster center.

Update cluster centers using the average of all nodes belonging to the given cluster.

Repeat steps 2-3 until the stop criterion is reached.

Hierarchical clustering method:

The hierarchical clustering method consists of the following steps:

Start with each node in a separate cluster.

Merge nearest clusters until all nodes are merged into one cluster or until the stop criterion is reached.

The joining criteria can be different, for example, cosine distance or Euclidean distance between nodes.

Community detection:

Community detection is a method of identifying groups of nodes in a network that are more closely related to each other than to the rest of the nodes in the network. There are several methods for community detection, including:

Louvain method:

The Louvain method is an iterative community detection method that optimizes the modularity that describes the quality of network partitioning into communities. The algorithm consists of the following steps:

Assign each node to a separate community.

For each node v, consider all possible reassignments of the node to another community, and calculate the change in modularity for such a reassignment.

Reassign node v to the community that gives the greatest increase in modularity.

Repeat steps 2–3 for each node in the network until the stop criterion is reached.

Method of graph theory of spectral clustering (Spectral clustering):

Spectral clustering is a community detection technique that uses the spectral decomposition of a graph's adjacency matrix to extract communities. The algorithm consists of the following steps:

Calculate the adjacency matrix of the graph.

Calculate the spectral decomposition of the adjacency matrix.

Select the first k eigenvectors corresponding to the k smallest eigenvalues.

Apply the K-means method to the obtained vectors to partition the graph into k communities.

These methods of analyzing information transfer processes can be used to understand the properties of networks, identify important nodes and groups of nodes, and also optimize information transfer processes in networks.

Application of information dissemination models in social networks. Social media dissemination models are used to analyze how messages and ideas spread among network users. These models can be useful for predicting how quickly and in what way information will spread on social networks, as well as identifying the most influential users and communities. Below are a few examples of the application of social media dissemination models.

User power analysis: Information dissemination models can help identify powerful users in a social network. This can be useful for marketing as these users can be used to promote products or services.

Community analysis: Information dissemination models can help define user communities in a social network and evaluate their interaction. This can be helpful in understanding cultural differences and identifying potential audiences.

Predicting User Behavior: Information dissemination models can help predict user behavior on a social network. This can be useful for decision making in marketing and politics.

Trend detection: Information dissemination models can help identify trends in a social network, such as changing user interests and trends in public opinion.

Create Viral Campaigns: Information dissemination models can help create viral campaigns that will spread quickly on social media. For example, a company can create a video that generates strong user interest and then use distribution models to determine how it will be distributed across the network.

Determining the most effective promotion channels: Information dissemination models can help determine the most effective channels for promoting products and services in social networks. For example, a company can use distribution models to determine which social networks are most popular among its target audience and then focus their efforts on those channels.

Ad response analysis: Information dissemination models can help analyze user response to social media ads. For example, a company can use information dissemination models to determine how many users saw and react to an ad and then tailor its strategy accordingly.

Negative Information Control: Information dissemination models can be used to control the dissemination of negative information on social media. They can help identify users who may be spreading negative messages and prevent those messages from spreading further.

Prevention of cyberattacks: Information dissemination models can help prevent cyberattacks on social networks. For example, they can help identify users who may be vulnerable to attack and take steps to protect against cyberattacks.

Event Response Analysis: Information dissemination models can be used to analyze user reactions to social media events. For example, they can help determine how users react to news, political events, sports events, and so on (Batura, 2012: 13).

Conclusion

The article presents an overview of the main models of information dissemination that are used to analyze the processes of information dissemination in various social networks. The article describes various models, including viral spread models, IC and LT models, competition models, etc.

The article also considers the main applications of information dissemination models, including predicting user behavior in social networks, marketing and advertising campaigns, controlling negative information and preventing cyber-attacks, some methods for analyzing information transmission processes are considered to understand how information is distributed on the network and how it is affected. various factors.

The article's findings highlight that information dissemination models have great potential in various areas such as social networking, marketing, and security, and that the use of these models can help improve social media performance and marketing campaigns. However, it is important to understand that the choice of model should depend on the specific task and context, as well as on the data on which the model will be based.

There are several areas for further research in the field of information dissemination models in social networks:

Development of new information dissemination models that take into account the complex interactions between users and the characteristics of the social network, such as the topology and dynamics of connections between users.

Development of more accurate methods for estimating the parameters of information dissemination models, taking into account the complexity and heterogeneity of data in social networks.

Development of more efficient algorithms for predicting and controlling user behavior in social networks based on information dissemination models.

Exploring the interaction between information dissemination models and other social network models such as social network evolution models and community formation models.

Applying information dissemination models to analyze a wider range of social media issues, such as analyzing the impact of social media on public opinion and decision making.

Development of innovative methods for predicting and controlling user behavior based on deep learning and natural language analysis.

Research in these areas can help improve understanding of social media dissemination processes and apply them to a variety of purposes such as improving marketing campaigns, preventing cyberattacks, and controlling negative information.

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