Method of Choosing Objects for Informational Influence in Social Networks during Information Campaign Based on the Analytic Hierarchy Process

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Abstract. The purpose of this work is to develop the method of choosing objects for informational influence in social networks based on the analytic hierarchy process to increase the efficiency of informational influences during informational confrontations. The modeling of the process of disseminating informational influences in segments of a social network was carried out with the possibility of choosing objects for informational influence based on the analytic hierarchy process and other approaches. The experiments to verify the effectiveness of the analytic hierarchy process for choosing informational influence objects for compared with other methods of their choosing were conducted. The results of the experiments on the developed program model of a social network confirm the possibility of applying the analytic hierarchy process for assessing the prospects of a chosen object of information influence and the accuracy of the predicted best alternative – the predicted result corresponds to the result, which was obtained during the experiment. And the alternatives than chosen by the analytic hierarchy process show the better result than the social network nodes, witch chosen at random taking into account only their structural position in the network.

Keywords: social networks, analytic hierarchy process, informational influence, information security, behavioral strategies, behavioral strategies.

1 Introduction

For many Internet users, social networks are becoming one of the main sources of information and current news. At the same time, these Internet resources are becoming the convenient environment for the dissemination of informational and psychological influences on ordinary users during informational campaigns, that is, planned actions with specific goals and objectives of disseminating information, with the ultimate goal of forming a certain opinion among a certain social group of users. Posts and comments on social networks are increasingly used to manipulate public opinion, in particular, both to promote goods/services/content [1] using viral marketing methods, and during information wars [2]. To disseminate information influences, attackers can be used both real and fake accounts and created entire bot farms. To understand the scale of the phenomenon should be noted that according to Facebook for the period from October 2018 to March 2019, a total of 3.39 billion fake accounts on this web-resource were deleted [3].

Thus, the research of the spread of informational-psychological influences in social networks and ensuring information security on these resources is an urgent scientific and practical task.

One of the tools for research the methods of disseminating information influences in social networks and methods of protection against them is computer modeling. In [4], the research of the main methods for modeling the spread of informational-psychological influences, namely the epidemic model, models based on cellular automata, models with thresholds and models of independent cascades, models using Markov chains was conducted. There was found that all these models do not take into account at all, or only partially take into account the possibility of parameterizing the personal qualities of influence objects. The mathematical and computer model of the dissemination of informational influences in social networks with the presence of personality trait parameters of users of the network was created [5, 6], in particular, the level of trust, strength of influence, level of activity, etc. The model is designed for research methods of disseminating informational influences in social networks and methods of protection against them.

Dissemination of informational influences can occur according to different strategies. In [6], two behavioral strategies with the conditional names “Bush” and “Tree” were proposed and they were tested on the computer model. The strategy “Bush” provided for the choice of nodes for an attack - randomly among connections of influence subjects, after a successful attack on influence target, he (or she) becomes “get infected” by the information influence and also turns into the influence subject after the certain accumulation of influences. The strategy “Tree” consisted of choosing targets for an information attack taking into account certain characteristics, for example, the number of friends and subscribers, and required additional time to analyze a social network and search for targets for the attack. The research showed that the success of an information campaign significantly depends on the information dissemination strategy and the correct choice of the source of influence, which after the “informational infection” will be able to distribute the necessary information among as many users as possible.

Typical methods of neutralizing information attacks in social networks used in practice [7]:

- “Umbrella” - the blockage access to information, witch containing information-psychological influences;
- “Funnel” - the neutralization of the message by its absorption by a large number of other messages;
- “Wheel” - the replace a message with another, more status and important.
- “Replacement” - the refutation of certain information by causing distrust in the source of its dissemination.

The first method of neutralization of informational influences is purely technical. The following three are related to the creation and dissemination of messages containing informational influences by the defending subject, which aimed at protecting against an information attack. Thus, when modeling informational confrontation, there is advisable to model the neutralization of informational influences as the distribution of other informational influences with the opposite or distracting messages.

The goal of this work is to develop the method of choosing objects for informational influence in social networks during an information campaign based on the analytic hierarchy process. This method can be used both to increase the effectiveness of methods for disseminating information influences and to increase the effectiveness of methods for neutralizing such influences.

2 The main material

The research and the experiments [6] showed that the effectiveness of information influences and the speed of information dissemination depend significantly on the choice of target nodes for the attack. The choice of target nodes is a rather difficult task, which cannot be fully automated. On the one hand, this task is multi-criteria, on the other hand, only a part of the criteria can be simply evaluated in numerical terms. Numerical estimates of the characteristics according to some criteria are quite complex tasks, the solution of which is based on expert estimates. These characteristics of a node, first of all, include the structural position of an influence object in a social network.

But even with assessments of the characteristics of nodes claiming to be the best alternative, from the point of view of the effectiveness of informational influence processes, the task of choosing the best alternative remains quite difficult.

Therefore, there is the need to develop a method for choosing nodes for an information attack in a multi-criteria assessment. In this paper, is proposed to use the analytic hierarchy process to choice nodes for attack. Also, the adaptation of the analytic hierarchy process to the solution of the researching scientific and practical problem is considered.

The analytic hierarchy process (AHP) is the mathematical procedure for hierarchical structuring of elements in order to determine the essence of some problem; it is applied to complex decision-making problems. The method consists in decomposing the problem into simpler component parts, as well as in processing the judgments of decision-maker persons based on paired comparisons of priorities (criteria) of expediency. This allows evaluating the level of interaction of hierarchy elements [8].

Hierarchy – the type of multi-level structure, which involves the division of a system into subsystems according to the given classification of attributes.

The analytic hierarchy process involves several stages:

1. Building a model of a problem in the form of a hierarchy.
2. Pairwise comparison of all hierarchy elements to determine priorities.
3. Mathematical processing of information than obtained from decision-makers (search for eigenvectors of matrices for pairwise comparison of alternatives).
4. Elimination of inconsistency of matrices of pairwise comparisons (if necessary).

The prerequisites for the application of the above steps are:

– Finite subset of alternatives was selected among all possible options; the most acceptable (in the opinion of the decision-makers) options are taken as alternatives in terms of the effectiveness of achieving existing goals;

– Set of criteria, by which alternatives will be evaluated, been established.

Below is the brief description of the contents of the AHP stages.

The first stage involves the preliminary ranking of criteria, as a result of which they are arranged in descending order of importance.

At **the second stage**, the pairwise comparison of the importance of the criteria on the nine-point scale with the creation of the corresponding matrix (table) of dimension $n \times n$ is made, where n – is the number of selected criteria. The system of pairwise comparison leads to a result that can be represented as an invertible symmetric matrix. The element $a(i, j)$ of the matrix is the intensity of the manifestation of the element i of the hierarchy (that is, determining of influence this criterion on decision-making) with respect to the element j of the hierarchy and evaluated on the intensity scale from 1 to 9, where the estimates have the following meaning: Equal importance 1; Slight advantage 3; Significant advantage 5, Strong advantage 7; Very strong advantage 9; In intermediate cases, assessments are given: 2, 4, 6, 8.

The matrix of pairwise comparisons has the form (1):

$$A = \begin{pmatrix} 1 & a_{12} & a_{13} & \dots & a_{1n} \\ 1/a_{12} & 1 & a_{23} & \dots & a_{2n} \\ 1/a_{13} & 1/a_{23} & 1 & \dots & a_{3n} \\ \dots & \dots & \dots & \dots & \dots \\ 1/a_{1n} & 1/a_{2n} & 1/a_{3n} & \dots & 1 \end{pmatrix}, \tag{1}$$

where a_{ij} is degree of the advantage of an object compared to the object a_j.

If several experts participate in decision-making, then the geometric mean of various estimates is entered into the matrix as a general estimate of judgments [9]:

$$\tilde{X}_{geom} = \sqrt[n]{x_1 \cdot x_2 \cdot \ldots \cdot x_n}, \tag{2}$$

where n is number of experts evaluating alternatives, a_i is assessment of the impact of the criterion or assessment of the alternative according to the selected criterion of an individual expert [11-13].

During the analysis, $(n+1)$ is created for such matrices, where n is the number of criteria: the matrix for comparing criteria (1) and n matrices for pairwise comparison of alternatives for the selected criterion $K_1, K_2, K_3 .. K_n$. The dimension of these matrices is $m \times m$, where m – is the number of alternatives among which it is necessary to choose the best option.

In **the third stage**, the matrix of pairwise comparisons is normalized.

The method based on approximate estimates can be used to search for eigenvectors. One can find eigenvectors by solving the system of linear algebraic equations obtained from equation (3).

Let the number λ and the vector $x \in L$, $x \neq 0$ be such that:

$$Ax = \lambda x\ . \tag{3}$$

Then the number λ is the eigenvalue of the linear operator A, and the vector x is the eigenvector of this operator having the eigenvalue λ.

In a finite-dimensional space L_n, the vector equality (3) is equivalent to the matrix equality:

$$(A - \lambda E)X = 0, X \neq 0\ . \tag{4}$$

There follows that the number λ is an eigenvalue of the operator A if and only if the determinant $\det(A - \lambda E) = 0$, that is, λ is the root of the polynomial $p(\lambda) = \det(A - \lambda E)$, which is called the characteristic polynomial of A. Here E is the identity diagonal matrix.

$$det(A - \lambda E) = \begin{vmatrix} a_{11} - \lambda & a_{12} & \dots & a_{1n} \\ a_{21} & a_{22} - \lambda & \dots & a_{2n} \\ \dots & \dots & \dots & \dots \\ a_{n1} & a_{n2} & \dots & a_{nn} - \lambda \end{vmatrix} = 0\ . \tag{5}$$

The coordinate column X of any eigenvector corresponding to the eigenvalue λ is a nontrivial solution to the homogeneous system (4).

But in practice, more simplified methods are used, for example, formulas (6-7) can be applied. Elements of the desired eigenvector can be found as normalized geometric mean numbers of elements that appear in the corresponding row of the original matrix. The eigenvector search formula will look like:

$$w_i = \sqrt[n]{\prod_{j=1}^{n} a_{ij}}\ , \tag{7}$$

$$v_i = \frac{w_i}{\sum_{i=1}^{n} w_i}\ . \tag{8}$$

Generalized priorities will be calculated using the criteria comparison matrix (Table 1):

Table Помилка! Не вказано послідовність.. Criteria comparison matrix.

	К$_1$	**К$_2$**	**К$_3$**	**Generalized Criteria**
Criteria	**μ_1**	**μ_2**	**μ_3**	
A$_1$	v_{11}	v_{12}	v_{13}	λ_1
A$_2$	v_{21}	v_{22}	v_{23}	λ_2
A$_3$	v_{31}	v_{32}	v_{33}	λ_3

where v_{ij} is obtained by formula (8), and μ_i is the eigenvector of the criteria comparison matrix. Then global priorities of alternatives (or generalized priorities) are calculated by the formula:

$$\lambda_k = \sum_{i=1}^{n} \mu_i a_{ki} , \tag{9}$$

where μ_i is eigenvector of the criteria comparison matrix.

At **the fourth stage**, the consistency of expert judgments is checked and the inconsistency of matrices of pairwise comparisons is eliminated (if necessary).

Since AHP cannot be completely formalized, due to the need to attract experts to evaluate alternatives according to criteria, subjective factors can influence the results of AHP – inattention of experts, errors of estimates, etc. To verify the consistency of expert judgments is used the technique based on the assessment of the consistency ratio (*CR*) of matrices of pairwise comparisons. To obtain estimates, the following formulas are proposed:

$$CR = \frac{CI}{M(CI)} , \tag{10}$$

where *CI* – the consistency index, which is calculated by the formula (11), *M*(*CI*) – the average value of the consistency index of a randomly compiled matrix of pairwise comparisons, based on experimental data, the value of which is the tabular value, the dimension of the matrix acts as the input parameter (Table 2).

Table 2. The average value of the consistency index (values determined experimentally [9, 10]).

n	1	2	3	4	5	6	7	8	9	10	11
***M*(*CI*)**	0	0	0.58	0.90	1.12	1.24	1.32	1.41	1.45	1.49	1.51

$$CI = \frac{\lambda_{\max} - n}{n-1} , \tag{11}$$

where $\lambda_{\max}$ is maximum eigenvalue; n is the rank of the matrix of pairwise comparisons (in fact - the number of alternatives).

There are various approaches to calculating the maximum eigenvalue of a matrix; one of the approaches involves the use of formula (12):

$$\lambda_{\max} = e^T AW , \tag{12}$$

where e^T is the unit vector with dimension n; A is matrix of pairwise comparisons; W is main (normalized) eigenvector of the matrix *A*.

After obtaining the *CI* value, it is compared with the value 0.10, the comparison matrix is considered consistent if *CI* <= 0.10. Although such an assessment is not unambiguous – a matrix with *CI* score of more than 0.10 can actually be consistent. From this, it follows that the assessment of *CI* is a certain marker that allows you to draw the attention of an expert and, possibly, revise (check) estimates.

The best alternative is determined by the maximum value of global priority.

In the course of the experiments [6], the necessity of choosing a node for an information attack based on he (or she) characteristics and significant dependence of the final result on the correctness of such choice were found.

The task of choosing a target node for an attack is the task of choosing in a multi-criteria assessment with the need to attract experts to evaluate the alternative according to certain criteria that cannot be formalized. To facilitate the solution of this problem (taking into account its formulation), we suggest the use of the analytic hierarchy process considered above.

To apply AHP for choosing objects for informational influence in social networks, its certain adaptation is necessary.

So, we will be to carry out the adaptation of the analytic hierarchy process for the task of choosing informational influence objects in a social network during an information campaign.

Alternatives: Node 1, Node 2 ... Node n (the set of chosen nodes potentially useful in terms of information dissemination).

The criteria should be divided into: ones than depending on the expert's assessment and quantitative - ones than independent of the subjective expert assessment.

Quantitative (independent of the experts) criteria include [12-14]:

- the number of node contacts;
- the activity (average number of messages per unit time).

To rank the alternatives according to this criterion, there is proposed to use the formula (13):

$$R(K_{vi}) = \left[9 \cdot \frac{K_{vi}}{Max(K_{vi})} \right]. \tag{13}$$

To obtain the criteria estimates values we will use the formula (13) with rounding, getting the range of consolidated estimates [0..9]. It should be noted that the evaluation of the criterion with the maximum numerical value will always be equal to $R(K_{\max}) = 9$. When pairwise comparing alternatives by criterion, we take the difference in the estimates of the corresponding alternatives.

For evaluation, experts should give the following information:

- the propensity of a node to α-idea (information contained in an informational influence);
- the structural position of a node in a social network;
- the reputation of a node in a social network.

In analyzing a real social network, an expert deals with personalities and can determine the tendency to α-ideas as the sum of indirect manifestations (topics that a person is interested in, participation in discussions, specific posts and publications, etc.). In the same way, an expert evaluates the reputation. In the developed computer model, these factors are formalized by indicators - information resistance ((O) Opposite) and reputation ((R) Reputation) [5, 6], so in the experiment these criteria will also be expert independent, but when analyzing of a segment of a real network, estimates these criteria are given by an expert [16-18].

In an expert assessment of the structural position of a node, one should evaluate not only the condition that the node, for example, is a bridge between different clusters, but also the analysis of the neighborhood of the node: the number of contacts inside different structural groups, the nodes' characteristics, general attitude to the α-idea of the structural subgroup, where attack node has connections. The adequacy of the expert assessment for this criterion is very important, the structural position is the most difficult, from the point of view of the assessment, characteristic.

The most favorable result is expected in case of an optimal balance of criteria. For example, attracting a node with a high reputation indicator, but also a high level of resistance will be quite difficult, which will affect the distribution dynamics. A node with high activity and an unfavorable structural position will have a minimal effect on the result as a whole.

To establish the balance, we propose to introduce compensating criteria:

– $\frac{R}{O}$ is the ratio of criteria based on the properties of the reputation R and resistance node O;

– $Act \cdot Str$ is the multiplication of criteria based on the properties of the node – activity and structural position.

Thus the method of choosing objects for informational influence in social networks during an information campaign based on the analytic hierarchy process was proposed.

2.1 Verification of the proposed method on the computer model

The effectiveness and feasibility of the proposed method is verified by the series of experiments on the developed computer model.

Let conduct the experiment preliminary evaluating the prospects of nodes based on the analytic hierarchy process. The experiment is carried out using the computer model, which was described in articles [5, 6, 15]. For the experiment in the model, created the segment of a social network containing several clusters (Fig. 1).

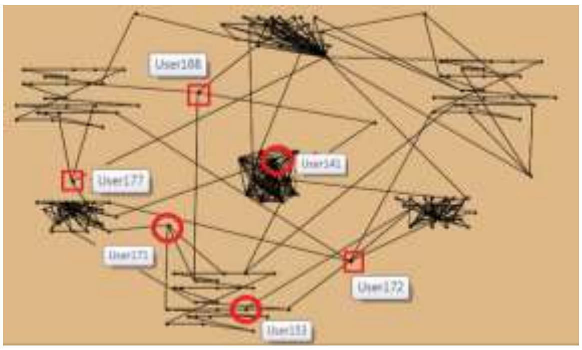

Fig. Помилка! Не вказано послідовність.**.** The social network segment generated for testing the proposed method.

Calculations were made to select the target nodes for informational influence based on AHP, and three alternatives were identified, these are the nodes: № 168, № 172, № 177.

The promising alternatives selected on the basis of AHP are highlighted in Fig. 1 by squares and the nodes that were randomly selected and will be considered in the experiment for comparison are selected by circles.

We illustrate the example of calculations by the analytic hierarchy process for comparing the prospects of nodes № 168, № 172, and № 177.

Quantitative indicators, expert assessment, and normalized indicators are shown in table 3.

Table 3. The assessment of the alternatives by the criteria.

Criteria	**The network nodes**					
	№ 177	**№ 172**	**№ 168**	**№ 177**	**№ 172**	**№ 168**
	The quantitative indicators			**The summary indicators**		
The relationships number	4	6	4	6	9	6
Activity (Act)	5	3	4	9	5	7
Opposition (O)	23	20	12	5	5	9
Structural position (Str)	6	5	9	6	5	9
Reputation (R)	30	54	67	4	7	9
R/O	1.3	2.7	5.6	2	4	9
Act * Str	40	18	36	8	4	9

Table 4 shows the ranking of the criteria.

As preliminary experiments and studies have shown, activity (especially in segments with tight relations) and structural position have the greatest influence on the distribution result. Note that the structural position has, in most cases, a more significant effect on the result than activity.

Table 4. Ranking of the criteria.

Criteria		$\mathbf{K_1}$	$\mathbf{K_2}$	$\mathbf{K_3}$	$\mathbf{K_4}$	$\mathbf{K_5}$	$\mathbf{K_6}$	$\mathbf{K_7}$
The relationships number	$\mathbf{K_1}$	1	0.25	5	0.17	3	2	0.14
Activity (Act)	$\mathbf{K_2}$	4	1	6	0.33	5	3	0.2
Opposition (O)	$\mathbf{K_3}$	0.2	0.17	1	0.17	0.5	0.2	0.13
Structural position (Str)	$\mathbf{K_4}$	6	3	6	1	5	3	0.2
Reputation (R)	$\mathbf{K_5}$	0.33	0.2	2	0.2	1	0.2	0.17
R/O	$\mathbf{K_6}$	0.5	0.33	5	0.33	5	1	0.25
Act * Str	$\mathbf{K_7}$	7	5	8	5	6	4	1

Therefore, the influence of the criteria (in descending order) will be as follows:

– balancing criterion: $Act \cdot Str$;
– structural position (evaluated by an expert);
- activity (quantitative independent indicator).

The example of the alternative comparison according to one of the criteria is given below (tab. 5-6).

Table 5. Matrix of pairwise comparisons of alternatives relative to the criteria K_1.

	№ 168	**№ 172**	**№ 177**
№ 168	1	0.333333	1
№ 172	3	1	3
№ 177	1	0.333333	1

Matrix vectors
$v_0 = 0.2$
$v_1 = 0.6$
$v_2 = 0.2$

$\lambda_{\max} = 3$, $CR = 2.46716227694479E-16$

Below is the matrix of generalized priorities (alternative comparison matrix).

Table 6. Alternative comparison matrix.

Nodes	**Criteria**						
	K1	**K2**	**K3**	**K4**	**K5**	**K6**	**K7**
	0.074084	**0.149205**	**0.02413**	**0.216401**	**0.034732**	**0.081467**	**0.419981**
№ 168	0.2	0.285714	0.625013	0.581552	0.730645	0.739594	0.46647
№ 172	0.6	0.142857	0.1365	0.109452	0.080961	0.093813	0.100498
№ 177	0.2	0.571429	0.238487	0.308996	0.188394	0.166593	0.433032

The generalized priorities will be equal to:
λ_0 = 0.479914570940781, λ_1 = 0.145406604199733, λ_2 = 0.374678824859486

Consequently, AHP among the proposed alternatives identified node № 168 as the best choice for an attack. The next priority is node № 177, and then node № 172.

The experiment on the computer model was carried. In the experiment, the selected alternative nodes were used as the initial subjects of information dissemination, the strategy “Bush” was used as the behavioral strategy of the attack nodes – is the strategy of behavior that is based on a random selection of nodes for attack among the contacts of the subject of influence, this strategy is proposed and described in detail in [6].

Considering the peculiarities of the strategy “Bush”, namely, in the final stage of disseminating informational influence, there remains a small number of nodes of the social network to which the target information will not arrive for a long time, we will evaluate the rate of capture 90% nodes in the network segment. The total number of nodes in the segment generated for the experiment is 178, so we will evaluate the capture speed of 160 nodes, as the initial generator-node, we will choose alternatives previously selected in sequence. For each of the alternative nodes, we carry out the series of 10 experiments and average the result. In addition to the nodes selected among promising alternatives (nodes No. 168, No. 172, No. 177), we will carry out the same series of experiments for three randomly selected nodes that do not belong to this promising alternatives and compare the results. So, will be taken the nodes:

– №153 – the node was randomly selected among the nodes of the cluster of type Group;

– №141 – the node was randomly selected among nodes of the cluster type Clique with the maximum number of relations in the monitored network segment;

– №171 – the node was randomly selected among nodes, which the bridge between several clusters.

The location of the nodes, which were chosen in the experiment, are presented in Fig. 1.

The experiment on the model showed the following results (table 7).

Table 7. The results of the experiment.

Node	**Experiment Number**										**Mean value**
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	
	The number of iterations spent for the capture 90% of the nodes in the network segment										
№168	147	142	151	142	138	152	142	147	152	144	146
№177	152	154	154	158	161	151	160	154	150	152	155
№172	166	168	172	174	168	164	166	168	174	172	169
№153	198	201	205	186	198	200	204	198	190	202	198
№141	169	159	156	162	165	158	162	160	162	151	160
№171	184	192	186	186	190	182	196	182	189	184	187

As can be seen from the results of the experiment, the nodes selected on the basis of AHP allow spreading informational influence among 90% of the nodes of the social network segment in less time. Also, the use of AHP made it possible to correctly prioritize selected alternatives.

Among the chosen alternatives according to AHP, node №168 was chosen as the first in priority, № 177 as the second, and № 172 as the third. The experiment on the computer model confirmed that the choice of node № 168, among other pre-selected alternatives, is the best option, in terms of the efficiency of information distribution in the network segment. Attack efficiency with an initial node № 168 is 6% higher than with a node № 177 and 14% higher than with a node № 172. Also, the nodes selected on the basis of AHP showed an average of 16% better results than the nodes selected randomly among the winning structural positions of the social network.

3 Conclusions

In this work, the method of choosing objects for informational influence in social networks during an information campaign based on the analytic hierarchy process was developed. The analytic hierarchy process can be quite simply implemented in software, does not require complex calculations. The main advantage of AHP is the ability to its adaptation to change the situation in the network segment being studied. For example, a change in the quantitative estimates of a node will require only a change in the coefficients in one of the alternative comparison matrices. The disadvantages of the AHP include the impossibility of its full formalization and the significant impact of expert opinion on the result. The errors of expert opinion can be reduced if using the average estimates of a group of experts, and not of one expert. AHP also provides for checking the uniformity of the assessment, which allows tracking potentially incorrect expert assessments in a certain way.

The experiments showed that the effectiveness of informational influences through nodes chosen based on the developed method is on average 16% higher than through nodes chosen randomly taking into account only their structural position in the network.

The results of the experiment on the developed computer model of a social network confirm the possibility of applying the AHP to assess the prospects of nodes for attack and the accuracy of the predicted best alternative – the predicted result corresponds to the result obtained during the experiment.

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