UDC 004.8

METHOD OF FORMING MULTIFACTOR PORTRAITS OF THE SUBJECTS SUPPORTING SOFTWARE COMPLEXES, USING A MULTILAYER PERCEPTRON

Pukach A. I. – PhD, Assistant at Department of Automated Control Systems, Institute of Computer Science and Information Technologies, Lviv Polytechnic National University, Lviv, Ukraine.

Teslyuk V. M. – Dr. Sc., Professor, Head of the Department of Automated Control Systems, Institute of Computer Science and Information Technologies, Lviv Polytechnic National University, Lviv, Ukraine.

ABSTRACT

Context. The problem of identification and determination of personalized comprehensive indicators of presence each of the impact factors in the processes of personal subjectivization of the researched supported object's perception by the relevant subjects interacting with it and making influence on its support, is being considered in this research. The process of forming multifactor portraits of subjects supporting software complexes, using a multilayer perceptron, is an object of study. While methods and means of forming such multifactor portraits of subjects supporting software complexes is the subject of study respectively.

Objective. The goal of the work is the creation of a method of forming multifactor portraits of subjects supporting software complexes, using a multilayer perceptron.

Method. A method of forming multifactor portraits of subjects supporting software complexes is proposed, using artificial neural networks of the multilayer perceptron type, which provides possibility to form appropriate personalized multifactor portraits of subjects which, directly or indirectly, interact with the object of support (which can represent both the supported software complex itself as well as the processes associated with its complex support activities).

Results. The results of functioning of the developed method are the corresponding models of multifactor portraits of subjects supporting software complexes, which later are used to solve a cluster of scientific and applied problems of software complexes' support automation, in particular, the problem of identification and determination of personalized comprehensive indicators of presence each of the impact factors (from appropriate pre-agreed and declared set of impact factors) in the processes of personal subjectivization of the researched supported object's perception by the relevant subjects interacting (directly, or indirectly) with it and making influence on its support. As an example, of practical application and approbation of the developed method, the results of resolving the applied practical task of automated search and selection of a maximal relevant candidate (from among the members of the support team of the supported software complex) for best solving of a stack of specialized client's requests (related to the support of this software complex), are given.

Conclusions. The developed method provides possibility to resolve the scientific and applied problem of identification and determination of personalized comprehensive indicators of presence each of the impact factors (from appropriate pre-agreed and declared set of impact factors) in the processes of personal subjectivization of the researched supported object's perception by the relevant subjects interacting (directly, or indirectly) with it and making influence on its support. In addition, the developed method provides possibility for creating appropriate models of multifactor portraits of subjects supporting software complexes, which makes it possible to use them in solving problems, tasks, or issues related to the automation of search and selection of subjects supporting software complexes, which (subjects) meet the given criteria both in the context of subjectivization processes of personal perception of the support objects (e.g. supported software complexes themselves, or processes directly related to their support), as well as in the context of compatibility in interaction with client's users of these supported software products (as those users, in fact, are also subjects of interaction with the same researched supported object).

KEYWORDS: automation, software complex, support, impact factor, multifactor portrait, neural networks, multilayer perceptron.

ABBREVIATIONS

DevOps – Development and Operations;
TC – test case;
MP – multilayer perceptron;
AI – artificial intelligence;
ANN – artificial neural networks.

NOMENCLATURE

Fmp[1..*p*][1..*q*] is a matrix function of converting the input data (incoming to the neurons of the input layer of the encapsulated pre-trained trained artificial neural network of the multilayer perceptron type) into the corresponding results at the output (i.e., to the neurons of the output layer) of the same ANN MP;

H[1..*q*] is a hidden layers of neurons of an encapsulated pre-trained artificial neural network of the multilayer perceptron type;

H[1][*y*(1)] is a specific neuron *y*(1) of the first hidden layer *H*[1] of an encapsulated pre-trained artificial neural network of the multilayer perceptron type, activated during simulation of the current test case;

H[*q*][*y*(*q*)] is a specific neuron *y*(*q*) of the last hidden layer *H*[*q*] of an encapsulated pre-trained artificial neural network of the multilayer perceptron type, activated during simulation of the current test case;

I[1..*n*] is a neurons of the input layer of an encapsulated pre-trained artificial neural network of the multilayer perceptron type;

DOI 10.15588/1607-3274-2025-1-12

I[*x*] is a specific *x*-th neuron of the input layer of an encapsulated pre-trained artificial neural network of the multilayer perceptron type, activated during simulation of the current test case;

Imp[1..*n*] is an input layer of neurons of an encapsulated pre-trained artificial neural network of the multilayer perceptron type;

O[1..*m*] is a neurons of output layer of an encapsulated pre-trained artificial neural network of the multilayer perceptron type;

O[*z*] is a specific *z*-th neuron of output layer of an encapsulated pre-trained artificial neural network of the multilayer perceptron type, activated during simulation of the current test case;

Omp[1..*m*] is a output layer of neurons of an encapsulated pre-trained artificial neural network of the multilayer perceptron type;

SubjMFP[*s*]*Inst*[*c*] is an instant slice of the multifactor portrait of the current researched subject *Subj*[*s*], obtained based on the simulation results of the current test case *TC*[*c*];

SubjMFP[*s*] is an in-process-of-formation multifactor portrait of the current researched subject *Subj*[*s*], obtained based on the results of fully completed simulation of all test cases available for this subject;

SubjPort[*x*] is a generalized representation of a multifactor portrait of some/any researched subject *Subj*[*x*];

TC[*1..s*][*i*(*1*),...,*i*(*n*)] is a matrix of test cases (from the set [*i*(*1*),...,*i*(*n*)]) for modeling/simulation processes (as well as obtaining relevant results) regarding the subjectivization of perception of the supported object by the relevant current researched subject (from the set *TC*[*1..s*]) interacting with this object.

INTRODUCTION

The current state of the software product support industry requires researches for new solutions and opportunities to provide, first of all, comprehensive and automated support. The need for comprehensive support of software products is dictated by the conditions of the entire information technologies field modern market – in particular: high requirements for the competitiveness of each software product, because clients, users, and investors are interested in the most complete and comprehensive support for all those software complexes which they use, or invest in. Meanwhile, support automation is driven by the extremely high intensity and dynamics of the information technology market, where speed and time are one of the greatest values and, again, a competitive advantage.

Thus, the topic (and the problematic, at the same time) of automation in the context of comprehensive activities related to software products' support continues to be an extremely relevant and non-trivial basic and formative component of the corresponding relevant scientific and applied problem, which includes a whole cluster of derived scientific and applied problems, one of which is the need to investigate the processes of subjectivization of the perception of researched support object (that can be represented by the supported software complex itself, as well as by processes related to its support) by relevant subjects which interact with the first (the supported object) directly or indirectly and make influence on its support. Therefore, to solve this task, as well as a corresponding stack of relevant and/or derived tasks, the method, proposed and presented in this work, has been developed. This method provides the possibility of building/constructing appropriate models of multifactor portraits of investigated subjects supporting dedicated software complexes, using artificial neural networks, in particular, a multilayer perceptron. However, the multilayer perceptron itself, like any other artificial neural networks, does not contain ready-made solutions for solving the given problem/task, therefore, it is used as a complementary tool in the development of the method represented in this research. At the same time, the use of a multilayer perceptron makes it possible to additionally apply all its advantages, the main of which is its extremely wide range and potential of possibilities, with (at the same time) a comparatively simple and clear implementation.

The object of study is the process of forming multifactor portraits of subjects supporting software complexes, using a multilayer perceptron. **The subject of study** are methods and means of forming multifactor portraits of subjects supporting software complexes, using a multilayer perceptron.

The purpose of the work consists in the development of a method of forming multifactor portraits of the subjects supporting software complexes, using a multilayer perceptron, which (the developed method) provides possibility to investigate the processes of personal subjectivization of the perception of the researched support object by relevant subjects who interact with the first (directly or indirectly) and affect its support.

1 PROBLEM STATEMENT

Let's consider the formalization of the researched problem/task of forming a multifactor portrait(s) of the subject(s) supporting investigated software complex(es), in the form of a multi-parameter multifunctional dependence task.

In such case, the input variable of this task is the trained multilayer perceptron, encapsulated into the corresponding subjective perception model of the support object (e.g. supported software complex, or processes of its support) – *Omp*[1..*m*]=*Fmp*[1..*p*][1..*q*](*Imp*[1..*n*]), as well as a set of test cases (TC) (for each of the subjects of interaction with the object of support) for modeling/simulation the processes of subjectivization of the perception of a given support object by each individual subject interacting with it – *TC*[1..*s*]=[*i*(1),...,*i*(*n*)].

The output variables of this task are the chains of neurons, activated in result of the simulation of each separate test case *TC*[1..*s*][1..*n*] (for each separate researched subject from declared set of subjects [1..*s*]).

DOI 10.15588/1607-3274-2025-1-12

Let a set of test cases, representing the processes of subjectivization of the perception of support object by the relevant subjects interacting with it, is given. After performing simulation of current test case by the existing pre-trained multilayer perceptron artificial neural network, we will get the corresponding chain of neurons activated on each of the layers of this multilayer perceptron: starting from the input layer of neurons $I[1..n]$, continuing with the neurons of all hidden layers of this MP – $H[1..q]$, and finalizing with neurons of the output layer of this MP – $O[1..m]$.

$$I[x]\text{->}H[1][y(1)]\text{->}\ldots H[q][y(q)]\text{->}O[z], \quad (1)$$

The main necessary criterion of the researched task is the finiteness of the sets of: researched subjects, modeling test cases, as well as predefined and declared impact factors, which is caused by the possibility of operating (in this specific kind of problem) only by the finite sets of these determined parameters and their values.

Limitation(s) of the task:

1. The data values of absolutely all test cases (for absolutely all investigated subjects) must be presented in the format of real numbers and (obviously) in a normalized form of representation (which means: in the range of values between 0.0 and 1.0): $TC[1..s][1..n] \in [0..1]$.

Expression (1) provides possibility to represent the resulting partial (instant, or "one-moment") interpretation of the researched support object by current considered/investigated subject.

However, this format of subjective interpretation of the researched support object represents only a partial (for only one specific test case) and at the same time combined (in the context of defined impact factors) influence of all the impact factors present in this interpretation in general, without any decomposition of this subjective interpretation partially by each (specifically) of the declared impact factors.

Thus, raises corresponding scientific and applied task of identifying and determining personalized complex indicators of presence each of the impact factors in the processes of personal subjectivization of the researched supported object's perception by the relevant subjects interacting with it and making influence on its support. Or in other words, this task can be interpreted as: the task of forming a multifactor portraits of the researched subjects, participating in support of dedicated software complexes. Thus, precisely to solve this scientific and applied task – the method of forming multifactor portraits of the subjects supporting software complexes, using a multilayer perceptron, has been developed and presented in this research.

The purpose of the paper is to highlight the developed method of forming multifactor portraits of the subjects supporting software complexes, using a multilayer perceptron artificial neural networks, as well as the corresponding developed algorithm for building/constructing relevant models, which, taken together, provides all needed possibilities for solving researched scientific and applied task of identifying and determining personalized complex indicators of presence each of the impact factors in the processes of personal subjectivization of the researched supported object's perception by the relevant subjects interacting with it.

2 REVIEW OF THE LITERATURE

The analysis of relevant researches and materials was carried out in two key directions: in the direction of studying the processes of subjective perception of the objects, as well as in the direction of software complexes' support automation (in particular, using AI and machine learning approaches). Resulted information on each direction is presented below.

For example, the authors of work [1] investigate the problem of distortion of the subject's perception of the researched objects in situations with presence of a "noise" (or various stimuli, which could be also represented by certain considered external impact factors) inside the main visual channel, through which these subjects receive all the necessary information about the researched object. So, investigation, performed in this work, actually, confirmed the influence of personal (internal) impact factors (in particular, specifically the "expectation" factor) of the subjects on the perception of the researched object, because, according to the results presented in this work: the perception of reasonably expected objects was enhanced (heightened) relatively to unexpected objects, when the visual data were unreliable (which means, these data were more influenced by present external impact factors), while this effect was changing in favor of unexpected objects when the signal was more reliable (which means, it was less exposed to external impact factors).

At the same time, authors of works [2] and [3] study in detail the problem of subjectivization of user's perception of software products' graphical interfaces. Since the correct approach to supporting the graphical interface of the developed software products requires taking into account and consideration the subjective perception of users and the principles of objects grouping (such as Gestalt laws), because users usually group simple objects (graphic elements and shapes) into connected visually dominant objects. In addition, according to the results of those authors' research, measuring the characteristics of visually emphasized objects of the graphical interface (of the supported software product), displayed on the screen, is a promising way for evaluation the quality of the user interface, although, on the other hand, it brings additional problems related to the ambiguity of object's recognition caused by the subjective perception of different users. That is why the authors analyzed the applicability of selected object-oriented metrics for quality assessment, in particular, the toolbars (as a key element of the graphical user interface) and the ability to distinguish well-designed samples, focusing mainly and precisely on the subjective perception of users.

While, another work [4] is already devoted to the development of a specialized algorithm for automating the processing of client requests (for support services) based

DOI 10.15588/1607-3274-2025-1-12

on their prioritization and the formation of an appropriate queue, to ensure their fair and balanced processing. Also, in the work [5], the authors, based on a review of the relevant specialized literature sources, conducted a generalized analysis of the current state of affairs in the field of client requests' (for support services) processing automation in order to identify certain trends or tendencies, according to which, for example: the creation of automated incident management tools is a major topic in this field, followed by escalating inquiries and predicting (forecasting) customers' sentiments, as well as various appropriate algorithms for a very wide variety of classifications in this field. In addition, the author of the work [6] presented research aimed at creation of an intelligent user "LAVA" – a solution that provides context-dependent support for users of a supported software product, taking into account the interaction with these users, and is based on machine learning and searching in a dedicated two-level distributed knowledge repository (e.g. knowledge base). At the same time, works [7] and [8] study in detail the problems of automating the process of classifying customer requests received in dedicated systems of support services, because it is an extremely time-consuming process in case it is performed manually, while the use of machine learning gives really good results when solving tasks of such type (e.g. classification tasks). At the same time, work [9] examines the problems of processing client's requests (received in support services) in the context of using machine learning algorithms (namely in the part of natural language processing), which are fundamental for optimizing the processing of requests in a wide variety of customer support services and systems. Also, it is worth noting the works [10], [11] and [12], which reveal, in fact, the basic issues of both the fundamental theoretical principles and principles of functioning, as well as the practical application, of an artificial neural networks and a multilayer perceptron, which provides possibilities for better understanding and realizing their full potential, both in the context of possible use in the field of software complexes support, and as a whole.

3 MATERIALS AND METHODS

The main functional purpose of the developed method of forming multifactor portraits of the subjects supporting software complexes, with the use of a multilayer perceptron, is to ensure the possibility of identification and determination personalized complex indicators of presence each of the impact factors (within a relevant pre-agreed and declared set of impact factors) in the processes of personal subjectivization of the researched supported object's perception by the relevant subjects interacting with it (directly or indirectly) and making influence on its support.

The main idea of the developed method, which provides possibility to achieve the declared goal and task of this research, is to use the results of another researches [13], [14] and [15] in order to ensure the possibility of solving the declared task of identification and determination personalized complex indicators of presence each of the impact factors in the processes of personal subjectivization of the researched supported object's perception by the relevant subjects interacting with it. In particular, researches [13] and [14] provides possibilities to identify the probabilities of belonging of the hidden layers' neurons (of the encapsulated trained multilayer perceptron artificial neural network) to the corresponding declared impact factors. Meanwhile, research [15] provides the possibility of modeling these processes using R-system and Python environments.

After all, having the specific numerical values of probability indicators of belonging each of the hidden layers' neurons (of the encapsulated trained MP ANN) to the appropriate relevant impact factors, it becomes possible to further step-by-step construction of a multifactor portrait of the corresponding researched subject. Since each chain of activated neurons obtained using expression (1) is, in fact, an instant slice of the researched subject's multifactor portrait:

$$SubjMFP[s]Inst[c] = [\ \textstyle\sum[c](F[1]),\ldots,\sum[c](F[f])\ ]. \qquad (2)$$

Thus, after fully completing the simulation for all available test cases belonging to one particular specific researched subject, we will obtain a corresponding set of various (perhaps, even partially repeated) chains of neurons activated during the simulation of each of these test cases (exactly for this one separate specific researched subject):

$$SubjMFP[s]=[\ \textstyle\sum[1..n](F[1])/n,\ldots,\sum[1..n](F[f]/n)\ ]. \qquad (3)$$

Expression (2) provides the possibility of interpreting the researched task by usage of relevant results obtained by simulation of previously trained multilayer perceptron artificial neural network, where:

– $\sum[c](F[1])$ – the sum of the belonging of all activated neurons (in simulation results of the current test case $[c]$) to the first one impact factor $F[1]$ from a pre-declared set of defined impact factors;

– $\sum[c](F[f])$ – the sum of the belonging of all activated neurons (in simulation results of the current test case $[c]$) to the last one impact factor $F[f]$ from a pre-declared set of defined impact factors.

Meanwhile, expression (3), in turn, provides the possibility of interpretation the researched task of forming multifactor portraits of the subjects supporting the investigated object (the supported software complex, or processes of its support), where:

– $\sum[1..n](F[1])$ – the sum of the belongings of all activated neurons (in obtained simulation results of all test cases $[1..n]$ for current researched subject) to the first one impact factor $F[1]$ from a pre-declared set of defined impact factors;

– $\sum[1..n](F[f]$ – the sum of the belongings of all activated neurons (in obtained simulation results of all test cases $[1..n]$ for current researched subject) to the last one impact factor $F[f]$ from a pre-declared set of defined impact factors;

DOI 10.15588/1607-3274-2025-1-12

– n – the number (amount) of test cases for the current researched subject.

In addition, expression (3) also provides additional normalization of the obtained resulting data.

Thus, expression (3) actually represents the corresponding relevant mathematical model of the multi-factor portrait of the subjects supporting investigated software complexes.

Below, in the Figure 1, a corresponding generalized block diagram of the developed algorithm of forming a multifactor portrait of the researched subject interacting with the investigated supported software complex is represented.

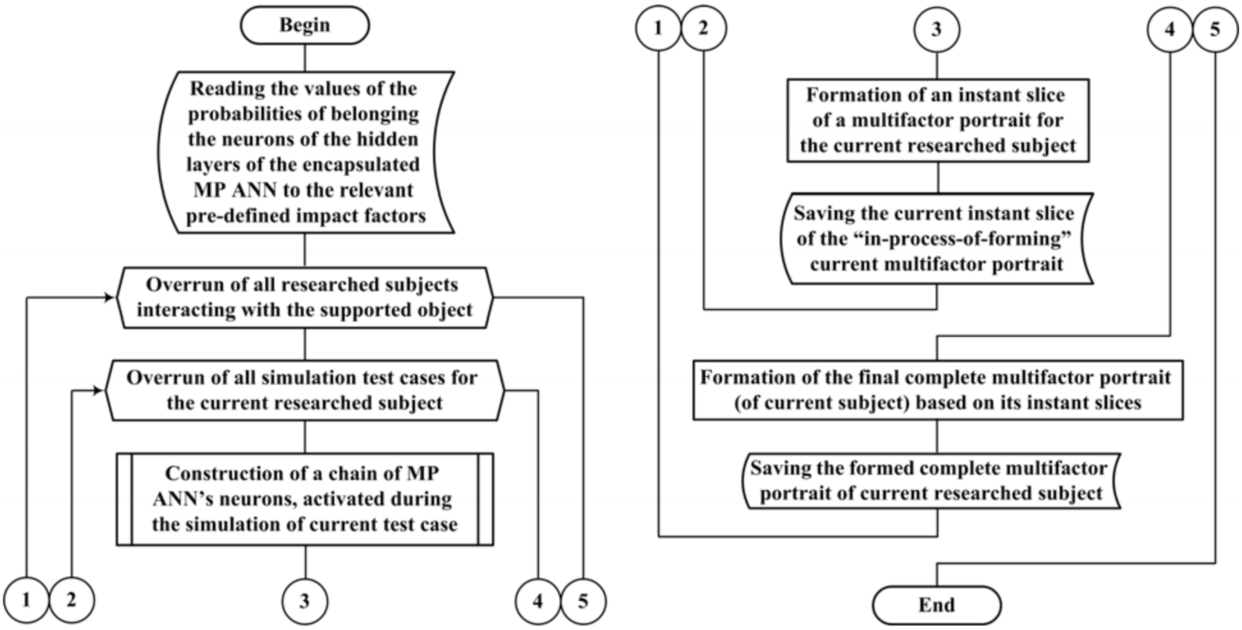


Figure 1 – Block diagram of the developed algorithm of forming a multifactor portrait(s) of the researched subject(s) interacting with the investigated supported software complex

The developed algorithm, block diagram of which is presented in Figure 1, as well as the corresponding mathematical model represented by expression (3), actually, create the needed basis of the developed method of forming multifactor portraits of the subjects supporting software complexes, with usage of a multilayer perceptron.

While the corresponding: mathematical model (represented in research [13]), the model of decomposed isolation dominance (represented in research [14]), as well as the appropriate information model (represented in research [15]) form up a complementary, but, at the same time, absolutely integral and irreplaceable component part of this method.

So, taken together, all these abovementioned constituent elements form a holistic method which provide possibility to resolve the declared scientific and applied task, namely: the task of identification and determination of personalized comprehensive indicators of presence each of the impact factors in the processes of personal subjectivization of the researched supported object's perception by the relevant subjects interacting with it and making influence on its support, is being considered in this research.

4 EXPERIMENTS

The experiment consists in a step-by-step execution of all the stages described in this research, namely: correct formulation of the researched task with all the necessary input data, as well as mandatory compliance with the declared restrictions; preparation and encapsulation of corresponding artificial neural network of a multilayer perceptron type, training this model, and obtaining all necessary results of the specific numerical values of probabilities of the hidden layers' neurons' belonging to the corresponding pre-declared impact factors; preparation of test cases for modeling the subjectivization processes of the perception of support object by all researched subjects (separately by each of these subjects); step-by-step execution of the developed algorithm of forming a multifactor portrait(s) of each of the studied/researched subjects by forming the corresponding instant slices of these ("in-process-of-constructing") multifactor portrait(s), as well as the final full and complete multifactor portrait(s) of the subject(s) based on the relevant developed and proposed mathematical model.

5 RESULTS

The main results of functioning of the developed method – are formed/constructed multifactor portraits of the subjects supporting investigated object (e.g. the supported software complex, or processes of its support). In fact, each these obtained in such a way multifactor portraits (for each particular researched subject) represents a set (or array) of personalized comprehensive indicators of presence each of the pre-declared impact factors in proc-

DOI 10.15588/1607-3274-2025-1-12

esses of personal subjectivization of perception of the investigated support object by the corresponding relevant researched subject(s).

Thus, any multifactor portrait of any researched subject of interaction with an investigated supported software complex can be presented using the following appropriate expression (4):

$$SubjPort[x]=[Presence(F[1]), \ldots, Presence(F[f])] \quad (4)$$

So, in accordance with the proposed generalized representation of a multifactor portrait(s) of the researched subject(s), formalized using expression (4), any multifactor portrait could be, in fact, represented by a corresponding set (array) consisting of elements, where:

– *Presence*(*F*[1]) – indicator of presence of the first (from a relevant set of all the pre-declared impact factors) impact factor *F*[1] in current considered multifactor portrait *SubjPort*[*x*];

– *Presence*(*F*[*f*]) – indicator of presence of the last (from a relevant set of all the pre-declared impact factors) impact factor *F*[*f*] in current considered multifactor portrait *SubjPort*[*x*].

Also, all these obtained resulting data of indicators of presence each of the impact factors in the researched multifactor portrait are already pre-normalized by using an expression (3).

Visually, any researched multifactor portrait is best perceived in the format of any standard diagram or histogram. In particular, below, in Figure 2, an example of visual interpretation of the obtained multifactor portraits of the researched subjects is presented, precisely with the help of a standard set of tools for constructing diagrams and/or histograms.

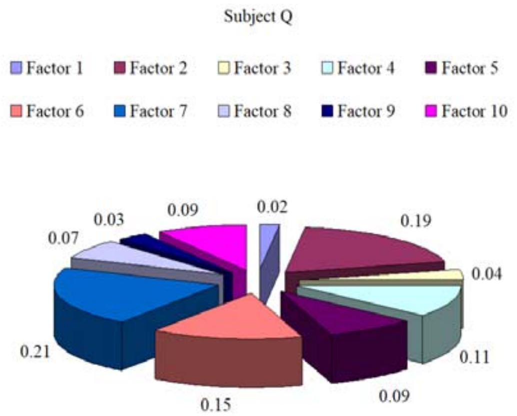
Also, as additional part of the research, carried out in this paper, the developed method has been tested on the example of resolving the specific applied practical task of automated search and selection of the candidate (from among the members of corresponding relevant support team of the supported software complex) which would be the best in resolving the stack of specialized client requests/task (related to supporting activities for this software complex).

The solution of the given applied practical task is reduced to the application of the developed method for purpose of forming appropriate multifactor portraits of the researched subjects: members of the support team of given software complex, followed by their comparison with a certain "reference" multifactor portrait of some "ideal" candidate, the most appropriate, and maximally suitable and/or adapted for solving the given stack of specialized client requests related to the support of this software complex.

Therefore, the member of the support team (of considered software complex), whose multifactor portrait is maximally comparable to the reference one – will be the most suitable candidate for delegating him the appropriate stack of specialized client requests regarding the support of this software complex.

Below, in Figure 3, appropriate personal multifactor portraits of the research subjects (of the applied practical task being solved) are presented, using the developed method, as well as the results of their comparison with the reference multifactor portrait of the "ideal" candidate, both with the selected result of this comparison and the corresponding maximal suitable candidate from among the researched subjects (which, looking ahead, appeared to be "Subject 12").

In addition, below, in Figure 4, the results of solving this applied practical problem are presented, visualized in a convenient form of representation with the help of a comparative histogram.



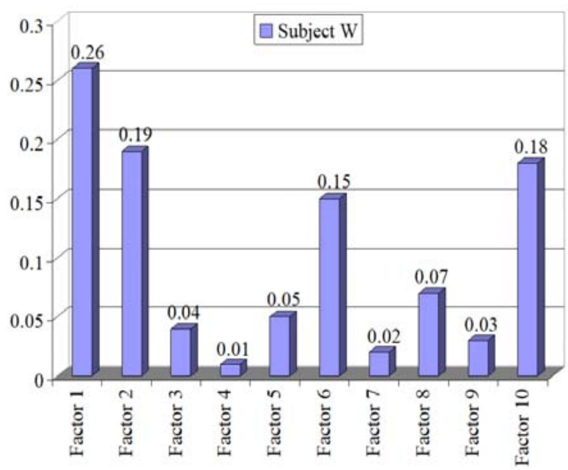


Figure 2 – Visualization examples of formed multifactor portraits of the researched subject using a standard set of tools for constructing diagrams and/or histograms

DOI 10.15588/1607-3274-2025-1-12

Portraits	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5	Factor 6	Factor 7	Factor 8	Factor 9	Factor 10	
Subject 1	**0.045**	**0.049**	**0.116**	**0.098**	**0.134**	**0.179**	**0.175**	**0.067**	**0.028**	**0.109**	
Subject 2	**0.037**	**0.092**	**0.187**	**0.121**	**0.082**	**0.076**	**0.164**	**0.045**	**0.078**	**0.118**	
Subject 3	**0.114**	**0.033**	**0.108**	**0.090**	**0.084**	**0.035**	**0.084**	**0.091**	**0.299**	**0.062**	
Subject 4	**0.126**	**0.055**	**0.095**	**0.102**	**0.087**	**0.079**	**0.117**	**0.124**	**0.107**	**0.108**	
Subject 5	**0.034**	**0.177**	**0.090**	**0.149**	**0.146**	**0.088**	**0.065**	**0.056**	**0.102**	**0.093**	
Subject 6	**0.046**	**0.113**	**0.049**	**0.096**	**0.152**	**0.076**	**0.064**	**0.123**	**0.164**	**0.117**	
Subject 7	**0.095**	**0.060**	**0.162**	**0.228**	**0.073**	**0.068**	**0.035**	**0.086**	**0.106**	**0.087**	
Subject 8	**0.084**	**0.033**	**0.143**	**0.026**	**0.045**	**0.104**	**0.301**	**0.123**	**0.104**	**0.037**	
Subject 9	**0.048**	**0.132**	**0.229**	**0.042**	**0.162**	**0.068**	**0.037**	**0.067**	**0.152**	**0.063**	
Subject 10	**0.126**	**0.172**	**0.076**	**0.036**	**0.084**	**0.140**	**0.038**	**0.152**	**0.083**	**0.093**	
Subject 11	**0.045**	**0.101**	**0.165**	**0.095**	**0.141**	**0.119**	**0.084**	**0.095**	**0.095**	**0.060**	
Subject 12	**0.087**	**0.067**	**0.099**	**0.183**	**0.122**	**0.095**	**0.068**	**0.044**	**0.128**	**0.107**	
Subject 13	**0.058**	**0.107**	**0.138**	**0.124**	**0.109**	**0.076**	**0.094**	**0.088**	**0.117**	**0.089**	
Subject 14	**0.054**	**0.065**	**0.083**	**0.071**	**0.072**	**0.097**	**0.127**	**0.208**	**0.105**	**0.118**	
Subject 15	**0.131**	**0.063**	**0.203**	**0.121**	**0.083**	**0.115**	**0.046**	**0.074**	**0.086**	**0.078**	
Reference	**0.089**	**0.058**	**0.107**	**0.202**	**0.064**	**0.092**	**0.106**	**0.049**	**0.086**	**0.147**	
ComparisonABS	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5	Factor 6	Factor 7	Factor 8	Factor 9	Factor 10	**Sum**
Subj.1 vs Refer.	**0.044**	**0.009**	**0.009**	**0.104**	**0.07**	**0.087**	**0.069**	**0.018**	**0.058**	**0.038**	**0.506**
Subj.2 vs Refer.	**0.052**	**0.034**	**0.08**	**0.081**	**0.018**	**0.016**	**0.058**	**0.004**	**0.008**	**0.029**	**0.380**
Subj.3 vs Refer.	**0.025**	**0.025**	**0.001**	**0.112**	**0.02**	**0.057**	**0.022**	**0.042**	**0.213**	**0.085**	**0.602**
Subj.4 vs Refer.	**0.037**	**0.003**	**0.012**	**0.1**	**0.023**	**0.013**	**0.011**	**0.075**	**0.021**	**0.039**	**0.334**
Subj.5 vs Refer.	**0.055**	**0.119**	**0.017**	**0.053**	**0.082**	**0.004**	**0.041**	**0.007**	**0.016**	**0.054**	**0.448**
Subj.6 vs Refer.	**0.043**	**0.055**	**0.058**	**0.106**	**0.088**	**0.016**	**0.042**	**0.074**	**0.078**	**0.03**	**0.590**
Subj.7 vs Refer.	**0.006**	**0.002**	**0.055**	**0.026**	**0.009**	**0.024**	**0.071**	**0.037**	**0.02**	**0.06**	**0.310**
Subj.8 vs Refer.	**0.005**	**0.025**	**0.036**	**0.176**	**0.019**	**0.012**	**0.195**	**0.074**	**0.018**	**0.11**	**0.670**
Subj.9 vs Refer.	**0.041**	**0.074**	**0.122**	**0.16**	**0.098**	**0.024**	**0.069**	**0.018**	**0.066**	**0.084**	**0.756**
Subj.10 vs Refer.	**0.037**	**0.114**	**0.031**	**0.166**	**0.02**	**0.048**	**0.068**	**0.103**	**0.003**	**0.054**	**0.644**
Subj.11 vs Refer.	**0.044**	**0.043**	**0.058**	**0.107**	**0.077**	**0.027**	**0.022**	**0.046**	**0.009**	**0.087**	**0.520**
Subj.12 vs Refer.	**0.002**	**0.009**	**0.008**	**0.019**	**0.058**	**0.003**	**0.038**	**0.005**	**0.042**	**0.04**	**0.224**
Subj.13 vs Refer.	**0.031**	**0.049**	**0.031**	**0.078**	**0.045**	**0.016**	**0.012**	**0.039**	**0.031**	**0.058**	**0.390**
Subj.14 vs Refer.	**0.035**	**0.007**	**0.024**	**0.131**	**0.008**	**0.005**	**0.021**	**0.159**	**0.019**	**0.029**	**0.438**
Subj.15 vs Refer.	**0.042**	**0.005**	**0.096**	**0.081**	**0.019**	**0.023**	**0.06**	**0.025**	**0**	**0.069**	**0.420**

Figure 3 – Formed personal multifactor portraits of the researched subjects, as well as the results of their comparison with the corresponding reference multifactor portrait of the ideal candidate

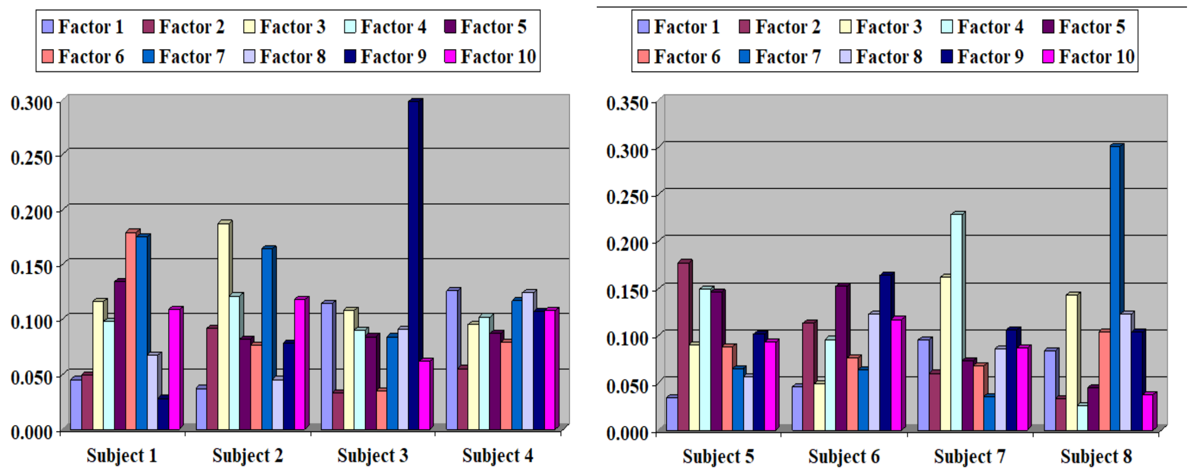


Figure 4 – The results of solving an applied practical task, obtained using the developed method, and visualized in a convenient form of representation by the usage of a comparative histogram

DOI 10.15588/1607-3274-2025-1-12

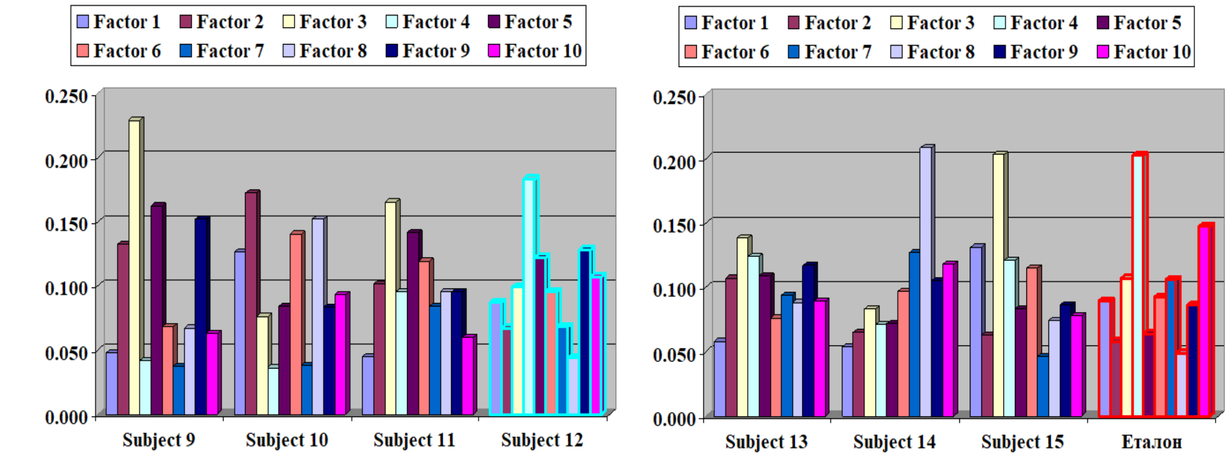


Figure 4 – The results of solving an applied practical task, obtained using the developed method, and visualized in a convenient form of representation by the usage of a comparative histogram (Continuation)

Thus, as an example of approbation and practical application of the developed method, the results of solving the applied practical task of automated search and selection of the candidate (from among the members of corresponding relevant support team of the supported software complex) which would be the best in resolving the stack of specialized client requests/task (related to supporting activities for this software complex), have been presented in this research.

In general, the obtained results testify to the suitability and effectiveness of the developed method for solving the declared scientific and applied task of identification and determination of personalized comprehensive indicators of presence each of the impact factors (from a pre-agreed and declared set of impact factors) in the processes of personal subjectivization of the researched supported object's perception by the relevant subjects interacting with it (directly or indirectly) and making influence on its support.

6 DISCUSSION

In the scope of research [16], a comprehensive study has been carried out aimed mainly at identifying and analyzing the most modern and actual methods, algorithms and sensor technologies in existing studies of the intellectual interaction of a person with a computer (e.g. more known ask a "human computer interaction" – HCI), the topic of trends in the area of this interaction, as well as potential directions for future researches in this area. In particular, it is also going about the corresponding intelligent user interfaces of the various used software products and complexes. Research in both these directions is mainly focused on intelligent recognition of emotions, gestures and facial expressions of users, involving a sensor technologies (such as camera, portable sensors / transducers, trackers, gyroscopes, etc.). At the same time, researchers and developers most often use the intellectual solutions they need – based on the methods, algorithms and sensor technologies of artificial intelligence, machine learning, artificial neural networks, including a multilayer perceptron.

At the same time, another research [17] presents an overview of research focused on a universal usability, plasticity of user interface design, and facilitating the development of an interfaces with universal usability. The basics of adaptive or intelligent user interfaces (of various software products and complexes) are presented, focused on three main areas: artificial intelligence, user modeling, and intelligent human-computer interaction. According to the results of this research, the interface of the developed and supported software product or complex should take into account the individual characteristics of users, based rather on the actual behavior of these users, then on their feedback about the supported software product. Also, the need for a more complete understanding of the human psychological model of the researched subjects (users) is emphasized, which requires a high-quality interdisciplinary approach and cooperation between different fields' researchers.

Additionally, the research [18] also investigates the interaction of subjects (users) with modern intelligent technological systems, which (interaction) goes far beyond just the concept of convenience of supported software products usage, extending to a person's emotions before, during and after using a system (e.g. software product / complex), and cannot be determined only by examining the main attributes of usability, such as the effectiveness and satisfaction of the actors (i.e. users) interacting with that system. Therefore, such research requires more intelligent and complex approaches, including artificial intelligence technologies as well as considering and taking into account the approach of a general intelligent computing environment.

Thus, the existing provided researches confirm the actuality, relevance and necessity of studying and taking into account the peculiarities of subjects interacting with developed and supported software products, complexes, or systems. At the same time, they study various options for taking into account these features of the subjects that interact (and influence accordingly) the developed and supported software products, systems and complexes. However, in none of the researched cases, the influence of

DOI 10.15588/1607-3274-2025-1-12

relevant factors, which, precisely, make impact onto these subjects themselves, is being considered and appropriately taken into account.

Meanwhile, the method of forming multifactor portraits of subjects supporting software complexes, developed and presented in current research, provides possibilities for carrying out the necessary identification and determination of personalized comprehensive indicators of presence each of the impact factors (from a pre-agreed and declared set of impact factors) in the processes of personal subjectivization of the researched supported object's (e.g. supported software product, complex, systems, as well as the processes of its support) perception by the relevant subjects interacting with it.

Thus, at the output of its functional operation, the developed method ensures obtaining a relevant suitable model(s) of the multifactor portrait(s) of the researched subject(s), which, later, makes it possible to take it into account when researching and resolving various related scientific and applied tasks of a more complex scientific and applied problem of software complexes support automation.

As a further practical application of the developed method, we can see the solution of a stack of relevant applied practical tasks, among which, for example, are such as:

– development of models of various subjects interacting with the researched and supported software complex(es);

– adjustment of personal characteristics, skills, and features of the researched subjects in order to correct their multifactor portrait(s) in the necessary vector of requirements;

– development of personal instructions for subjects in order to improve their characteristics, including, in particular, professional ones;

– research on the compatibility of various (interacting each other) subjects based on their multifactor portraits;

– and others.

Thus, taking into account a wide range of applied tasks, the expediency of further research in this direction is fully justified.

In addition, the developed method can also be used in other areas of science and practice, in particular, for example, in such fields as psychology and sociology, where the formation of various multifactor portraits is an extremely important stage in the investigation of any researched subjects.

CONCLUSIONS

The method of forming multifactor portraits of subjects supporting software complexes, using a multilayer perceptron, is developed. The main scientific and applied task, resolved by the developed method, is the task of identification and determination of personalized comprehensive indicators of presence each of the impact factors (from a pre-agreed and declared set of impact factors) in the processes of personal subjectivization of the researched supported object's (e.g. supported software complex, as well as the processes of its support) perception by the relevant subjects interacting with it (both directly or indirectly) and making influence on its support. The input data of the developed method of forming multifactor portraits of the software complex support subjects – is the relevant trained multilayer perceptron ANN, encapsulated into a corresponding model of subjective perception of the investigated support object (the supported software complex, or processes of its support). as well as a set of test cases (for each of the researched subjects interacting with the object of support) for modeling the processes of subjectivization of the supported object's perception by each separate researched subject interacting with this object.

The corresponding developed algorithm of forming a multifactor portrait(s) of researched subject(s) (interacting with the investigated supported software complex) is presented, as well as a corresponding mathematical model of multifactor portrait(s) of these subject(s) of interaction, which form the basis of the developed method. While the corresponding: mathematical model (represented in research [13]), the model of decomposed isolation dominance (represented in research [14]), as well as the appropriate information model (represented in relevant research [15]) – make up a complementary, but absolutely integral comprehensive and irreplaceable component of the developed method. So in aggregate, all these constituent elements form a complete method, which provide possibility to solve the declared scientific and applied task of this research.

The basic forms of representation of the multifactor portrait(s)' models of subjects (interacting with the supported software complexes) are presented, which includes: an appropriate developed mathematical form of representation, a visual form of representation using a standard set of tools for constructing diagrams and/or histograms; as well as the given examples of simulation results.

The developed method provides the possibility of building a relevant multifactor portraits' models of the researched subjects interacting with the investigated supported software complexes, as well as any other objects (or processes) of software products' complex support.

The scientific novelty consists in the development of a method of forming multifactor portraits of the subjects supporting program complexes, which provides possibilities for studying both, in general: the impact factors performing influence onto the investigated software complexes and their support, as well as the processes of perception's subjectivization of the investigated object of support by the relevant researched subjects who interact with the first (directly or indirectly), and affect its support.

The practical significance consists in the development of an appropriate specialized dedicated algorithm of forming a multifactor portrait(s) of the researched subject(s) interacting with the investigated supported software complex(es), as well as a corresponding mathemati-

DOI 10.15588/1607-3274-2025-1-12

cal model of the multifactor portraits of these researched subjects.

Prospects for further research consist in the development of appropriate additional specialized algorithmic and programming tools for modeling multifactor portraits of the researched subjects interacting with the investigated supported software complexes and products, as well as in the further application of the developed models in the fields of studying both the influence of impact factors as well as the relevant processes of perception's subjectivization of the investigated support object by the relevant subjects who interact with it, both in the direction of software complexes' support automation, and in other related (or possible potentially related) areas of scientific and applied research.

ACKNOWLEDGEMENTS

Work is proactive. The research was carried out as part of the scientific activity of the authors outside of working hours in their main positions.

REFERENCES

1. Rossel P., Peyrin C., Kauffmann L. Subjective perception of objects depends on the interaction between the validity of context-based expectations and signal reliability [Electronic resource], *Vision Research*, 2023, Vol. 206, article ID 108191. Mode of access: https://doi.org/10.1016/j.visres.2023.108191 (date of access: 30.09.2024). Title from screen.
2. Hynek J., Hruška T. Segmentation of Dashboard Screen Images: Preparation of Inputs for Object-based Metrics of UI Quality [Electronic resource], *In Proceedings of the 14th International Joint Conference on Computer Vision, Imaging and Computer Graphics Theory and Applications,* 2019, pp. 199–207. Mode of access: https://doi.org/10.5220/0007312301990207 (date of access: 30.09.2024). – Title from screen.
3. Hynek J., Hruška T. Application of Object-Based Metrics for Recognition of Well-Designed Dashboards [Electronic resource], *International Journal of Human-Computer Interaction,* 2018, Vol. 35, No. 13, pp. 1203–1215. Mode of access: https://doi.org/10.1080/10447318.2018.1518004 (date of access: 30.09.2024). Title from screen.
4. Clarin J. A. Priority-Based Scheduling Algorithm for Help Desk Support System [Electronic resource], *International Journal of Intelligent Systems and Applications in Engineering*, 2023, Vol. 11, No. 4, pp. 299–307. Mode of access: https://www.researchgate.net/profile/Jeffrey-Clarin/publication/374535831_International_Journal_of_INTELLIGENT_SYSTEMS_AND_APPLICATIONS_IN_ENGINEERING_Priority-Based_Scheduling_Algorithm_for_Help_Desk_Support_System/links/65226ad2fc5c2a0c3bc0afe2/International-Journal-of-INTELLIGENT-SYSTEMS-AND-APPLICATIONS-IN-ENGINEERING-Priority-Based-Scheduling-Algorithm-for-Help-Desk-Support-System.pdf (date of access: 30.09.2024). – Title from screen.
5. Fuchs S. Drieschner C., Wittges H. Improving Support Ticket Systems Using Machine Learning: A Literature Review [Electronic resource], *In Proceedings of the 55-th Hawaii International Conference on System Sciences*, 2022, pp. 1893–1902. Mode of access: https://doi.org/10.24251/HICSS.2022.238 (date of access: 30.09.2024). – Title from screen.
6. Baltic J. Structuring and Controlling the Knowledge for the Software User Support [Electronic resource], *Modern Computing,* 2021, Vol. 9, No. 2, pp. 195–209. Mode of access: https://doi.org/10.22364/bjmc.2021.9.2.04 (date of access: 30.09.2024). Title from screen.
7. Dlodlo D., Sibanda K. Automated Ticket Classification for Information Technology Helpdesks using Machine Learning [Electronic resource], *2nd Zimbabwe Conference of Information and Communication Technologies (ZCICT)*, 2023, pp. 1–7. Mode of access: https://doi.org/10.1109/ZCICT59466.2023.10528578 (date of access: 30.09.2024). Title from screen.
8. Gandla P. K. K., Verma R. K., Panigrahi C. R. et al. Ticket Classification Using Machine Learning [Electronic resource], *In Proceedings of the 7th International Conference on Advance Computing and Intelligent Engineering, Lecture Notes in Networks and Systems,* 2024, Vol. 1, pp. 487–501. Mode of access: https://doi.org/10.1007/978-981-99-5015-7_41 (date of access: 30.09.2024). Title from screen.
9. Zangari A., Marcuzzo M., Schiavinato M. et al. Ticket automation: An insight into current research with applications to multilevel classification scenarios [Electronic resource], *Expert Systems with Applications*, 2023, Volume 225, article ID 119984. Mode of access: https://doi.org/10.1016/j.eswa.2023.119984 (date of access: 30.09.2024). – Title from screen.
10. Chakraverty S., Mall S. Artificial Neural Networks for Engineers and Scientists: Solving Ordinary Differential Equations (1st ed.) [Electronic resource], CRC Press, 2017, 168 p. Mode of access: https://doi.org/10.1201/9781315155265 (date of access: 30.09.2024). Title from screen.
11. Samarasinghe S. Neural Networks for Applied Sciences and Engineering: From Fundamentals to Complex Pattern Recognition (1st ed.) [Electronic resource], *Auerbach Publications*, 2006, 570 p. Mode of access: https://doi.org/10.1201/9780849333750 (date of access: 30.09.2024). Title from screen.
12. Vang-Mata R. Multilayer Perceptrons: Theory and Applications [Electronic resource]. Hauppauge, New York, Nova Science Publishers, 2020, 153 p. Mode of access: https://novapublishers.com/shop/multilayer-perceptrons-theory-and-applications/ (date of access: 30.09.2024). Title from screen.
13. Pukach A. I., Teslyuk V. M. Mathematical model for analysis of influencing factors on software complexes support [Electronic resource], *Printing and Publishing,* 2024, 1(87), pp. 75–85. Mode of access: https://doi.org/10.32403/0554-4866-2024-1-87-75-85 (date of access: 01.10.2024). Title from screen.
14. Pukach A. I., Teslyuk V. M. Model of decomposed insulating dominance for the analysis of influencing factors of software complexes support automation [Electronic resource], *Scientific Bulletin of UNFU,* 2024, 34(5). pp. 170–179. Mode of access: https://doi.org/10.36930/40340521 (date of access: 01.10.2024). Title from screen.
15. Pukach A. I., Teslyuk V. M. Information model for automation of software complexes support influencing factors analysis with usage of the R-system and Python environments [Electronic resource], *Bulletin of Lviv State University of Life Safety*, 2024, 29, pp. 54–64. Mode of access: https://doi.org/10.32447/20784643.29.2024.06 (date of access: 01.10.2024). Title from screen.

DOI 10.15588/1607-3274-2025-1-12

16. Šumak B., Brdnik S., Pušnik M. Sensors and Artificial Intelligence Methods and Algorithms for Human-Computer Intelligent Interaction: A Systematic Mapping Study [Electronic resource], *Sensors*, 2022, 22(1), 20, 40 p. Mode of access: https://doi.org/10.3390/s22010020 (date of access: 01.10.2024). Title from screen.
17. Miraz M. H., Ali M., Excell P. S. Adaptive user interfaces and universal usability through plasticity of User Interface Design [Electronic resource], *Computer Science Review*, 2021, Vol. 40, article ID 100363. Mode of access: https://doi.org/10.1016/j.cosrev.2021.100363 (date of access: 01.10.2024). Title from screen.
18. Ntoa S., Margetis G., Antona M. et al. User Experience Evaluation in Intelligent Environments: A Comprehensive Framework [Electronic resource], Technologies, 2021, 9(2), 41, 36 p. Mode of access: https://doi.org/10.3390/technologies9020041 (date of access: 01.10.2024). – Title from screen.

Received 22.10.2024.
Accepted 14.12.2024.

УДК 004.8

МЕТОД ФОРМУВАННЯ МУЛЬТИФАКТОРНИХ ПОРТРЕТІВ СУБ'ЄКТІВ ПІДТРИМКИ ПРОГРАМНИХ КОМПЛЕКСІВ, З ВИКОРИСТАННЯМ БАГАТОШАРОВОГО ПЕРЦЕПТРОНА

Пукач А. І. – канд. техн. наук, асистент кафедри Автоматизованих Систем Управління Інституту Комп'ютерних Наук та Інформаційних Технологій Національного Університету «Львівська Політехніка», Львів, Україна.

Теслюк В. М. – д-р техн. наук, проф., завідувач кафедри Автоматизованих Систем Управління Інституту Комп'ютерних Наук та Інформаційних Технологій Національного Університету «Львівська Політехніка», Львів, Україна.

АНОТАЦІЯ

Актуальність. Розглянуто проблему ідентифікації та визначення персоніфікованих комплексних показників наявності кожного з факторів впливу в процесах особистісної суб'єктивізації сприйняття досліджуваного об'єкта підтримки відповідними суб'єктами, які з ним взаємодіють і впливають на його підтримку. Об'єктом дослідження є процес формування мультифакторних портретів суб'єктів підтримки програмних комплексів, з використанням багатошарового перцептрона. Предметом дослідження є методи та засоби формування мультифакторних портретів суб'єктів підтримки програмних комплексів.

Мета роботи – розроблення методу формування мультифакторних портретів суб'єктів підтримки програмних комплексів, з використанням багатошарового перцептрона.

Метод. Розроблено метод формування мультифакторних портретів суб'єктів підтримки програмних комплексів, з використанням штучних нейронних мереж типу багатошарового перцептрона, що дає змогу формувати відповідні персональні мультифакторні портрети суб'єктів, котрі, напряму або опосередковано, взаємодіють з об'єктом підтримки, в якості якого може виступати як сам підтримуваний програмний комплекс, так і процеси, пов'язані з його комплексною підтримкою.

Результати. Результатами роботи розробленого методу є відповідні моделі мультифакторних портретів суб'єктів підтримки програмних комплексів, які, в подальшому, використано для розв'язання кластеру науково-прикладних задач автоматизації підтримки програмних комплексів, зокрема, задачу ідентифікації та визначення персоналізованих комплексних показників присутності кожного із факторів впливу (наперед узгодженої та задекларованої множини факторів впливу) в процесах персональної суб'єктивізації сприйняття досліджуваного об'єкта підтримки відповідними суб'єктами, котрі взаємодіють з першим (напряму або опосередковано), та впливають на його підтримку. В якості прикладу практичного застосування розробленого методу, наведено результати розв'язання прикладної практичної задачі автоматизованого пошуку та підбору кандидата (з числа членів команди підтримки програного комплексу) для розв'язання стеку спеціалізованих клієнтських запитів (щодо підтримки цього програмного комплексу).

Висновки. Розроблений метод вирішує поставлену задачу ідентифікації та визначення персоналізованих комплексних показників присутності кожного із факторів впливу (наперед узгодженої та задекларованої множини факторів впливу) в процесах персональної суб'єктивізації сприйняття досліджуваного об'єкта підтримки відповідними суб'єктами, котрі взаємодіють з першим (напряму або опосередковано), та впливають на його підтримку. В доповнення, розроблений метод забезпечує можливість побудови відповідних моделей мультифакторних портретів суб'єктів підтримки програмних комплексів, що дає змогу використовувати їх при розв'язанні будь-яких задач, пов'язаних з автоматизацією пошуку та підбору суб'єктів підтримки програмних комплексів, що відповідають заданим критеріям як в контексті процесів суб'єктивізації персонального сприйняття об'єктів підтримки (підтримуваних програмних комплексів, чи процесів їх підтримки), так і в контексті сумісності у взаємодії з клієнтами та/або користувачами підтримуваних програмних продуктів (оскільки ці користувачі, фактично, теж являються суб'єктами взаємодії з тим же досліджуваним об'єктом підтримки).

КЛЮЧОВІ СЛОВА: автоматизація, програмний комплекс, підтримка, фактор впливу, мультифакторних портрет, нейронні мережі, багатошаровий перцептрон.

ЛІТЕРАТУРА

1. Rossel P. Subjective perception of objects depends on the interaction between the validity of context-based expectations and signal reliability [Electronic resource] / P. Rossel, C. Peyrin, L. Kauffmann // Vision Research. – 2023. – Vol. 206. – article ID 108191. – Mode of access: https://doi.org/10.1016/j.visres.2023.108191 (date of access: 30.09.2024). – Title from screen.
2. Hynek J. Segmentation of Dashboard Screen Images: Preparation of Inputs for Object-based Metrics of UI Quality [Electronic resource] / J. Hynek, T. Hruška // In Proceedings of the 14th International Joint Conference on Computer Vision, Imaging and Computer Graphics Theory and Applications. – 2019. – P. 199–207. – Mode of access: https://doi.org/10.5220/0007312301990207 (date of access: 30.09.2024). – Title from screen.

DOI 10.15588/1607-3274-2025-1-12

3. Hynek J. Application of Object-Based Metrics for Recognition of Well-Designed Dashboards [Electronic resource] / J. Hynek, T. Hruška // International Journal of Human–Computer Interaction. – 2018. – Vol. 35, No. 13. – P. 1203–1215. – Mode of access: https://doi.org/10.1080/10447318.2018.1518004 (date of access: 30.09.2024). – Title from screen.
4. Clarin J. A. Priority-Based Scheduling Algorithm for Help Desk Support System [Electronic resource] / J. A. Clarin // International Journal of Intelligent Systems and Applications in Engineering. – 2023. – Vol. 11, No. 4. – P. 299–307. – Mode of access: https://www.researchgate.net/profile/Jeffrey-Clarin/publication/374535831_International_Journal_of_INTELLIGENT_SYSTEMS_AND_APPLICATIONS_IN_ENGINEERING_Priority-Based_Scheduling_Algorithm_for_Help_Desk_Support_System/links/65226ad2fc5c2a0c3bc0afe2/International-Journal-of-INTELLIGENT-SYSTEMS-AND-APPLICATIONS-IN-ENGINEERING-Priority-Based-Scheduling-Algorithm-for-Help-Desk-Support-System.pdf (date of access: 30.09.2024). – Title from screen.
5. Fuchs S. Improving Support Ticket Systems Using Machine Learning: A Literature Review [Electronic resource] / S. Fuchs, C. Drieschner, H. Wittges // In Proceedings of the 55-th Hawaii International Conference on System Sciences. – 2022. – P. 1893–1902. – Mode of access: https://doi.org/10.24251/HICSS.2022.238 (date of access: 30.09.2024). – Title from screen.
6. Baltic J. Structuring and Controlling the Knowledge for the Software User Support [Electronic resource] / J. Baltic // Modern Computing. – 2021. – Vol. 9, No. 2. – P. 195–209. – Mode of access: https://doi.org/10.22364/bjmc.2021.9.2.04 (date of access: 30.09.2024). – Title from screen.
7. Dlodlo D. Automated Ticket Classification for Information Technology Helpdesks using Machine Learning [Electronic resource] / D. Dlodlo, K. Sibanda // 2nd Zimbabwe Conference of Information and Communication Technologies (ZCICT). – 2023. – P. 1–7. – Mode of access: https://doi.org/10.1109/ZCICT59466.2023.10528578 (date of access: 30.09.2024). – Title from screen.
8. Ticket Classification Using Machine Learning [Electronic resource] / [P. K. K. Gandla, R. K. Verma, C. R. Panigrahi et al.] // In Proceedings of the 7th International Conference on Advance Computing and Intelligent Engineering, Lecture Notes in Networks and Systems. – 2024. – Vol. 1. – P. 487–501. – Mode of access: https://doi.org/10.1007/978-981-99-5015-7_41 (date of access: 30.09.2024). – Title from screen.
9. Ticket automation: An insight into current research with applications to multilevel classification scenarios [Electronic resource] / [A. Zangari, M. Marcuzzo, M. Schiavinato et al.] // Expert Systems with Applications. – 2023. – Volume 225. – article ID 119984. – Mode of access: https://doi.org/10.1016/j.eswa.2023.119984 (date of access: 30.09.2024). – Title from screen.
10. Chakraverty S. Artificial Neural Networks for Engineers and Scientists: Solving Ordinary Differential Equations (1st ed.) [Electronic resource] / S. Chakraverty, S. Mall. – CRC Press, 2017. – 168 p. – Mode of access: https://doi.org/10.1201/9781315155265 (date of access: 30.09.2024). – Title from screen.
11. Samarasinghe S. Neural Networks for Applied Sciences and Engineering: From Fundamentals to Complex Pattern Recognition (1st ed.) [Electronic resource] / S. Samarasinghe. – Auerbach Publications, 2006. – 570 p. – Mode of access: https://doi.org/10.1201/9780849333750 (date of access: 30.09.2024). – Title from screen.
12. Vang-Mata R. Multilayer Perceptrons: Theory and Applications [Electronic resource] / R. Vang-Mata Hauppauge. – New York : Nova Science Publishers, 2020 p. – 153 p. – Mode of access: https://novapublishers.com/shop/multilayer-perceptrons-theory-and-applications/ (date of access: 30.09.2024). – Title from screen.
13. Пукач А.І. Математична модель аналізу факторів впливу підтримки програмних комплексів [Електронний ресурс] / А. І. Пукач, В. М. Теслюк // Поліграфія і видавнича справа. – 2024. – 1(87). – С. 75–85. – Режим доступу: https://doi.org/10.32403/0554-4866-2024-1-87-75-85 (дата звернення: 01.10.2024). – Назва з екрана.
14. Пукач А. І. Модель декомпонованої ізоляційної домінації для аналізу чинників впливу на автоматизацію підтримки програмних комплексів [Електронний ресурс] / А. І. Пукач, В. М. Теслюк // Науковий вісник НЛТУ України. – 2024. – 34(5). – С. 170–179. – Режим доступу: https://doi.org/10.36930/40340521 (дата звернення: 01.10.2024). – Назва з екрана.
15. Пукач А. І. Інформаційна модель аналізу факторів впливу автоматизації підтримки програмних комплексів з використанням середовищ R та Python [Електронний ресурс] / А. І. Пукач, В. М. Теслюк // Вісник Львівського державного університету безпеки життєдіяльності. – 2024. – 29. – С. 54–64. – Режим доступу: https://doi.org/10.32447/20784643.29.2024.06 (дата звернення: 01.10.2024). – Назва з екрана.
16. Šumak B. Sensors and Artificial Intelligence Methods and Algorithms for Human–Computer Intelligent Interaction: A Systematic Mapping Study [Electronic resource] / B. Šumak, S. Brdnik, M. Pušnik // Sensors. – 2022. – 22(1), 20. – 40 p. – Mode of access: https://doi.org/10.3390/s22010020 (date of access: 01.10.2024). – Title from screen.
17. Miraz M. H. Adaptive user interfaces and universal usability through plasticity of User Interface Design [Electronic resource] / M. H. Miraz, M. Ali, P. S. Excell // Computer Science Review. – 2021. – Vol. 40. – article ID 100363. – Mode of access: https://doi.org/10.1016/j.cosrev.2021.100363 (date of access: 01.10.2024). – Title from screen.
18. User Experience Evaluation in Intelligent Environments: A Comprehensive Framework [Electronic resource] / [S. Ntoa, G. Margetis, M. Antona et al.] // Technologies. – 2021. – 9(2), 41. – 36 p. – Mode of access: https://doi.org/10.3390/technologies9020041 (date of access: 01.10.2024). – Title from screen.

DOI 10.15588/1607-3274-2025-1-12