European Proceedings of
Social and Behavioural Sciences
EpSBS
www.europeanproceedings.com
e-ISSN: 2357-1330

DOI: 10.15405/epsbs.2021.12.02.52

ICHEU 2021
International Conference «Humanity in the Era of Uncertainty»

MATHEMATICAL MODEL FOR DEFINING ACADEMIC INTERESTS OF STUDENTS IN PERSONALIZED EDUCATION

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Abstract

The paper appeals to the problem of individual learning paths or the so-called personalized education, which is an educational trend of the 21st century. Education for a complex society should form the student / specialist's professional and communicative competencies, self-management skills, the ability of self-education, digital-skills, and most importantly, the ability to make choices in conditions of uncertainty. The key subject of the work is «visual perception». The authors use an interdisciplinary approach, relying primarily on the experience of analyzing human perception based on data from Mouse Tracking, Eye Tracking, Touch Tracking. A method is proposed for the targeted selection of information blocks being interesting to the user on the basis of considering the movements of the cursor. The researchers suggest that there is a possibility of a correlation between the student's degree of attention, expressed in the movement / delay of the mouse cursor, with his academic interests. While viewing an educational information resource, the user constantly monitors the activity of the mouse pointer. Thus, considering the movement of the cursor, it is possible to form interest and the choice of the necessary information on the educational resource.

Keywords: Personalized education, mathematical model, visual perception, heat maps

https://doi.org/10.15405/epsbs.2021.12.02.52
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Selection and peer-review under responsibility of the Organizing Committee of the conference
eISSN: 2357-1330

1. Introduction

The actual trend of higher education in the XXI century is the personalization of education at all levels. According to V. Falkov, «in the XXI century we are entering a fundamentally different model of education. It must become more individual not to find talent, but to reveal talent in everyone. We need to make higher education individual, meaning work with each person in a special way. Medicine is already personalized; we demand individualization in everything. So why should education be different? (as cited in Individual educational trajectories in Russian universities, 2020, parag 1).

Possession of competences beyond the basic specialty is not a new idea, it was discussed even in the late 19th and early 20th centuries by K. Marx, V.I. Lenin, N.K. Krupskaya, being the greatest minds: a well-balanced developed individual was opposed to a narrow specialist, whom K. Marx called in his works either a «professional moron» or a «professional idiot». A professional moron is a person «who knows only his profession well, is limited to it and does not participate in the life of society» (as cited in Bakshutova et al., 2018, p. 6). In addition to a wide range of competencies (hard skills, soft skills, self skills, etc.) a new level of specialist is required to be resistant to uncertainty, decision-making skills in these conditions, courage to be free in choice. The information availability on the Internet creates the illusion of accessibility of any knowledge. This is partly true, but students need to be taught to look for valid and reliable information (Lin et al., 2018). In order to «ease the participation» of students in finding and choosing the right information, a method of targeting information blocks of interest based on the user's cursor movements is proposed.

2. Problem Statement

It is required to determine which information blocks (IB) of information educational resource (IER) are the most interesting according to user’s visual perception (VP) in order to further use the information obtained for a number of processes, such as:

– targeting information blocks, in whose topics the user is interested;

– building individual information tracks to study the information on the topics of interest. We understand information tracks as a set of information blocks (resources) studied in a certain sequence, for example, from simple to a complicated one.

VP is determined by the behavior of the mouse cursor moved by the user in the process of perception of the information on the screen. There is a number of works and ready-made solutions for analysis of human perception based on Mouse Tracking, Eye Tracking, Touch Tracking data (Chen et al., 2001; Faulkenberry & Rey, 2014; Fischer & Hartmann, 2014; Rheem et al., 2017; Tanjim-Al-akib et al., 2017; Schoemann et al., 2021).

3. Research Questions

The main question is whether it is possible to determine the list of topics of information blocks posted on the IER, which the user is most interested in, based on the analysis of its interaction with the IER. And whether we can determine the degree of attention and interest with the help of «heat» maps by methods

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of Mouse Tracking and Touch Tracking to further select and provide the user with information according to his academic interests.

4. Purpose of the Study

The purpose of the study is to develop a mathematical model to determine the academic interests of students based on the analysis of their interaction with the IER and determine the degree of attention and interest using heat maps, using Mouse Tracking and Touch Tracking methods.

5. Research Methods

In this work Mouse Tracking and Touch Tracking technologies are used. Since the user uses up to 88% of display controls, it is possible to determine the types of cognitive perception and particular subject of interest with the same accuracy for further targeting information blocks, excluding irrelevant ones. In addition to this method, the method of determining the exact positioning of IS on IER in order to place the information in user's attention center (UAC) is proposed. UAC is determined by the heat map of Mouse Tracking, Touch Tracking by defining the maximum concentration of micro-movements of the mouse cursor. The mathematical model was also developed to classify users according to their interests.

6. Findings

There is a sufficient amount of work focused on tracking an individual educational approach at all levels of education revealing such aspects as: human-centred education (Mosin, 2018; Shilova & Fetisova, 2020), project training (Piven & Chelombitko, 2021), e-learning (Bakanova & Javorcicova, 2020), artificial intelligence in education (Kuvaldina, 2021). However, there is only one scientific work (Chen et al., 2001), which investigated the correlation between eyes and mouse cursor movements: What can a mouse cursor tell us? It says that there is about 84-88% of strict connection between the mouse and eye movement. First of all, the article claims that with a probability of 84%, if there was a cursor in a certain place on the page, the IER visitor looked there (not necessarily at the same time!), and with a probability of 88%, if he did not look anywhere, there was no cursor there either. Nevertheless, the fact that the user looked at the cursor spot, it doesn't mean at all that the cursor was there where the user was looking! That means that the mouse motion heat map shows some part (it is unknown how big or small) of what the user presumably saw. The second conclusion is that the temporal parameters of information perception, including the sequence of this perception, cannot be assessed by mouse movement.

The article also leads to an important conclusion that mouse movements and related perceptions of information are conscious, which indicates that it is advisable to apply the methods discussed in this paper.

Definition of the subject area the user is interest in. To solve the problem, the entire IER is divided into IBs. For each IB a three-dimensional unit vector t_i is defined, characterising the general thematic information section to which it belongs as a direction to a sphere defined in three-dimensional space with the centre T_i. The sphere is a mathematical interpretation of the subject matter of IB and its coordinates in space are given when modelling the system... and the t_i vector is specified when it is placed in the IER. The

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radius of the sphere is set as the total number of single-thematic blocks in the IER and may vary depending on that number.

During the viewing of the IER, the user constantly executes activity monitoring (AM) of the mouse pointer (MP). Touch screen systems also use the equivalent of a mouse pointer, and in the future both types of event management will be used under the term «mouse pointer».

AM is used as part of the Mouse Tracking method to collect information, which is a coordinate-time sequence (CTS) in the form of:

Point $A(x_1,y_1)$ ->

Time of the UM at a given point ->

Moving to point $B(x_2,y_2)$ ->

Time to move from point A to B.

Based on CTS, behavior patterns (BPs) for solving problems of MP characterizing the degree of user attention on IB are determined:

the rapid movement of MP to IB characterizes the switch of attention to information security;

micromovements of MP in the coordinate field of IB characterizes the user's increased attention to information security;

scrolling and placing IB in the user's field of view characterizes the beginning of the user's analysis of information in IB;

continuing to scroll IB in the user's field of view characterizes increased attention to IB;

continuing scrolling and going beyond the previous IB characterizes a loss of attention to the current information security;

no activity of the MP.

The type of BP MP is determined by CTS on the basis of the product rules, which are drawn up on the basis of the features of each type of pattern:

Type 1 is characterized by a long distance between points A and B and the output of the MP from one IB and moving to another IB; the minimum relative time of movement between points.

Type 2 is characterized by a small distance between points A and B and being in the same IB zone or slightly leaving the area; the time of movement between points is not taken into account, the total time of attention to IB is taken into account.

Type 3 is characterized by type 1 behavior, but the position of the window is further analyzed and the sign of scrolling and stopping on a certain IB is determined.

Type 4 is characterized after determining BP type 3, the average and slow time interval between scrolling.

Type 5 is characterized by little focus time on the current IB and switching to another one.

Type 6 is characterized by a lack of any MP activity. At the same time, the analysis of MP activity is suspended until new events become available.

In the course of applying the method, a user's interest matrix characterizing the user's field of interest and consisting of all t_i vectors is determined:

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$$\begin{array}{cccc} x_1 & y_1 & z_1 & w_1 \\ x_2 & y_2 & z_2 & w_2 \\ x_3 & y_3 & z_3 & w_3 \\ & \dots & & \\ x_n & y_n & z_n & w_n \end{array}$$

where x_n, y_n, z_n are the coordinates of the corresponding vector t_i; w_n is the weight of the information security that characterizes the user's interest in the IB; i is the index of IB.

The weight of w_n is calculated as the total time of the user's focus on IB.

The vector t_i is written in the row of the matrix only when determining the BP MP, which characterizes a high level of activity for the corresponding IB. With further analysis of the BP MP, the corresponding weight changes in the matrix, according to the BP MP.

Since it is impossible to unambiguously judge the user's thematic interests only by the direction of the vector t to a certain area of interest, this matrix is used for more accurate determination of the user's interests by calculating the average vector of interests. To do this, pairs of vectors with the highest weights are selected from the matrix and the sum of these vectors multiplied by their weights is calculated. In this case, the sum of the vectors shows a new vector, which can additionally indicate another area of interest of the user in the space of topics.

The belonging of a vector to a certain topic in space is determined by the search for the intersection of the sphere of the topic with the found vector.

After finding the sphere, the vectors with which the sphere search operation was performed are removed from the matrix and the found vector with the average weight of the previous two is placed.

The operation of determining the user's areas of interest continues until all the vectors in the matrix are sorted out and only with vectors with an angle between them of no more than 45 degrees (close subject areas or topics).

Mathematical model of user classification.

Normalization of data by time

Let us sum up the time $z = z_1 + \dots + z_n$ and let $z = 1$. We get a normalized time in minimax format, which does not depend on the behavior of a particular user. We will plot a uniform grid for a time; we will calculate the cursor coordinates at the grid nodes by linear interpolation, as was done in (Mosin & Abashkin, 2020). We get a tuple of functions (x, y).

Tuple representation of trajectories. Now the cursor position is read at discrete time points t, resulting in a series of pairs (x_t, y_t). The number of reads for all users is constant, the total observation time for each user is constant (and is equal to 1), the behavior of an individual user is described by a series of triples $\{t \in R, (x_t, y_t) \in R^2\}$. We denote $u_t = (x_t, y_t)$. Then the data on the behavior of the user sample has the form:

$$\begin{array}{ccccc} \mathbf{u_{11}} & \mathbf{u_{12}} & \dots & \mathbf{u_{1n}} & \mathbf{f_1} \\ \mathbf{u_{21}} & \mathbf{u_{22}} & \dots & \mathbf{u_{2n}} & \mathbf{f_2} \\ \dots & \dots & \dots & \dots & \dots \\ \mathbf{u_{m1}} & \mathbf{u_{m2}} & \dots & \mathbf{u_{mn}} & \mathbf{f_m} \end{array} \qquad (1)$$

where the data u_{st} is of the tuple type, and the objective function $f_s$means that the user belongs to a particular cognitive class, $f_s \in \{c_1, c_2, \ldots, c_l,\}$.

Distance between trajectories. We will introduce the distance between the trajectories based on the Euclidean metric, similar to how it was done in (Mosin & Abashkin, 2020):

$$d(u_s, u_{s'}) = \sqrt{\sum_{i=1}^{n}(x_{si} - x_{s'i})^2 + (y_{si} - y_{s'i})^2}. \quad (2)$$

Taking into account the fact that in the context of the problem, the functions x and y are continuous functions of time, this metric is a discrete version of the metric in the space L_2.

Classification of trajectories

We use kNN as a classifier. We fix the classification object, then for each sample object (1), based on the metric (2), we calculate the distances $d_s$between the classification object and the sample object, order the sample objects in an ascending order of the distance and leave the first k_o objects in the sample. Among them, k_1 objects belong to class c_1; $k_2$objects belong to class c_2; and so on; finally, k_l objects belong to class c_l. Therefore, the object to be classified belongs to class c_1 with probability $p_1 = k_1/k$; class c_2 – with probability $p_2 = k_2/k$; and so on; class c_l – with probability $p_l = k_l/k$. We select the highest probability and assign the object to the appropriate class.

7. Conclusion

In this study, the authors propose a mathematical model that allows determining the list of topics and academic interests of the user in order to form and provide the user with information that corresponds to their academic interests. The model allows you to select information blocks, including those representing adjacent (close) to the main topics of the user's academic interests, allowing you to gradually expand the user's areas of interest, forming a personalized learning trajectory in the future.

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https://doi.org/10.15405/epsbs.2021.12.02.52
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eISSN: 2357-1330

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