The Use of a Fuzzy Cognitive Maps and Eye Tracking in Exploitation of Online Advertising Resources

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Abstract: Current trends in the area of digital marketing and online promotion indicate the increasing role of highly targeted online advertising. The method of designing advertisements evolved in the direction of one-to-one communication, which forces to create personalized advertising messages. In the case of interactive media modelling changes can occur in a dynamic way based on audience and content characteristics. The purpose of this article is to develop a model supporting the selection of parameters and localization of advertising content with the use of fuzzy cognitive maps and possibility to perform simulations based on content selection towards increased efficiency.

1 INTRODUCTION

Nowadays in marketing different promotional instruments and measures, with which a company communicates with the surrounding, are used. The increase in the importance of interactive technologies, especially of the Internet in an organization's marketing activity, is related, among other things, to new media, which emerged thanks to the development of information technology (Kotler and Postma, 1999). Functions of the traditional media are being taken over by the electronic media or their combination in the form of multimedia. The interactive media with *one-to-one* model allows to send an announcement to a recipient and receive feedback (Hoffman and Novak, 1995) what is a result of evolution of *one-to-many* communication model from traditional media (Rust, 1989). The basic feature, which distinguishes the electronic media (including the Internet), is a possibility of employing bidirectional communication which led to the development of new communication models (Hoffman and Novak, 1995). The way of designing advertisements is moving in the direction of targeting (Goldfarb and Tucker, 2011), maximizing the level of personalization with the use of morphing techniques (Theocharous and Thomas, 2015), usage of ad recommendation systems (Theocharous and Thomas, 2015) or the use of characteristics derived from social network connections (Wan-Shiou et al., 2006). In the case of modelling an interactive message, its changes can be dynamic and on the basis of observations one can systematically introduce changes in order to compare different concepts and designs (Theocharous and Thomas, 2015). Assisting decision-making processes concerning broadcasting a spot is of great importance to Internet advertising campaigns. A number of factors make it difficult to choose a proper criterion for activity optimization. Presented in this paper approach is based on the eye tracking and advertising content representation based on fuzzy cognitive maps (FCM). In modelling with the use of FCM one needs to take into consideration the fact that prepared characteristics are in most cases based on human knowledge. In order to avoid subjective opinions the paper proposes the solution which applies eye tracking to calculate relations between the elements of and parameters of examined advertising content. Paper is organised as follows. Section 2 introduces theoretical background concerning tools used to construct a model, that is fuzzy cognitive maps as well as the eye tracking methodology. Section 3 shows authors' example of employing cognitive maps in modelling an interactive message and presents the description of the experiment with the use of an eye tracker. Section 4 discusses the achieved results and is followed by Summary.

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2 MATHEMATICAL REPRESENTATION AND STRUCTURE OF FUZZY COGNITIVE MAPS

Methodological background of proposed approach is based on a fuzzy cognitive maps as an extension of knowledge maps first proposed by Robert Axelrod, a political scientist, in 1976 (Axelrod, 1976). They were used to present social scientific knowledge. A fuzzy cognitive map is presented in the form of a directed graph which can be represented in the following manner (Froelich and Juszczuk, 2009):

$$\langle N,w \rangle \quad (1)$$

where:

$N = [N_1,\dots N_n]^T$ - map factor values related to each other by means of dependencies,
$w = \{w_{ij}\}$- connection weights assigned to the edges between nodes x expressed in the form of relation matrices, where are w_{ij} are numbers from the interval [-1,1]; i,j = 1,….n, n- a number of factors.

Every edge w_{ij} is related to a given node N_n and has an attributed value. The value demonstrates a kind of relations between factors. If an edge of a node N_1 to a node N_2 has a value of > 0, it means a positive influence of a factor A on a factor B. If an edge coming from the factor B in the direction of A has a negative value, it means that the factor B has a negative influence on the factor A. When a value of the edge equals 0, there is no mutual factor influence. One needs to point out that the weight of the edge $w_{ij} \neq w_{ji}$. A disadvantage of cognitive maps was a presentation of relations between factors. The presentation showed only a kind of connection. Kosko suggested a change of a method for determining node connection force (Kosko, 1986) (Kosko and Postma, 1988). Instead of using marks only, each edge had an assigned number which determined the level of connection between examined factors. Presented values were in the range of [-1,1]. Consequently, the relations between the factors could be described by means of fuzzy terms, such as weak, medium or strong (Kosko, 1986). The factor value depends on determining map dynamics with a formula:

$$x_i(t+1) = f(x_i(t) + \sum_{j\neq i}^{n} x_j(t) * w_{ij}) \quad (2)$$

where: i,j - factor numbers (i,j = 1, …n); n- the number of factors; f - threshold number; t - discreet time, x_i - a value of i-th factor ; w_{ij} – a value of edges between a factor x_i and a factor x_j (Froelich and Juszczuk, 2009). The construction of a fuzzy cognitive map is based, to a large extent, on input date. This methodology uses the knowledge of indicated subjects to represent their experiences and behaviour by means of a map. The indicated way of gathering information is subjective, therefore, it is necessary to collect possibly the largest group of experts or to rely on research which included a broad sample (Sobczak, 2007). Therefore, in the first stage one needs to gather main factors which have the most vital influence on a analysed phenomenon. The factors are chosen on the basis of the number occurrences. If a factor, among many independent experts' opinions, occurs many times, it ought to be included in the model (Sobczak, 2007). The next step is to indicate connections between the selected factors. The connections need to be indicated on the basis of real mutual factor interaction. Determining edges and their direction allows defining interaction force between them and it is determined on the basis of experts' knowledge. Interaction force of a relation C_i with regard to C_j can be described by means of linguistic variables (Papageorgiou and Kontogianni, 2011). Having assigned linguistic values from a set T to the edges of the map one can determine a numerical value to every edge. The fuzzification of the obtained dependences between the nodes of the map improves mapping of real relations between the elements of the researched environment.

3 MODEL ASSUMPTIONS AND THE EYE TRACKING EXPERIMENT

The universality of FCM is expressed in its wide application in various areas. In the literature one can find examples of its application in solving engineering (Mohr, 1997), industrial (Stylios and Groumpos, 2004), military (Kosko, 1988) or economic problems (Tsadiras and Margaritis, 1999). Cognitive maps can also be adapted to solve problems related with the optimization of an online advertising message. The issue of optimization is concerned with dynamic changes of content of an advertising message and its multitude. By applying FCM one can quickly define the effectiveness of a given combination and choose the most favourable one. Such an approach minimizes the time spent on keeping online low-efficiency advertisements. Furthermore, in order to minimize human contribution like in surveys in estimating the value of correlation between map nodes, eye tracking research was conducted. Still, the approach involves human commitment and his or her influence on shaping research, and the approach also assumes that subjective opinions are excluded. For the sake of the study experimental websites had been prepared. Every website contained four elements. Three of them presented a text with a headline. The content concerned current events related to e-commerce. The fourth element showed an advertisement constructed on the basis of three elements: level of persuasion based on the colour intensity (P), size (S) and location (L) on a website. Each feature could appear in three variants what gave in total 27 combinations of advertisements which are possible to obtain. Elements of websites with advertisements were displayed on a 19-inch monitor with the display resolution of 1024 x 768 pixels to 16 participants. The functioning of the device was explained to every participant before the experiment. Every participant's position was appropriately set to minimize individual differences in head placement. After setting a proper angle and a distance, the calibration process took place. In the calibration procedure, which was 15 seconds long, the participant's task was to observe 9 points arranged on the screen. After a proper calibration, the user was acquainted with the procedures during the experiment. The task involved reading headlines and first sentences of every paragraph. Every screen element presenting a website was shown for 15 seconds and then automatically another page was displayed. The measurement was conducted with the 60Hz sampling rate. In order to measure participants' visual activity on every page there were allotted areas of interest (AOI). Used measured factors include the number of viewers to the marketing content (MV), percentage of total time spent on the website with the focus on advertisement (MTP), focus time on the marketing content (MT), time to the first view of the advertising content after the website is fully loaded (MFV), the number of repeated visits to the advertising content (MRV) and the total number of returning visitors (MRVN). Results for selected variants are showed in the Table 1.

On the basis of data received, a number of statistical analyzes was performed in order to identify links between factors of P, L, S. The first step was a conducted analysis of the correlation between test components and test results obtained. At a significance level of 0.05, the strongest correlations were observed between the number and location of revisited advertisement (-0.49). The other element proved to be poorly correlated. Cluster analysis based on the method of Ward with a measure of Euclidean distance was used. Based on the Mojeny rule, it is suggested that level of division occurs at stage 2. Based on the resulting graph, it can be determined by ad groups, which have received similar results as the number of users who noticed the ad. The best were advertising the group in which repeated factor was the size of the ad (S) at level 2, i.e. 250x200. To find out whether a number is linked to a return visit with elements of advertising, the obtained data was subjected to analysis of main factors variance (ANOVA). The number of ad visits was affected by its size ($F(2,20) = 4.32$, $p = 0.028$). The analysis showed that the ads, which are medium in size have a greater impact on the return visit than ads with larger dimensions. Their effectiveness is about 23% higher. Based on these results, important factors proved to be the location ($p = 0.003$) and ad size ($p = 0.014$). The intensity of the colour turned out not to be significant ($p = 0.313$).

4 THE FORM OF THE FCM MODEL FOR CHOOSING ADVERTISING CONTENT

The data obtained from measurements constitute N_i factors containing information about characteristics

Table 1: The values from eye tracking for selected variants.

ID	Factors	MV	MFV	MT	MTP	MRVN	MRV
1	1-1-1	7	5.2	0.56	3.76	5	1.4
3	2-3-2	9	7.27	0.46	3.09	1	1
8	2-2-2	9	7.39	0.67	4.49	5	1.8
12	1-1-3	8	3.2	0.68	4.51	6	2.7
14	3-3-1	5	8.14	0.41	2.71	1	1
17	3-2-1	2	6.75	0.06	0.37	1	1
18	2-1-2	6	8.68	0.21	1.4	2	1.5
21	2-3-3	5	8.48	0.66	4.37	2	1.5
25	1-3-2	5	4.71	1.21	8.06	3	1.7
27	1-3-3	8	5.72	0.2	1.32	4	1.3

of an advertisement and its effectiveness. Independent variables, which can be controlled in a direct way, are the size, colour and location of the advertisement. Other information obtained on the basis of the research by means of the device are seen as dependent variables whose value depends on a user's reaction. Here is the list of all variables (nodes): N_1 - advertisement size (S); N_2 - location of the advertisement on a website (L); N_3 - persuasion based on colour intensity (P); N_4 – the number of visits; N_5 - time after which the advertisement is noticed for the first time (s); N_6 - total time in which the advertisement caught attention (s); N_7 - percentage share time of advertisement visits in relation to other content on the website (%); N_8 - the number of return visits.

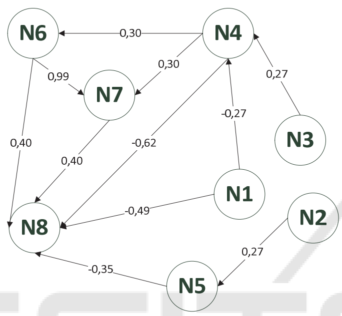

Figure 1: Diagram of a fuzzy cognitive map for the issue of advertisement content and localisation selection.

The initialisation of map parameters in a relation matrix was constructed on the basis of the analysis of parameters obtained from the eye tracking research and is showed in Fig. 1. The calculated correlations were used to create connections between map nodes w_{ij}. The matrix based on the obtained values is presented in the Table 2. The zero value means that given nodes do not influence significantly each other.

On the basis of charts of surface adjustment between individual advertisement elements one can observe the changeability of effectiveness of individual combinations with relation to intensity of each feature. Fig. 2 shows the relationship between two most essential factors. The surface chart displays that most effective is the combination of location on level L=1 and of size on level S=2. Figure 3 presents the relation between the location and colour intensity. It turns out that the best results are achieved for an advertisement placed on the highest place on a website and for colour on lever P=2. The location change is responsible for a drop of users' return visits. The diversity of a mutual influence wielded by the size and colour intensity turned out to be irrelevant.

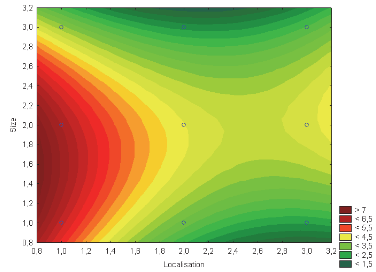

Figure 2: Surface adjustment Size – Location.

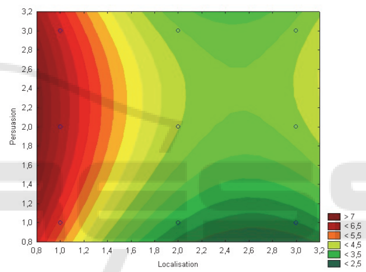

Figure 3: Surface adjustment Colour – Location.

The prepared cognitive map also allows conducting, in a short period of time, a large number of simulations for different values of decision variables. When the defining values of advertisement elements are introduced to the model, it is possible to verify the results of effectiveness which a given combination of elements is able to achieve. Also, the proposed model can be used to predict effectiveness results. When introducing a demanded value to a given node from N_4 to N_8, one can define which values adopt independent nodes. This solution enables the dynamic selection of advertisement content depending on the desired results. This solution

Table 2: Relation matrix of the discussed map.

	0	0	0	-0.27	0	0	0	-0.49
	0	0	0	0	0.27	0	0	0
	0	0	0	0.27	0	0	0	0
W=	-0.27	0	0.27	0	0	0.30	0.30	0.62
	0	0.27	0	0	0	0	0	-0.35
	0	0	0	0.30	0	0	0.99	0.40
	0	0	0	0.30	0	0.99	0	0.40
	-0.49	0	0	0.62	-0.35	0.40	0.40	0

seems to be correct given the fact that in advertising campaigns the demanded effect can be diversified. Figures 4 - 5 represent selected part of possible scenarios. Values in highlighted nodes refer to elements constructing advertising content (Fig. 4 - 5) or a predicted value (Fig. 6 - 7).

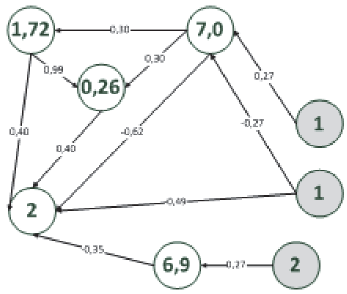

Figure 4: Effectiveness results for settings L=2, S=1, P=1.

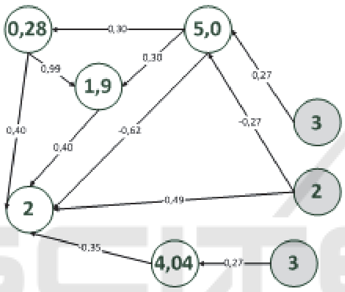

Figure 5: Effectiveness results for settings L=3, S=2, P=3.

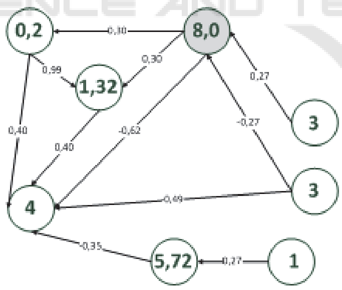

Figure 6: Forecasted values of independent nodes for an expected value of a node N4 ≥ 8.0.

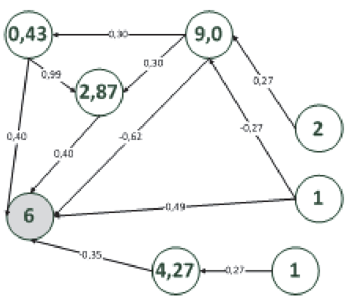

Figure 7: Forecasted values of independent nodes for an expected value of a node N8 ≥ 6.0.

Figures 4 and 5 present achievable effectiveness results of nodes N_4 -N_8. Generated results are based in full on the values of nodes N_1, N_2 and N_3. In both cases a given list of independent variables generates a given domain of results. In cases presented in Figures 6 and 7, FCM was used to predict the settings of independent variables. The forecast range of values in both cases is an inequality. Because of that, the number of generated settings, which fulfil this inequity, of advertisement content is higher than one. Other calculations will generate different element combinations in nodes N_1-N_3. The conducted research also allowed defining the influence of individual variables on each other. This illustrates the complexity of the modelled system of advertising content selection.

5 SUMMARY

The introduced modelling of an interactive message is an example of using fuzzy knowledge maps combined with the eye tracking. The presentation of changeability of features constructing a message as well as the evaluation of effectiveness of results obtained in the model makes it possible to have a wider range of decision support with relation to deterministic solutions. The obtained results, because of the possibility of evaluation of their realization certainty in a changeable environment, indicate that fuzzy cognitive maps can be employed in the optimization of planning a transmission of a certain type of advertisement on the Internet. They can be applied in strategic planning when looking for solutions which ensure the best use of available resources and be the basis for the evaluation of broadcasting resources from a point of view of achieved results. In order to test the universality of the model it is possible to adapt a similarly constructed advertisement and to check the correctness of the results generated by FCM. Adding other nodes with independent values to the constructed map would enable stronger personalization of a generated message, what in consequence would increase the level of effectiveness.

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