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THE “PRISM AND RAYS METHOD” FOR RESEARCHING SUBJECTIVIZATION OF PERCEPTION OF HUMAN-MACHINE INTERACTION OBJECTS

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ABSTRACT

Context. The task of representation formalizing as well as possibility of further research of the scientific and applied problem of perception subjectivization of the human-machine interaction objects by relevant interaction subjects, in the context of global problems of automation and intellectualization of the component processes and environments of human-machine interaction, is considered, investigated, and resolved in scope of current research. **The object of research** are processes of perception subjectivization of the human-machine interaction objects by relevant subjects of same interaction. **The subject of research** are methods and means of mathematical, computer, and simulation modeling. **Objective** – development of a method for researching the perception subjectivization of the human-machine interaction objects by relevant subjects of the same interaction.

Method. The development of the “prism and rays method” (author’s name of the method) is proposed and performed, which provides the possibility to resolve the scientific and applied problem of representation formalizing as well as possibility of further research into the processes of perception subjectivization of the human-machine interaction objects by relevant interaction subjects (of the same interaction).

Results. The results of the developed method – are corresponding models that represent and allow to investigate the researched processes of perception subjectivization of the human-machine interaction objects by relevant interaction subjects (of the same interaction). The developed method provides the possibility of both formalization as well as further interpretation and investigation of the researched processes of perception subjectivization of human-machine interaction objects. As a practical approbation, the developed method has been applied for synthesis of the basic model of perception subjectivization of the object of complex (comprehensive) support (one of the most highlighted examples of HMI/HCI) of software product(s), using the example case of an experimental task of estimating the approximate processing time of client request by the department of customer-and-technical support of the given software product.

Conclusions. The developed “prisms and rays method” solves the declared task of representation formalizing as well as possibility of further research of the scientific and applied problem of perception subjectivization of the human-machine interaction objects by relevant interaction subjects, in the context of global problems of automation and intellectualization of the component processes and environments of human-machine interaction. At the same time, the obtained results of experimental practical approbation of the developed method confirm its effectiveness and efficiency in the context of solving relevant practical applied tasks of the scientific and applied problem of human-machine interaction objects’ perception subjectivization.

KEYWORDS: human-machine interaction, object of interaction, perception subjectivization, impact factors, automation, intellectualization.

ABBREVIATIONS

AAR is an After Action Review;
AI is an Artificial Intelligence;
ApHT is an Approximate Handle Time;
ANN is an Artificial Neural Networks;
EI is an Emotional Intelligence;
HCI is a Human-Computer Interaction;
HMI is a Human-Machine Interaction;
ML is a Machine Learning;
MP is a Multilayer Perceptron;
PRM is a “Prisms and Rays Method”.

NOMENCLATURE

$Chr_{[i]}$ is an i-th (original) characteristic of the researched object;

$Chr_{[i]}^{[j-1]}$ is an i-th characteristic of the object at the entrance (j–1)-th prism of perception;

$Chr_{[i]}^{[j]}$ is an i-th characteristic of the object at the entrance j-th prism of perception;

$Chr_{[io]}^{[1]}$ is an io-th original characteristic of the researched object at entrance of the 1-st perception prism;

$Chr_{[noc]}^{[1]}$ is a noc-th original characteristic of the object at the entrance of the 1-st perception prism;

$Fpr_{[1]}()$ is a transformation function of the 1-st perception prism of the existing prism system;

$Fpr_{[j]}()$ is a transformation function of the j-th prism of perception;

$Fpr_{[npr]}()$ is a transformation function of the npr-th (the last one, in case there are npr prisms in current prism system configuration) perception prism of the existing prism system;

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$Fpr_{[j]}.RAc()$ is a subfunction of the j-th prism's transformation function, which returns the refraction angle value of current prism depending on the value of the argument (current characteristic of the researched object);

$Fpr_{[j]}.BWc()$ is a subfunction of the j-th prism's transformation function, which returns the bandwidth value of current prism depending on the value of the argument (current characteristic of the researched object);

$McPfCsDp()$ is a complex subjectivization function (of the human-machine interaction object);

$Obj\lfloor Chr_{[1]...[noc]}\rfloor$ is a set of objective (true, original) characteristics of the researched human-machine interaction object, where *noc* – count of these characteristics;

$SbP_{[i]}$ is an i-th (subjective) characteristic of the perception (subjective) of the researched object;

$SbP_{[is]}$ is an *is*-th subjective characteristic of the perception of researched object (which corresponds to the *io*-th original characteristic of the same researched object);

$Subj\lfloor SbP_{[1]...[nss]}\rfloor$ is a set of subjective (relative, modified) characteristics of the researched human-machine interaction object, where *nss* – count of these characteristics.

INTRODUCTION

One of the relevant areas of research nowadays is HMI/HCI, which is a complex concept that combines an extremely large variety of derivative problems, areas, and tasks. With the active introduction of AI and ML technologies, some of the problems of HMI/HCI have gained new opportunities in terms of conceptual approaches, methods, and means of research and resolution. Despite that, there are still a fairly significant number of relevant scientific and applied issues in this area which require both developing new and revision of existing methods and means for solving them. One of such actual issues is the task of representation formalizing (with the possibility of further research) of the scientific and applied problem of perception subjectivization of the HMI/HCI objects by relevant interaction subjects, in the context of global problems of automation and intellectualization of the component processes and environments of HMI/HCI. Since perception subjectivization problematic is extremely important, as it allows to understand the reasons of (both existing and potential) "incompatibilities" of the subjects – participants of the HMI/HCI, as well as, in general, subjects of any other intersubjective interactions, including the "human-human" class as well.

The object of research are processes of perception subjectivization of the human-machine interaction objects by relevant subjects of same interaction. **The subject of research** are methods and means of mathematical, computer, and simulation modeling.

The objective of the research consists in the development of a method for studying the processes of human-machine interaction objects' perception subjectivization by the relevant interaction subjects, which will provide the possibility of solving the declared task of representation formalizing (as well as possibility of further research) of the scientific and applied problem of perception subjectivization of the human-machine interaction objects by relevant interaction subjects, in the context of global problems of automation and intellectualization of the component processes and environments of HMI/HCI.

1 PROBLEM STATEMENT

Let's consider the formalization of the problem of human-machine interaction object(s)' perception subjectivization in the form of a problem of multi-criteria multifunctional cascade dependence. In such case, the input variables of the problem are set of objective (true, original) characteristics of the researched human-machine interaction object: $Obj\lfloor Chr_{[1]}, Chr_{[2]}, ..., Chr_{[noc]}\rfloor$.

While the output (i.e., resulting) variables of the problem are set of subjective (relative, modified) characteristics of the same researched object, but already within the framework of its perception by the subject(s), in the context of their existing human-machine (and/or computer, as well as, in general – any other intersubjective) interaction: $Subj\lfloor SbP_{[1]}, SbP_{[2]}, ..., SbP_{[nss]}\rfloor$.

Let's consider a set of multi-criteria multifunctional cascade dependencies (given by some complex subjectivization function, named as *McPfCsDp*(), representing the processes of perception subjectivization of the researched object (of interaction) by the relevant subjects (of same interaction):

$$Subj\lfloor SbP_{[1]..[nss]}\rfloor = McPfCsDp(Obj\lfloor Chr_{[1]..[noc]}\rfloor). \quad (1)$$

The main necessary criterion of the problem is the finiteness of corresponding sets of both objective and subjective characteristics (of the researched object), as well as the previously agreed and defined dimension of the multi-criteria multifunctional cascade dependence existing between these sets.

Problem limitations:

1. The complex subjectivization function *McPfCsDp*() should provide the "many-to-many" relation type/scheme between the sets of both objective and subjective characteristics (of the researched object), because only such relation type/scheme corresponds to the proposed methodology for HMI/HCI objects' perception subjectivization within the framework of current research (while the "one-to-one" or "one-to-many" relation types/schemas doesn't correspond the declared principles of the proposed methodology).

Expression (1) provides the possibility of representation formalizing of perception subjectivization of the researched object(s) (of HMI/HCI, as well as any intersubjective interaction in general).

However, such format provides an exclusively basic generalized representation. Thus, there arise a need for

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further, more deeper disclosure of the subjectivization function itself, which would provide the possibility of not only pure formalization, but also further research into the complex processes of the perception subjectivization of any object(s) in the context of both HMI/HCI, as well as any intersubjective interaction in general as the most universalized approach.

The purpose of the research is to highlight the developed "prisms and rays method" (which is author's name of the method) for studying the processes of HMI/HCI objects' perception subjectivization, intended to solve the declared task of representation formalizing as well as possibility of further research of the scientific and applied problem of perception subjectivization of the human-machine interaction objects by relevant interaction subjects, in the context of global problems of automation and intellectualization of the component processes and environments of HMI/HCI.

2 REVIEW OF THE LITERATURE

HMI/HCI contains an extremely wide variety of different existing aspects and problems. For example, a recent study [1] presented a sociolinguistic model of HMI which provides opportunity for studying interaction of technological capabilities, user cognitive awareness, and language strategies, and is based on these three continua: technological capabilities, user cognitive awareness, and language strategies. At the same time, the author of another recent study [2] analyzed the evolution of HCI in the era of AI, examining the path of AI in the context of this interaction from competitor to partner, emphasizing the importance of preserving a human will in this partnership between men and machines.

While, research [3] considers some aspects of modern achievements in HMI, AI, and robotics. Meanwhile, authors of another research [4] conducted a comprehensive study in the context of the issues of building relationships in HMI, namely, in the direction of confirming the concept of the influence of self-disclosure on mutual understanding in coaching chatbots using psychophysiological measurements. In another research [5], the author conducted an ethnographic study which confirms the obvious shortcomings in emotional interaction and social feedback in the context of HMI, and therefore: the ability of machines to understand emotions and cope/manage with complex scenarios still requires further development, improvement, and refinement.

The author of the work [6] studied the physiological and psychological characteristics and limitations of humans in human-machine systems, as well as the rules of human-human and human-machine interaction, applying the results of fundamental research to the development of human-machine systems in order to obtain safe, convenient, and effective human-machine systems.

The team of authors of the work [7] investigates the issue of probabilistic human-machine cooperation in the context of product personalization, proposing a user interaction paradigm for recommendation and configuration systems based on appropriate Pass Bayesian Reasoning and Suitability Probability Tables approaches. In work [8], the author explores the interaction between humans and AI using AI-artifacts that can understand the relevant properties of their users (e.g., states, skills, needs) and accordingly personalize the interaction in a way that preserves transparency, user control, and trust.

The authors of research [9] conducted a comprehensive review of the current state of the issue of EI, which includes a review of main methods for measuring EI, as well as the problems, which EI faces with.

At the same time, authors of research [10] substantiated the need to improve adaptation mechanisms in human-machine systems, including: by using a functional networks to solve ergonomic design problems, as well as by combining functional and neural networks, which, in aggregate, provides the properties of adaptive human-machine interaction.

So, as it can be seen from the conducted review of existing researches, the issue of HMI/HCI is extremely relevant and actual nowadays, and covers a whole range of various aspects, tasks, issues and problems, most of which have already been sufficiently well-disclosed and researched, in particular, for example, the issue of HMI / HCI personalization.

However, in the context of HMI/HCI object(s)' perception subjectivization, there is still a significant gap among the conducted researches. In turn, this leads to the emergence of a relevant task of representation formalizing as well as possibility of further research of the scientific and applied problem of perception subjectivization of the human-machine interaction objects by relevant interaction subjects, in the context of global problems of automation and intellectualization of the component processes and environments of HMI/HCI.

3 MATERIALS AND METHODS

The main concept of the proposed "prisms and rays method" (for researching the HMI/HCI objects' perception subjectivization) is to represent the complex subjectivization function as a set of prisms (which, in turn, are representing the existing defined impact factors, influencing the perception subjectivization of the object – by relevant subjects of interaction with this object), which appropriately modify the rays (which emanate from an imaginary "light source" and pass through the object, representing its characteristics), refracting those rays (due to prisms' refraction angle) and changing their intensity (due to prisms' bandwidth), and forming at the output of the prism system spectral characteristics that corresponds to the subjectivized perception of the researched object – by each relevant subject (who acts as an "observer" of the researched object).

Thus, the complex spectral characteristic of the object of observation, passing through the perception prisms' system, is changed (modified, or "subjectivized") accordingly by this system, receiving at the output new values (of this complex spectral characteristic) that reflect the subjectivized perception of the object of observation – by the appropriate relevant subject (observer).

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At the same time, each spectral component of the incoming "beam" of rays (at the exit of observation object) necessarily and mandatory (without exception) passes through each of the perception prisms.

As for the perception prisms themselves, they have two basic characteristics/properties, such as:

1. The bandwidth of the perception prism, which is responsible for the loss/gain coefficient of the intensity of each individual (depending on its current spectrum) spectral component (entering the prism), as a result of which, at the output of this prism this spectral component receives a new intensity value;

2. The angle of refraction, which is responsible for changing the value of the spectrum of the input spectral characteristic itself, as a result of which, at the output of this prism – this spectral characteristic receives a new spectral value, which, in turn, directly affects its further processing by the next prism of the existing cascade of perception prisms.

Thus, each individual spectral component of the incoming "beam" of rays (representing the original "objective" characteristics of the object) passes through each of the prisms of perception, enters the input of each separate prism with the input values of its current spectrum and intensity, and exits the same prism with completely new values of its updated spectrum and intensity, with which it, in turn, enters the input of the next prism of perception, and so on, until it exits the last prism (of the entire existing system of perception prisms), representing the corresponding subjective perception (subjective interpretation) of these individual specific original characteristics of the object, turning them from "objective" to "subjective".

Accordingly, the resulting subjective perception of the object is represented by a set of subjective characteristics, the dominant one of which (i.e. the one whose output ray's intensity is maximal among all other rays of the remaining resulting subjective characteristics' "beam") actually represents this resulting subjective perception of the object. So, the more rays from the perception prism system fall into a specific output subjective characteristic, and the greater is the intensity of these rays at the output of the prism system, – the greater will be, accordingly, the share of this specific characteristic in the resulting subjective perception of the researched object. In turn, this feature provides the possibility of using the proposed "prisms and rays method" for solving the classification problem(s) as well.

Figure 1 below represents a graphical interpretation of corresponding simulation model of the proposed "prism and rays method".

It is important to note that the number of input characteristics of the researched object does not necessarily have to coincide with the number of output characteristics of the subjective perception of the same object, because the whole essence of subjective perception is that any subjective perception of an object is not, directly, this object itself. At the same time, the existing spectral components of the researched object(s)' characteristics can either merge with each other or be divided into subcomponents due to the dispersion property (if such possibility is provided by the existing prism system, specific prisms of this system, as well as clear conditions for such a scenario).

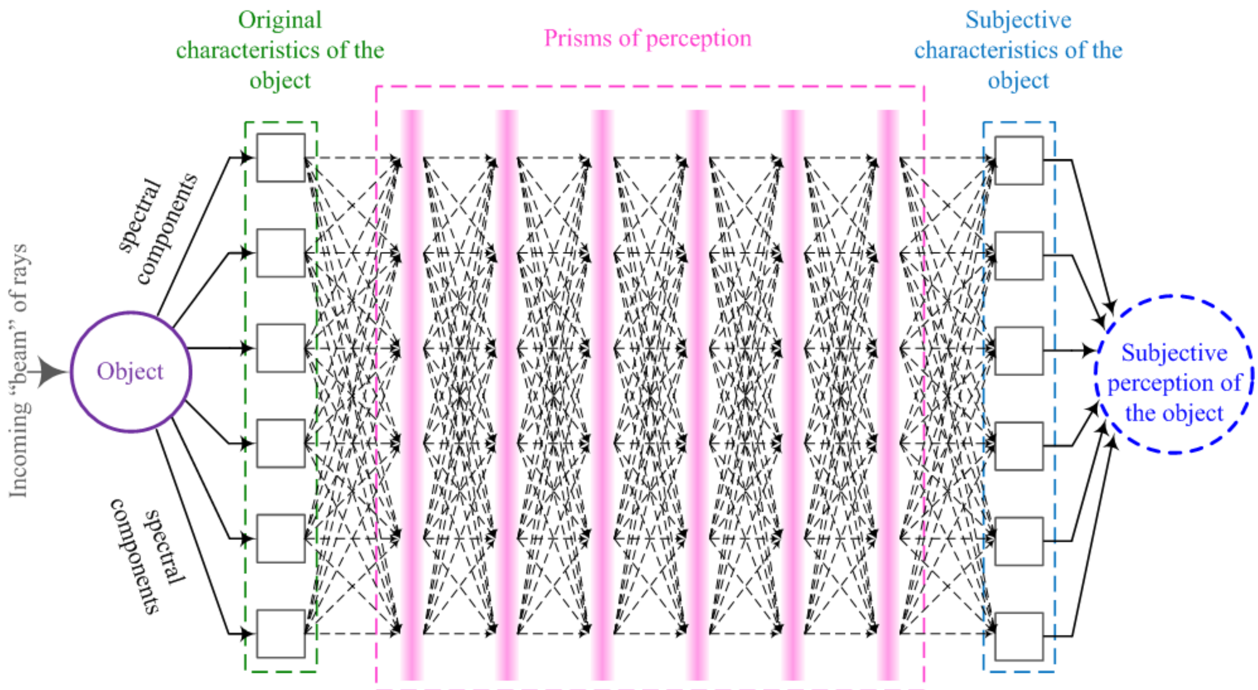

Figure 1 – Graphical interpretation of the simulation model of proposed "prism and rays method"

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However, it should also be noted that the practical implementation of such a scenario requires additional refinement (improvement) precisely in the context of the most detailed coordination of all possible scenarios and conditions of both the merging of characteristics as well as their dispersion. That is why, within the framework of current research, the "classical" option is considered, according to which the number of output characteristics of the object's perception is equal to the number of input characteristics of the same object. So, in this "classical" version/variant, each output characteristic of the object's perception could represent, in essence, a subjective perception of a certain input original characteristic of the same object. While the whole subjective perception of the object itself is, actually, a set of subjective perceptions of each of its original (objective) characteristics.

Thus, according to the developed simulation model of the proposed "prism and rays method", the system of perception prisms, in fact, plays the role of the complex perception function.

The main feature of the developed simulation model, as well as PRM in general, is the possibility of combining separate prisms in a prism system (in accordance with various scenarios, situations, or conditions), as well as the possibility of forming and preparing certain "templates" of sets (or systems) of prisms that correspond to some "classic" (known or frequently repeated) scenarios, situations, or conditions.

The general strategy for positioning: both the input original characteristics of the research object and the prisms of perception in the prism system, as well as the impact factors within the corresponding prisms, consists in the sequential placement of each of these elements according to their decreasing priority within their groups, that is: from the highest priority at the initial position of the corresponding group – to the lowest priority at the final position of the same group. While the priorities themselves, in turn, may depend on the specific objectives of researching the investigated processes of subjectivization. At the same time, activation of each individual impact factor from the pre-defined set of declared impact factors within their prisms of perception is carried out in accordance with a specific scenario(s) or so-called situational case(s).

Therefore, the next stage of implementation of the proposed PRM is the development of an appropriate basic mathematical model of perception subjectivization of the HMI/HCI object(s).

Expression (2) represents the moment of passage of a separate component characteristic's ray (of the researched object) through one separate specific prism of perception:

$$Chr_{[i]}^{[j]} = Fpr_{[j]}\left(Chr_{[i]}^{[j-1]}\right). \quad (2)$$

At the same time, each individual transformation function works on the basis of the principle laid down by the above-mentioned structural and functional feature of the corresponding prism of perception itself, relevant to this transformation function.

This feature is common for absolutely all prisms of perception, and lies in the basic properties of the prisms: the bandwidth and the refraction angle.

Thus, the operation principle of absolutely all transformation functions, which detail the function(s) itself, can be described by expression (3) below:

$$Fpr_{[j]}\left(Chr_{[i]}^{[j-1]}\right) = \begin{cases} Fpr_{[j]}.BWc\left(Chr_{[i]}^{[j-1]}\right) \times Chr_{[i]}^{[j-1]}; \\ Fpr_{[j]}.RAc\left(Chr_{[i]}^{[j-1]}\right) \times Chr_{[i]}^{[j-1]}. \end{cases} \quad (3)$$

In the context of expression (3), it is important to note that the basic properties of prisms (namely: the bandwidth and the refraction angle) act precisely as functions, the arguments of which are the input characteristic(s) of the researched perception object. Thus, both coefficients (the bandwidths and the prism refraction angle) are not static constants, but the dynamic ones, which provide greater flexibility and adaptability of the proposed solution and PRM-method in general.

Accordingly, any (arbitrary) resulting subjective characteristic at the output of the model, which represents a component characteristic of the corresponding subjective perception of the researched object, is, in essence, the result of performing a cascade of transformation functions applied sequentially (by each of the perception prisms) in relation to a certain input (separately taken) original characteristic of this object.

Therefore, expression (4) below reflects the described regularity pattern:

$$SbP_{[is]} = Fpr_{[npr]}\left(Fpr_{[npr-1]}\left(\ldots\left(Fpr_{[1]}\left(Chr_{[io]}^{[1]}\right)\right)\right)\right), \quad (4)$$

where: npr – number of perception prisms of the existing prism system.

Thus, the possibility of declaring a complex subjectivization function of the researched HMI/HCI object(s), represented by expression (5) below, is provided:

$$McPfCsDp = \begin{cases} Fpr_{[npr]}\left(\ldots\left(\ldots\left(Fpr_{[1]}\left(Chr_{[1]}^{[1]}\right)\right)\right)\right); \\ Fpr_{[npr]}\left(\ldots\left(\ldots\left(Fpr_{[1]}\left(Chr_{[2]}^{[1]}\right)\right)\right)\right); \\ \vdots \\ Fpr_{[npr]}\left(\ldots\left(\ldots\left(Fpr_{[1]}\left(Chr_{[noc]}^{[1]}\right)\right)\right)\right), \end{cases} \quad (5)$$

where noc – the number of objective (true, original) characteristics of the researched HMI/HCI object.

A key feature of the developed basic mathematical model is its complete correspondence to the relevant form of declared multi-criteria multifunctional cascade dependence.

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The final stage of implementation of the declared "prism and rays method" is the development of an appropriate algorithm of perception of HMI/HCI objects' perception subjectivization, which fully corresponds to the previously developed simulation model, as well as the relevant basic mathematical model.

Figure 2 below represents a flowchart of the developed algorithm of HMI/HCI objects' perception subjectivization in the context of declared PRM.

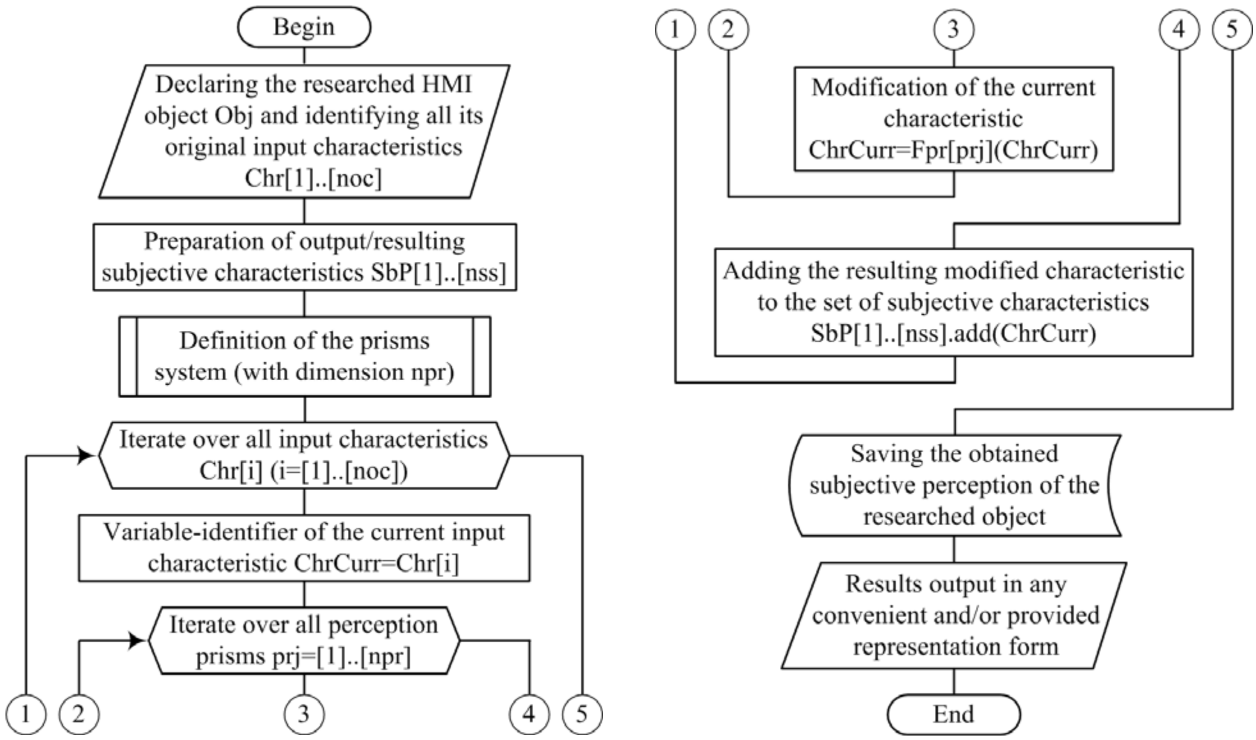

Figure 2 – Flowchart of the developed algorithm of HMI/HCI objects' perception subjectivization in the context of declared PRM

Thus, the implementation process of the declared PRM (for researching the perception subjectivization of the objects of HMI) has been completely finalized.

In addition, it should be emphasized that the prisms of perception are constructively synthesized from the relevant impact factors, which, in an appropriate way(s), affect the perception subjectivization of any investigated object(s) – by the existing relevant subject(s) of interaction with this object(s).

In turn, such a constructive feature of the fundamental-conceptual structure of the prisms of perception provides an additional, extremely relevant, feature of the developed PRM, which consists in its capabilities for fundamental and comprehensive research of both: directly the prisms of perception themselves, as well as the relevant impact factors which, actually, form/construct these prisms of perception. Because, it is the impact factors that are the basic elements that forms the individual personalized characteristics (of objects' perception) of each separate subject (interacting with this object).

Therefore, the key to understanding the individuality of perception of any subject lies precisely in the study / research of the impact factors which form individual (and in many cases, even unique and unrepeatable) personalized systems of perception prisms of each separate individual subject.

4 EXPERIMENTS

The experiment consists in the step-by-step execution of all stages of the specialized developed algorithm of the declared PRM, as well as in the usage of the developed models (both simulation and basic mathematical ones) for investigating the perception subjectivization of the experimental researched object of the investigated HMI / HCI.

At the same time, it is extremely important to determine (as accurately as possible) the original characteristics of the researched object, as well as the system of perception prisms in the context of the specific vector of perception that will be investigated in any separate/specific individual case of research.

In addition, it is equally important to clearly identify the subjects of perception that are closely related to the prism system, in order to (if necessary) further adjust the prism system in the context of the selected subject(s) of performed investigation/research.

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5 RESULTS

The main results obtained by the developed PRM – are the corresponding simulation models that provide the possibility of initial formalization of any problem of HMI/HCI object(s)' perception subjectivization, with the subsequent possibility of a more detailed investigation of the component processes of subjectivization of each individual characteristic(s) of the researched object(s).

In particular, as a practical approbation of the developed PRM, a relevant scientific and applied problem of synthesizing a basic model of perception subjectivization of an object of software product's comprehensive support has been resolved, using the example of an experimental case of estimating the approximate processing time for a client's request – by the customer-and-technical support department of pre-defined software product.

Comprehensive support of software products is one of the most highlighted examples of HMI/HCI, and includes such mandatory components as:

– an object of interaction, or an object of support (which is the supported software product itself, or the processes related to its comprehensive support);

– interaction/support subjects (which interact with the support object, and directly provide and implement the components of its comprehensive support);

– as well as the impact factors that affect/influence the perception subjectivization of the support object – by relevant existing subjects, which, in turn, directly affects executing by subjects their functional duties regarding the comprehensive support of the supported object, as well as the efficiency and the effectiveness of the relevant components of such comprehensive support.

As a specific example of an experimental case, the task of evaluating the ApHT indicator of a client's request, received by the customer-and-technical support service of a specific pre-defined supported software product, by the employees of this service has been considered in scope of current research.

The approximate time of client's requests processing by the customer-and-technical support service department of software development companies – is an extremely relevant and actual practical applied problem, as it provides the possibility(-ies) to rationalize resources, as well as prevent the occurrence(s) of any problematic situations related to the potential delays in processing client's requests. Unfortunately, there is still no any "one-size-fits-all"-solution/mechanism for assessing this ApHT indicator, since it involves a lot of human factors (some of which will be presented, in particular, in the relevant list(s) of provided prism factors described below in the text), so most existing solutions are based primarily on the empirical (i.e., heuristic) experience of relevant professionals and specialists (i.e., experts) in this subject area.

Thus, in this particular specific considered investigated case: the researched "object" (of a defined software product's comprehensive support) – will be, in fact, the client's request (namely: its true ApHT indicator); the subjects – will be employees, members of the customer-and-technical support team (of the defined supported software product); the input characteristics of the object – will be the data obtained from the request; and the output characteristics of the resulting perception of the researched object – will be, respectively, subjective ApHT indicator(s).

The resolution of the given experimental exemplary practical applied problem depends on several consecutive stages, namely:

– determining the input characteristics of the object (based on the data/information from obtained client's request);

– identification of the perception prisms and the impact factors;

– declaration of resulting characteristics (i.e. ApHT indicators).

So, the first stage in resolving the declared practical applied problem – is to determine the input characteristics of the object of perception, which is carried out on the basis of data/information contained directly in the obtained client's request, since this is the only existing source of objective information at this stage/phase of investigation in the context of given task.

Thus, among the main input characteristics, following ones could be distinguished, in particular, such as:

– request's original priority set directly by the client himself;

– problematic area of the supported product (system, subsystem, area, environment, node, interface, etc.);

– type of request (not working, delay in operation/functioning, unstable operating/functioning, incorrect operating/functioning, how exactly should it work, can it work differently, need it to work differently, etc.);

– scale of the request (classified based on a general/total number of affected users);

– receipt date and time of the request (to identify whether it is "business hours" or not);

– availability of all necessary (according to previously agreed/defined request-filling templates) information/data from the client at this stage of entering the request into the customer-and-technical support service department/team.

In turn, among the main prisms of perception and impact factors, in the context of solving the given experimental practical applied problem, the following ones could be highlighted:

1. Professional prism, where the relevant impact factors could be:

1.1. employee's current position (within current place of work);

1.2. employee's experience in scope of the current project;

1.3. employee's experience in scope of the current company;

1.4. employee's experience at the relative global market;

1.5. employee's experience working with the given problematic area of the product;

1.6. employee's experience working with the given specific type of request;

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1.7. presence of any specific features of working with this separate given client;

1.8. experience working with this separate given client and/or its specifics/features;

1.9. having experience working with similar requests;

1.10. having the necessary/needed level of general education (eruditeness, intelligence, specialized education, certification, etc.).

2. Organizational prism, where the relevant impact factors could be:

2.1. the reliability of the information/data contained in the request;

2.2. availability and serviceability of access to the client's environment (if required);

2.3. day of the week and time of the day (to identify whether it is "business hours" or not);

2.4. availability and serviceability of all necessary hardware;

2.5. availability and serviceability of all necessary software;

2.6. availability and serviceability of all the material and technical equipment necessary for the organization of the workplace;

2.7. skills for effective use of all needed and available hardware;

2.8. skills for effective use of all needed and available software;

2.9. skills for effective use of all needed and available material and/or technical equipment;

2.10. availability and completeness of all necessary technical documentation (functional requirements, knowledge base, requests archive, frequently asked questions, etc.);

2.11. skills for effective use of all needed and available technical documentation;

2.12. availability and accessibility of all necessary teams (of the development company) and their relevant and necessary representatives;

2.13. availability and completeness of all necessary protocol (procedural, as well as situational) documentation;

2.14. skills for effective use of all needed and available protocol (procedural, as well as situational) documentation;

2.15. the presence of clear criteria for assessing the quality of work, and the complete/full familiarity of the customer-and-technical support department's employee with these criteria.

3. Motivational prism, where the relevant impact factors could be:

3.1. personal intangible level of motivation of the given employee of the customer-and-technical support department/team (to what extent the resolution of this separate/specific client's request/problem is a "personal challenge" for this employee, without the presence of any other additional material and/or non-material incentive);

3.2. the employee's sense of its personal image and reputation;

3.3. the employee's personal well-being (in all aspects);

3.4. the employee's favorability level of any interaction conflictedness (since the presence of any conflicts between subjects negatively affects the level of their motivation, as well as the level of their interaction quality, efficiency and effectiveness);

3.5. personal, intangible level of motivation of the employees of other departments/teams involved in processing the current given client's request;

3.6. availability of material incentives (bonuses, allowances, etc.);

3.7. availability of corporate/organizational incentives (rating system, opportunity for promotion and career growth, etc.);

3.8. the presence of a positive reaction, feedback, approval from the client;

3.9. presence of a "team spirit", ability and desire to work in a team;

3.10. the employee's sense of corporate image and reputation;

3.11. presence of a punitive mechanism for poor performance of functional duties (financial penalties, demotion, dismissal, etc.).

4. Communication prism, where the relevant impact factors could be:

4.1. completeness and clarity (i.e., quality) of the information contained directly in the obtained client's request itself;

4.2. level of proficiency in the language of the client/request (since very often nowadays the companies of customers/users, the software development companies, and the customer-and-technical support departments/teams may be located in completely different countries, even overseas);

4.3. openness to communication, understanding of its importance, and absence of individual / personal communication complexes and/or problems;

4.4. client/user availability for communication;

4.5. availability of necessary members of other involved teams to enable communication with (and between) them;

4.6. availability and accessibility of all necessary channels and means of communication;

4.7. skills in using existing channels and means of communication (both for "external" and "internal" communication);

4.8. personal communication characteristics of the given employee of the customer-and-technical support department/team;

4.9. personal communication characteristics of the client/user;

4.10. personal communication characteristics of the rest members of other involved teams of the development company.

It is also important to note that each of the impact factors can bring both negative and positive connotation to the perception subjectivization of the researched object, depending on the context and prerequisites.

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That is why, in order to simplify the understanding of the exact connotation of each separate impact factor, in practice, when designing/synthesizing basic simulation models (of HMI/HCI objects' perception subjectivization), it is recommended to use not only single impact factor(s), but instead – a pairs of the "protagonist-antagonist" type for each separate impact factor, which will ensure the most unambiguous understanding of the connotation of this impact factor during simulation modeling of almost any arbitrary investigated situational case(s).

The final stage of solving the declared experimental practical applied problem – is declaration of the output / resulting characteristics (i.e. ApHT indicators).

To do this, the ApHT indicator(s) are presented in the format of a compliance coefficient(s) of the resolution time of obtained client's request (with given type / class / priority), regulated by the relevant customer-and-technical-support contract/agreement concluded with each separate client.

In this case, the following possible values of the output/resulting characteristics of the subjective perception of the ApHT assessment process (by a relevant employee(s) of the customer-and-technical support department/team of the supported software product development company) based on the received client's request have been proposed/highlighted in scope of resolving the declared practical applied problem:

– <0.5, which means that the obtained client's request will be processed more than twice faster then the expected processing time;

– [0.5–1] – from expected time to twice faster;

– [1–1.5] – from the expected time to one and a half times longer;

– [1.5–2] – from one and a half times longer than expected – to twice longer then expected;

– >2 – more than twice longer then expected.

Thus, the identification of all necessary components, carried out at the previous stages of solving the given practical applied problem, makes it possible to obtain the necessary basic model of perception subjectivization of the object of software product's comprehensive support, using the example of an experimental case of estimating the approximate processing time of client's request by the customer-and-technical support department/team employee(s) of a defined software product.

In particular, the corresponding simulation model is presented below, at Figure 3.

The components of each of the perception prisms (marked at Figure 3 by numbered elements 1.1–1.10, 2.1–2.15, 3.1–3.11, 4.1–4.10) correspond to the same positions in the above-provided list of impact factors that are part of the corresponding four perception prisms (namely: professional, organizational, motivational, and communication), given above in the text, just as the input and the output characteristics correspond to the same items in the appropriate above-provided list(s) of elements of the corresponding stages of solving the given practical applied problem, described above as well.

In fact, in this case, the developed simulation model operates in a classification mode, which is also available for the developed PRM, where the resulting/output perception of the object (i.e., the subjective ApHT indicator) is presented in the format of the probabilities of each of the categories (the resulting output characteristics). Accordingly, the category (the resulting output subjective characteristic) that will gain the maximal value among all others – will represent the result of the subjective perception of the researched object (in this case, the ApHT indicator).

In particular, at Figure 4, provided below, there are also examples of few specific experimental cases of simulation modeling performed on the basis of a synthesized simulation model (of this experimental research on the assessment of ApHT indicator), which represent specific situational cases (scenarios) based on the analysis of some previously processed archived client requests (of this specific given researched supported software product, provided for investigation and resolution of this separate specific experimental practical applied problem).

The main objective of this experiment is to investigate the possibility of using the developed "prisms and rays method" and, in particular, the basic simulation models of perception subjectivization of the researched object(s) (in this particular case – the ApHT indicator, as such researched object) synthesized by means of the developed PRM, – as an environment for modeling procedures of the AAR-methodology class, since this methodology is extremely effective for a better understanding of the researched processes and their cause-and-effect relationships, which, in turn, is quite relevant in the context of investigating the relevant issues of perception subjectivization of the objects of HMI/HCI.

As examples of modeling, four specific situational cases of processing client's requests and subjective forecasting of the ApHT indicator (which was later compared with the real one, after the request's resolution has been completely finalized), have been presented.

Each of these 4 experimental cases, provided below at Figure 4, reflects precisely those key impact factors (within the relevant perception prisms), established through the AAR-interview with the subject, which, in fact, played a major determining and/or decisive role in the subject's decision-making regarding the expected (by this subject) value of the ApHT indicator when processing this specific case.

The obtained results of modeling provided experimental cases of the investigated practical applied problem (of client's request(s) ApHT estimation) confirm the effectiveness of the relevant simulation models synthesized by means of the developed PRM in providing opportunities and possibilities for modeling the processes of perception subjectivization of the objects (as well as the processes) of HMI/HCI – by the relevant existing subjects of this interaction.

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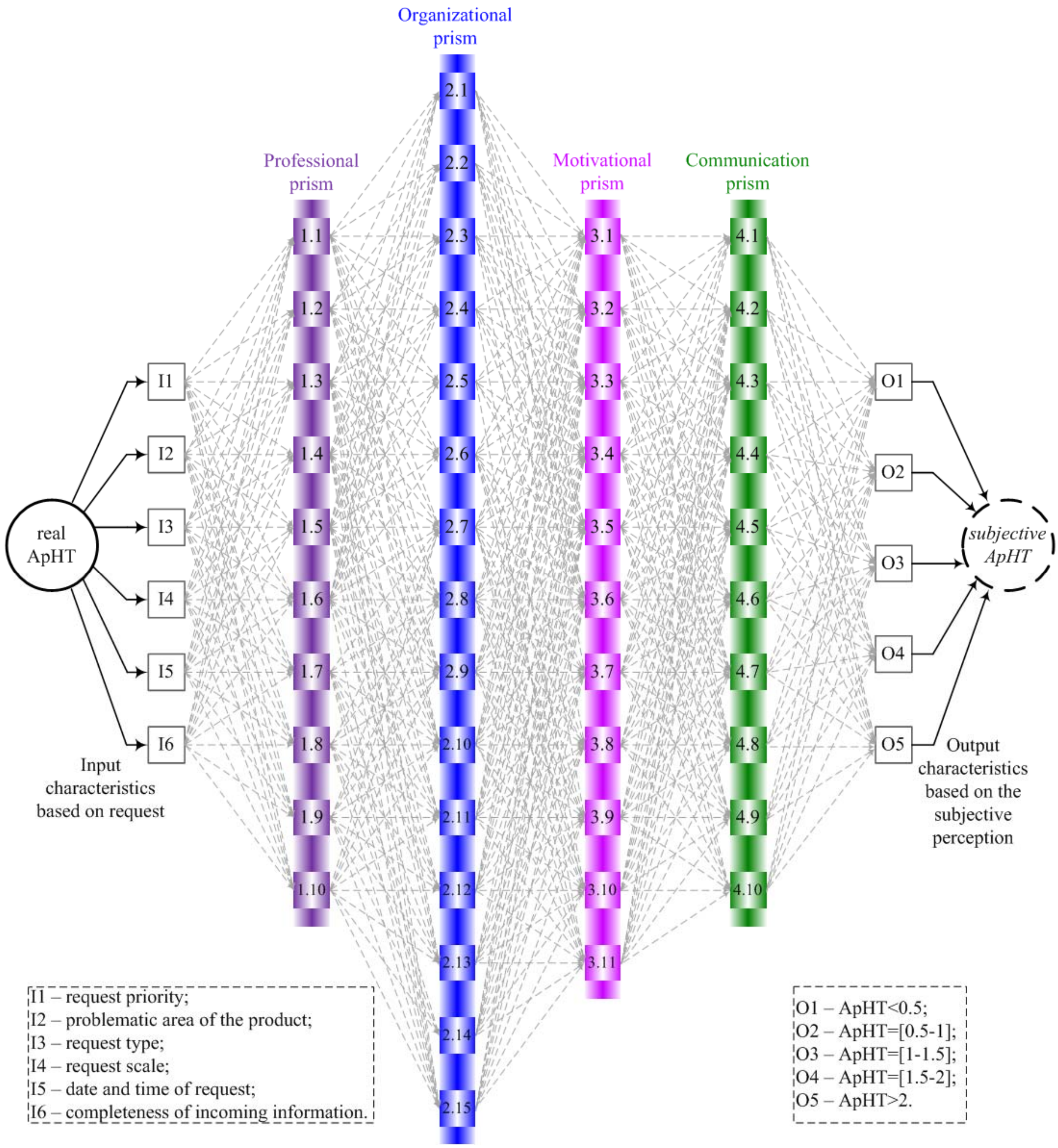

Figure 3 – An example of a synthesized basic simulation model of perception/estimation subjectivization of the approximate processing time for a client's request by the customer-and-technical support department/team employee of the supported software product

The developed simulation model (of the object's perception subjectivization) is a fundamental component, or a kind of "coordinate system" for a specific investigated problem, which provides the possibility of further complex research into the processes of perception subjectivization of HMI/HCI objects in scope of this specific "coordinate system".

In particular, it provides possibilities for modeling the dynamics and tendency of perception subjectivization of researched HMI/HCI object – by the same investigated subject, changing only the parametric indicators (i.e., bandwidth and refraction angle) of the perception prisms for specific impact factors.

In this way, by selecting different experimental values of the parametric indicators (i.e., bandwidth and refraction angle) of the component perception prisms, it is possible to achieve certain optimal results in which the resulting subjective perception of the researched object (for example, investigated subjective ApHT indicator) will be as close as possible to the real object (i.e., real ApHT obtained already from the results of final processing of appropriate client's request).

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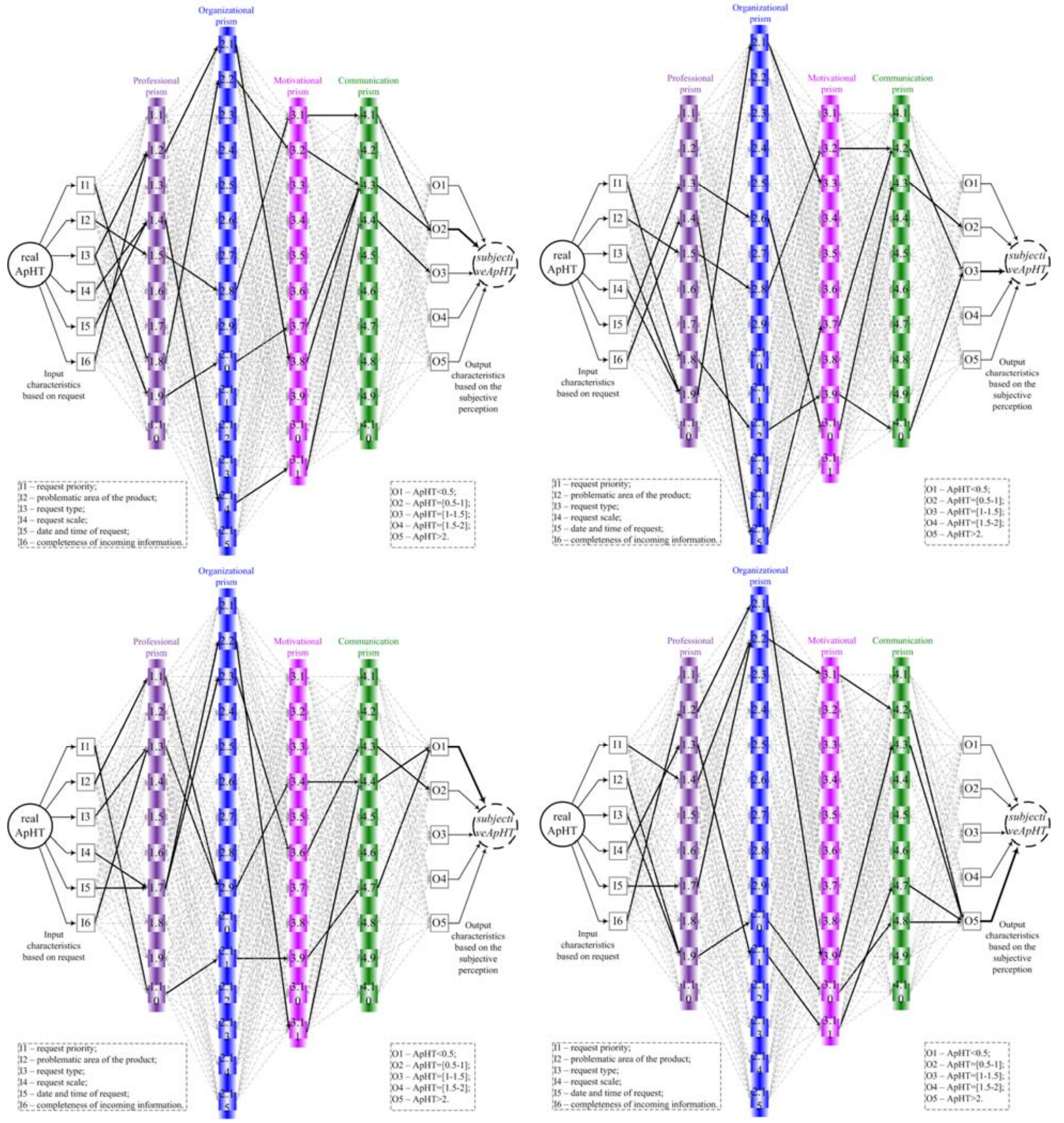

Figure 4 – Examples of experimental cases of simulation modeling performed on the basis of a generalized subjective perception model synthesized by the developed PRM

Thus, the developed "prisms and rays method" (for researching the HMI/HCI objects' perception subjectivization) has been practically approbated on the example of solving an experimental case of relevant practical applied problem of estimating the approximate processing time for a client's request by the customer-and-technical support department/team employee(s) of a relevant supported software product. In turn, the obtained approbation results confirm the effectiveness and efficiency of the developed "prisms and rays method" for researching both the scientific and applied problem of HMI/HCI object(s)' perception subjectivization, as well as the relevant derived practical applied problems, both in the field of human-machine interaction as well as in the context of any inter-subjective interaction in general.

Besides that, the developed method provides additional possibilities for a comprehensive research of the impact factors that directly affect the subjectivization of the perception of HMI/HCI objects – by relevant subjects of the same interaction.

6 DISCUSSION

In research [11] authors explore the role of digital twin technology in many aspects of designing, modeling, and

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optimizing complex systems, as well as the possibilities of integrating this technology into simulation, data analytics, machine learning, the Internet of Things, networks, and human-machine interaction. In particular, as an example of such integration, the human-machine interaction model of an intelligent digital twin presented in [12] is given, which improves user interaction by visualizing big data in a way that makes it easy to understand and process, including through the usage of new interaction methodologies, thanks to which the user has full control over the data flow, using gaze, gestures and a voice recognition interface that will provide contextual information.

The research presented in work [13] is devoted to the study of the problems of human perception based on text information, where the authors carried out a comparative analysis of methods like Decision Tree, K nearest neighbors, Naive Bayes, and generalized linear models in the context of human perception analysis based on text mining using a precisely selected data set(s) of customer support discussions at one of the social networks. As a result of the comparative analysis, it was found that the decision tree algorithm is the best, followed by Naive Bayes.

At the same time, the work [14] investigates the issue of personalized individual perception of AI chatbots by users through the mediating role of the categories of usefulness and ease of use of the latter, based on cross-temporal measurement of the relevant indicators using a specialized questionnaire, using, among other things, partial least squares structural equation modeling, as a result of which a significant positive direct relationship between the quality of an AI chatbot and its perception by a human user during their human-machine/computer interaction was confirmed, and the results of the indirect relationship show that the expected usefulness and ease of use partially mediated the relationship between the quality of AI chatbots and their perception by the users (human).

While, in the work [15], modern aspects of human-machine interaction in the field of systems engineering are investigated, due to the active intervention into this area of ML, AI, autonomous systems, and the issue of how these technologies change whole this activity field, positioning people not only as end users, but also as critical components in extensive software ecosystems, exploring the complex interaction between technical and human factors that affect the mutual perception of subjects (human and machines) on both sides of their joint human-machine interaction.

Thus, existing researches confirm the relevance of the researched issues and the significant both pure scientific as well as scientific-practical interest of scientists, researchers and professionals in the field of HMI/HCI and a large number of its constituent components and derived scientific-applied problems and tasks, one of which is, in fact, the issue of perception subjectivization of the HMI/HCI objects by the relevant subjects of this interaction.

At the same time, the research of this specific component of HMI/HCI requires additional actualization and updating, since there is a certain lack of attention of researchers (scientists, and/or professionals) to this component, which, nevertheless, is one of the basic, fundamental and conceptual components of HMI/HCI, since it provides the possibility of formalizing the fundamental basis of the manifestations of any further HMI/HCI problems and issues, the root cause of which, in a global sense, is, among other things, different perception subjectivization of the same HMI/HCI object by various subjects (of this interaction) as all these subjects could perceive this same object in completely different ways, which is due to the individual properties of each subject to personalize and subjectivize their own perception of the objects (both HMI/HCI objects, as well as any other objects in general case).

In turn, the developed ”prisms and rays method” provides needed possibility(-ies), carrying out both preliminary formalization of the researched processes of perception subjectivization of HMI/HCI objects, as well as the possibility of further processing, researching, and modeling of these processes, thereby filling the existing gap in a scope of fundamental understanding of the root causes of an extremely large number of derivative HMI/HCI problems, caused, precisely, by differences in the individual personalized perception(s) of the same HMI/HCI objects by different subjects.

As a prospect for further research and practical application of the developed MPR, authors see the potential of its use in solving both scientific-applied and practical-applied problems of automation and intellectualization of software products' comprehensive support, where the perception subjectivization of the support objects plays one of the key roles both in the context of the quality of customer support services (and/or any other parts of comprehensive support) and in the context of the effectiveness of intersubjective interaction of those subjects who directly implement and provide such comprehensive support of software products.

CONCLUSIONS

The “prism and rays method” (author's name of the method) has been developed to study the perception subjectivization of the objects of HMI/HCI. The main scientific and applied problem solved by the developed method is the problem of representation formalizing as well as possibility of further research of the scientific and applied problem of perception subjectivization of the HMI/HCI objects by relevant interaction subjects, in the context of global problems of automation and intellectualization of the component processes and environments of HMI/HCI. The input data of the developed method are the original (i.e. objective) characteristics of the researched object of perception. While, the output results of the developed method is the subjective perception of the researched object, represented by the subjectivized values of its objective characteristics.

The main feature of the developed method is its ability to conduct fundamental and comprehensive research not only on the processes of interaction objects' perception subjectivization, but also on the perception prisms them-

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selves, and therefore on relevant impact factors which form the subjective personalized perception and vision of the same objects by different subjects of interaction.

A simulation model (of HMI/HCI objects' perception subjectivization) has been developed, key feature of which is the possibility of combining individual prisms in a relevant prism system in accordance to various scenarios, situations, or conditions, as well as the possibility of forming and preparing certain "templates" of prisms sets (or systems) which correspond to some "classic" (known or frequently repeated) scenarios, situations, or conditions.

Also, a basic mathematical model (of HMI/HCI objects' perception subjectivization) has been developed, the main feature of which is its complete correspondence to the declared form of the relevant multi-criteria multifunctional cascade dependence. In addition, a specialized algorithm of HMI/HCI objects' perception subjectivization has been developed, which provides possibility of further automation (including computer modeling) of the researched processes.

The scientific novelty consists in development of the "prism and rays method" (author's name of the method) for researching the perception subjectivization of HMI/HCI objects, which provides possibility of solving the declared scientific and applied task of representation formalizing as well as possibility of further research of the scientific and applied problem of perception subjectivization of the HMI/HCI objects by relevant interaction subjects, in the context of global problems of automation and intellectualization of the component processes and environments of HMI/HCI.

The practical significance consists in development of: a simulation model, a basic mathematical model, and the algorithm of HMI/HCI objects' perception subjectivization processes, which provide the possibility of comprehensive research and modeling of these processes, as well as lay the foundations for ensuring the possibilities of further computer/software implementation and modeling of these processes by developing (on their basis) appropriate dedicated specialized software.

Prospects for further research consist of two key areas of potential improvement and expansion of application area of the developed "prism and rays method". In particular, the first direction is the encapsulation of ANN, including, possibly, a MP, especially at the initial stage, taking into account the constructive similarity of the developed simulation model (of objects' perception subjectivization) with the structure of the MP itself, but not only limited to it, but also considering and investigating the prospects for encapsulating other neural networks – into the simulation models, synthesized by the developed PRM, which will provide opportunities and possibilities for increasing the level of automation and intellectualization of the scientific and applied potential of the developed method. While the second direction will provide the possibility of research and further disclosure of the entire inherent scientific and applied potential of the developed method, not being limited exclusively to a narrow direction of research in the context of only the HMI/HCI objects' perception subjectivization, but instead – investigating the potential of the developed PRM in the context of the perception subjectivization of any objects in any environments of any intersubjective interaction, such as, for example: socionics, conflictology, psychology, and an extremely wide variety of other relevant areas of intersubjective interaction, both in the context of relevant scientific and applied as well as derivative practical applied problems.

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МЕТОД «ПРИЗМ ТА ПРОМЕНІВ» ДЛЯ ДОСЛІДЖЕННЯ СУБ'ЄКТИВІЗАЦІЇ СПРИЙНЯТТЯ ОБ'ЄКТІВ ЛЮДИНО-МАШИННОЇ ВЗАЄМОДІЇ

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АНОТАЦІЯ

Актуальність. Розглянуто задачу формалізації представлення з можливістю подальшого дослідження науково-прикладної проблеми суб'єктивізації сприйняття об'єктів людино-машинної взаємодії – суб'єктами цієї взаємодії, в контексті глобальної проблематики автоматизації й інтелектуалізації складових процесів та середовищ людино-машинної взаємодії. **Об'єктом дослідження** є процеси суб'єктивізації сприйняття об'єктів людино-машинної взаємодії – суб'єктами цієї взаємодії. **Предметом дослідження** є методи та засоби математичного, комп'ютерного, а також імітаційного моделювання.

Метою роботи – розроблення методу для дослідження суб'єктивізації сприйняття об'єктів відповідними суб'єктами людино-машинної взаємодії.

Метод. Запропоновано розроблення методу «призм та променів» (авторська назва методу), що забезпечує можливість вирішення науково-прикладної задачі формалізації представлення з можливістю подальшого дослідження процесів суб'єктивізації сприйняття об'єктів людино-машинної взаємодії відповідними суб'єктами цієї взаємодії.

Результати. Результатами роботи розробленого методу є відповідні моделі, що репрезентують суб'єктивізацію сприйняття досліджуваного об'єкта людино-машинної взаємодії відповідними суб'єктами цієї взаємодії. Розроблений метод забезпечує можливість як формалізації, так і подальшої інтерпретації та дослідження процесів суб'єктивізації сприйняття об'єктів людино-машинної взаємодії. В якості апробації, розроблений метод застосовано для синтезу базової моделі суб'єктивізації сприйняття об'єкта комплексної підтримки (як одного з найбільш поширених прикладів людино-машинної взаємодії) програмних продуктів, на прикладі експериментального кейсу оцінки приблизного часу опрацювання клієнтського запиту відділом клієнтської та технічної підтримки програмного продукту.

Висновки. Розроблений метод вирішує поставлену задачу формалізації представлення з можливістю подальшого дослідження науково-прикладної проблеми суб'єктивізації сприйняття об'єктів людино-машинної взаємодії – суб'єктами цієї взаємодії, в контексті глобальної проблематики автоматизації й інтелектуалізації складових процесів та середовищ людино-машинної взаємодії. Водночас, отримані результати експериментальної апробації розробленого методу підтверджують його дієвість в контексті вирішення прикладних практичних задач науково-прикладної проблематики суб'єктивізації сприйняття об'єктів людино-машинної взаємодії.

КЛЮЧОВІ СЛОВА: людино-машинна взаємодія, об'єкт взаємодії, суб'єктивізація сприйняття, фактори впливу, автоматизація, інтелектуалізація.

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