

HCI Subjects' Role Identification Method Based on Their Multifactor Portraits of Perception Subjectivization for HCI Object

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ABSTRACT This research is devoted to the problem of developing a specialized novel method for identifying the role of HCI subjects based on their multifactor portraits of perception subjectivization of the object of this interaction, which provides the possibility of increasing the level of HCI automation and intellectualization by additional evaluation of the factor of perception subjectivization of the interaction object by the subjects of this interaction. The proposed method is based on the developed polycomponent model, which can contain any (and necessary) number of impact factors as its components, and also is represented in two variations, namely strongly structured (when the placement order of dominant impact factors has significant and fundamental importance, and must be met), or weakly structured (when the placement order of dominant impact factors is not required and obligatory). Another fundamental component of the proposed method is a specialized algorithm developed for identifying the role of HCI subjects based on their multifactor portrait, which provides the possibility of algorithmization of the researched processes, as well as the opportunity for further software implementation and computer modeling of the developed method. As a practical approbation of the developed method, the relevant applied task of identifying a potential candidate(s) from among all available into the highly specialized support team of the given software product based on their compliance with the declared role pattern, has been solved. The obtained results confirm the effectiveness of the developed method, as well as its perspective in the context of further research in the field of automation and intellectualization of HCI and its components.

KEYWORDS human-computer interaction; interaction object perception subjectivization; impact factors; multifactor portrait; subject role identification.

I. INTRODUCTION

Research of human-computer interaction (HCI) continues to be an active scientific and applied direction nowadays, the relevance of which is due, among other things, to the extremely wide variety of manifestations of this interaction, as well as the factors which influence it, as, for example, even culture, according to the results of research presented in scope of work [1], has an extremely significant impact on HCI. Additionally, the authors of work [2], in the scope of their study, attempted to gain a deeper understanding of the complexity of HCI, caused by past and future achievements that have significantly changed the period of human development, considering HCI as a sequence of protocols, dialogues, and actions, which people use to communicate with computers, all of which involve data input and guidance through a graphical (user) interface to achieve the desired result(s).

The authors of [3] presented a comprehensive study of HCI, in which the HCI design process and its current state, as well

as practical applications were briefly explained. They also emphasized the combination of human-centered design and Agile interface design methodologies, highlighting the need for further study of HCI interface design methodologies, particularly in relation to mobile and cloud technologies, virtual and augmented reality technologies, the Internet of Things technologies, and other relevant organizational information systems.

At the same time, the authors of work [4] conducted a comprehensive and thorough study of key fundamental trends in the stages of HCI development over the past six decades noting a clear transition in HCI research from machine-oriented systems to human-oriented systems, which indicates its future direction towards context-dependent adaptive systems. In turn, study [5] outlined some future perspectives for HCI research, emphasizing among other things, that technologies are increasingly becoming active agents capable of learning, adapting, and making decisions, which, in turn, may lead to the

fact that the classic approach to user-centered design, which places the user squarely at the center of the whole system infrastructure, may no longer be sufficient. Additionally, a comprehensive overview of current research and future directions in this field was also carried out, in particular, such important topics as human-centered artificial intelligence, augmented and virtual reality, user-centered design, and child-computer interaction were considered. Insights into how these areas would continue to influence and transform human interaction with all these modern technologies were provided.

Thus, the considered studies and researches confirm the relevance of the scientific and applied direction of HCI, caused both by an extremely wide range of its practical applied applications and manifestations, as well as by a significant variety of factors, not only of human etymology, but also including those related to the development and implementation of modern technologies (mobile and cloud, artificial and augmented reality, the Internet of Things and artificial intelligence, as well as a lot of others), which significantly affect HCI as a whole, maintaining a constant and intensive level of influence, and therefore the need for its deeper research and investigation. Among the key factors affecting and influencing further development of HCI nowadays is, in particular, artificial intelligence, as one of the basic and fundamental tools for increasing the level of automation and intellectualization of this interaction.

Work [6] examined the HCI evolution in the age of artificial intelligence, tracing the transformation from early “chess-computers” to modern collaborative systems and platforms, and exploring how artificial intelligence has transformed from a human competitor to a collaborative partner in various industries, including healthcare, finance, and professional workspaces; as well as examining the development of sophisticated interfaces that enable natural human-machine interactions, the emergence of autonomous artificial intelligence systems, and the impact of these technologies on workplace efficiency and employee well-being, changing the professional environment, and emphasizing the importance of supporting human activity in human-machine partnerships. Study [7] examined the issues of artificial intelligence and mixed reality within the framework of HCI in healthcare field, introduced new approaches to patient care and clinical education, expanding cognitive and emotional support for users (patients) in the specialized dedicated virtual spaces.

At the same time, within the framework of work [8], in particular its first section, the issue of implementation and practical application of the achievements of the symbiosis of artificial intelligence and HCI in the context of applied issues of improving virtual assistants was revealed. In turn, within the framework of ethnographic research [9], it was found that although robotic systems cope well with automated operations and increased efficiency, they still have obvious shortcomings in emotional interaction and social feedback, which are manifested, in particular, in the lack of emotional communication, one-way and asymmetric interaction, the indispensable nature of interpersonal communication when HCI is not smooth, and differences in technical adaptability, which creates new challenges and trends in the prospects for further development of HCI as a whole.

Research [10] explored the evolution of voice chatbots, highlighting advances in voice recognition, contextual understanding, and real-time conversational capabilities, and

examined the challenges these systems face, such as language ambiguity, misinterpretation of user intent, the need for multilingual support, and ethical issues such as data privacy and algorithmic bias, along with examining the role of deep learning, sentiment analysis, and adaptive learning methods and techniques in improving chatbot responsiveness and emotional intelligence.

The authors of research [11] performed investigation using deep learning approaches, including the Yolo model, the Inception Net+LSTM model, the 3-D CNN+LSTM, and the time-distributed CNN+LSTM in the applied field of studying the problem of gesture recognition in the context of HCI, as a result of which the Yolo model was determined to obtain better results in comparison to three other types of considered models. At the same time, research [12] explored the integration of emotional, cognitive and interactive processes in scope of development an educational technologies through the prism of HCI (since it is precisely emotional interaction which still remains quite underdeveloped in many tools, which limits the effectiveness of whole learning process), proposing a theoretical holistic framework that integrates usability, emotional intelligence and adaptive interaction, also applying the theory of cognitive load, the theory of emotional intelligence and the theory of self-determination to assess their effectiveness, including psychology, cognitive science and user experience design integration.

In turn, research [13] addressed the issue of improving HCI, which had become possible thanks to brain-computer interaction (BCI). The authors focused, in particular, on greater simplicity and convenience, specifically for those users with certain physical limitations; solving the problem of signal noise and user adaptability, as well as exploring neural decoding, neuroscience, artificial intelligence and user interface engineering, which together act as the most relevant design indicators for a smooth, cognitively-friendly interactive era. Study [14] presented the general direction and achievements of recent HCI research, in particular in the context of its combination with big data, and also investigated the method of applying HCI technologies to analyze the emotional behavior of subjects (in particular, in scope of educational applied field), during which the method of pure human intervention was compared with methods of facial emotion recognition, voice emotion recognition, body-sensations based HCI, and methods of virtual scene training based on HCI technologies.

While in scope of another study [15], in order to improve the accuracy of visual emotion recognition, including the context of HCI, a visual emotion recognition method was proposed, which integrates a self-learning and attention mechanism, where the semantic information of the image is learned and assimilated using an auxiliary task with self-control based on a backbone feature extraction network. An appropriate emotion mapping was generated based on the attention mechanism in order to improve the features representation, which, together, provides improved HCI, as well as expands the capabilities of the system’s intelligent interaction. At the same time, study [16] proposed an interactive strategy for optimizing a computer-aided design (CAD) system based on user behavior and design psychology, and also analyzed the HCI interaction experience of the system by combining a user emotion classification model based on the support vector machine (SVM) method, which helps to reduce the cost of design, the number of design iterations, and

promotes further innovation in the context of relevant HCI interaction as a whole.

Thus, in the context of performed review of existing researches, a significant variety of existing impact factors affecting HCI has been considered, including, in particular, such factors as: voice and speech recognition, analysis of large language models, analysis of facial expressions and gestures, recognition of users emotions [17], and many others, which, in one way or another, definitely affect the HCI interaction between these users (as a “human” component of HCI) from one side and computer systems (as a “computer” component of HCI) from another side, using, among other things, artificial intelligence technologies to analyze and process these factors.

Furthermore, considering the influencing factors within the context of weakly structured and strongly structured forms of representation of the declared role patterns (which are based on these impact factors), this largely corresponds to the use of point random processes [18], which could be optionally used for detecting and identifying these two types of influence. However, unfortunately, there are a number of impact factors that still remain poorly researched and insufficiently revealed in the context of HCI and relevant existing researches, one of which is, in particular, the factor of perception subjectivization of the HCI object by the subjects of this interaction. At the same time, this factor is extremely important (and in many cases even decisive and fundamental) in the context of issues related to automation and intellectualization of HCI components, since it makes it possible to take into account the irrational component of HCI subjects interaction, namely their subjective perception of the common object of their interaction. After all, it is, actually, the difference or similarity (or compatibility and incompatibility) of personalized perception of the common object of human-computer interaction (by different subjects of this same interaction) that directly affects the quality, efficiency and effectiveness of this interaction, especially when forming appropriate teams, groups or communities of interacting subjects.

In turn, one of the effective criteria for grouping any interacting subjects is their role identification and affiliation, which is, actually, the process of identifying subjects based on certain markers of their common defined coordinate system, where the role of the subject is determined by the corresponding pre-declared set of markers (i.e., characteristics, factors, etc.) inherent to all subjects of this role.

Thus, the development of appropriate method(s) for role identification of interacting subjects is a relevant scientific and applied task in the field of research into the problems of both the formation of HCI teams as well as increasing the level of automation and intellectualization of the components of this intersubjective interaction, including HCI as its particular manifestation.

II. MATERIAL AND METHODS

The main idea of the proposed method, presented in this research, is to provide the possibility for identifying HCI subjects according to the principle of their role affiliation, which is determined by a set of specific combinations of common dominant, i.e., the most influential impact factors (from a common set of previously considered, agreed and declared impact factors), which form their personalized multifactor portraits of perception subjectivization of the common object of their joint interaction.

In the scope of research [19], a specialized impact factors reverse analysis method for software complexes’ support automation was introduced, the main feature of which is its ability to identify the shares of influence (of pre-declared impact factors) onto the perception subjectivization of the support object (i.e., supported software product, or components of its comprehensive support processes) by subjects performing direct interaction with this support object, based on the processing of relevant situational cases of modeling this interaction using a pre-designed and trained artificial neural network(s) of a multilayer perceptron type. At the same time, the principles underlying this method ensure its actual application in the context of research not only in scope of processes of software products’ comprehensive support (as one of the most relevant manifestations of HCI), but also of HCI in general.

Thus, having processed a batch of situational (modeling) cases of interaction between the researched subject and object (of investigated HCI) using the aforementioned impact factors reverse analysis method for software complexes’ support automation, – it becomes possible to obtain the corresponding set of values of the shares of influence of each of the declared impact factors influencing the perception subjectivization of the object of interaction by the specific investigated subject of this same interaction, for each of the processed situational (modeling) cases. After that, by averaging these values (for each of the declared impact factors), it is possible to obtain a set of unique values regarding the influence of each of the declared impact factors onto the perception subjectivization of the object of interaction by the specific subject of this interaction, which, in fact, represents the subject’s personalized multifactor portrait of perception subjectivization of the given object of investigated interaction.

Expression (1) below represents a multifactor portrait of perception subjectivization of the interaction object by a separate subject of this interaction:

$$MIFPS[i] = \{Fsh[j]\}, j = \overline{1, m}, \quad (1)$$

where $MIFPS[i]$ – a multifactor portrait of separate specific subject of interaction, $Fsh[j]$ – a share of presence of the j -th impact factor in the multifactor portrait of the currently considered / investigated subject of interaction, m – a total amount of previously declared impact factors within the researched interaction.

It is important to note that within the framework of this study we fully accept any impact factors (regardless of their amount, types, species, forms, aspect of their dependence or independence, etc.) which affect the perception subjectivization of the object by the subjects of the investigated HCI. The only mandatory condition (which is, by the way, guaranteed by aforementioned specialized impact factors reverse analysis method) is normalization of the values of their influence shares within each separate researched subject.

Therefore, the multifactor portraits of the subjects of the investigated HCI, obtained in this way, act as input data for the developed method of HCI subjects’ role identification method based on their multifactor portraits of perception subjectivization of HCI object, presented within the framework of this research.

At the same time, the basis of the developed method is the developed polycomponent model of HCI subjects’ role

identification, as well as a specialized algorithm for such role identification of the researched subjects, both developed and presented in the scope of this research.

In particular, expression (2) below represents the generalized pattern of the HCI subject's role, formed on the basis of a previously declared set of factors influencing the perception subjectivization of the given object of particular investigated HCI:

$$DRLh[k] = \{PFsh[j] = \{\overline{1, m}\} \vee \{0\}\}, j = \overline{1, m}, \quad (2)$$

where $DRLh[k]$ – k -th pattern of the subject's role, $PFsh[j]$ – the index value of the j -th impact factor in the current pattern of the role of subject (can acquire: either integer values in the range from "1" to "m", which corresponds to the dominance of the corresponding impact factor: from the most dominant with the value "1" to the least dominant with the value "m", or the value "0", which corresponds to the absence of corresponding impact factor for current role of the subject, which means, in other words, that the value "0" for a certain impact factor in the subject's role pattern indicates the absence of this particular specific impact factor in the formation of the given specific role of the subject), m – a total amount of previously declared impact factors within the researched interaction.

It should be worth noting right away that above-provided expression (2) is used for a strongly structured form of representation of the role identification model of the investigated HCI subjects, in scope of which the placement order of the dominant impact factors has an essential and fundamental importance, and the value of the index of the corresponding impact factor precisely provides this order, according to which: the value of index of the impact factor increases (from "1" to "m") with decreasing the level of its dominance within the multifactor portrait of the researched subject of the investigated HCI. In turn, expression (3) below represents the pattern of the role of subject, formed on the basis of a previously declared set of factors influencing the perception subjectivization of the interaction object of the investigated HCI, which is used for a weakly structured form of representation of the model of HCI subjects' role identification, in scope of which the placement order of the dominant impact factors is actually unimportant, so it could be just omitted or even completely taken out of consideration:

$$DRLl[k] = \{PFsh[j] = \{1\} \vee \{0\}\}, j = \overline{1, m}, \quad (3)$$

where $DRLl[k]$ is k -th pattern of the role of the subject, $PFsh[j]$ – the index value of the j -th impact factor in the current pattern of the role of the subject (can acquire either value "1", which indicates the presence of the contribution of this specific impact factor in formation of the given specific role of subject, or value "0", which indicates the absence of this specific impact factor in the formation of the given role of the subject), m – a total amount of previously declared impact factors within the researched interaction.

In fact, expression (3) is a partial representation of the set of variations obtained using previously described expression (2), with the only conceptual difference – that in the weakly structured form of representation (represented by expression (3)), the index value of any impact factor in the current considered role pattern of the subject can only take the values

of "1" or "0", while in the strongly structured form of representation (represented by expression (2)), the same index value can take both the same value "0" (which carries an absolutely identical semantic load of total absence of the corresponding specific impact factor in formation of the current role of the subject), and integer values greater than "1" ("2", "3", and so on, up to "m", where m is the total amount of these declared impact factors within the framework of the studied HCI) – precisely for the purpose of strict gradation of the dominance level of each of the impact factors which form the pattern of the current considered investigated role of the subject. Thus, the strongly structured form of representation of the role-based polycomponent model of the HCI subject can be interpreted using the following expression (4):

$$Sbh[i] = \{SbFsh[j] = \{\overline{1, q}\} \vee \{0\}\}, j = \overline{1, m}, \quad (4)$$

where $Sbh[i]$ – i -th researched subject of the considered HCI, $SbFsh[j]$ – the index value of the j -th impact factor in the current investigated role's polycomponent set for the researched subject (can take either integer values in the range from "1" to "q" – which corresponds to the dominance of the corresponding separate specific impact factor: from the most dominant with the value "1" to the least dominant with the value "q" from the set of "top-q" dominant impact factors, or the value "0" – for all subsequent impact factors, i.e., outside the considered "top-q" rating), q – the dimensionality of the considered polycomponent model, or in simpler words – the number of "top-q" dominant impact factors; m – a total amount of previously declared impact factors within the researched interaction.

In turn, the weakly structured form of representation of the role-based polycomponent model of the HCI subject can be interpreted using the following expression (5):

$$Sbl[i] = \{SbFsh[j] = \{1\} \vee \{0\}\}, j = \overline{1, m}, \quad (5)$$

where $Sbl[i]$ – i -th researched subject of the considered HCI, $SbFsh[j]$ – the index value of the j -th impact factor in the current investigated role's polycomponent set for the researched subject (can take either integer value "1", which indicates the presence of the corresponding specific impact factor inside the set of "top-q" dominant impact factors regardless of its position in this set, or the value "0" – for all subsequent impact factors, i.e., outside the considered "top-q" rating), q – the dimensionality of the considered polycomponent model, or in more simpler words – the number of "top-q" dominant impact factors; m – a total amount of previously declared impact factors within the researched interaction.

The final stage of the development of the proposed polycomponent model of HCI subjects' role identification is, actually, the determination of the specific subjects' role identification function within the framework of previously declared role patterns, which can be interpreted using the following expression (6):

$$Fri(Sbx[i], DRLx[k]) = \sum_{j=1}^m (Sbx[i].SbFsh[j] - DRLx[k].PFsh[j]), \quad (6)$$

where $Fri(Sbx[i], DRLx[k])$ – a role identification function of the i -th specific researched subject, represented by the corresponding (weakly structured or strongly structured) form of representation of its role’s polycomponent model in the context of a specific k -th role, represented by the corresponding representation form (i.e., weakly structured or strongly structured, but as mandatory as the representation form of the role’s polycomponent model for current specific researched subject), $Sbx[i]$ – i -th researched subject of the considered HCI, $Sbx[i].SbFsh[j]$ – the index value of the j -th impact factor in the current role’s polycomponent set of the i -th specific researched subject, $DRLx[k]$ – k -th pattern of the role of the subject, $DRLx[k].PFsh[j]$ – the index value of the j -th impact factor in the current pattern of separate specific k -th declared role, m – a total amount of previously declared impact factors within the researched interaction.

It is important to note that a prerequisite for the correct construction and functioning of the proposed model of HCI subjects’ role identification is the identity of the forms of representation of both the researched subject and the considered role. That is, in other words: if the form of representation of the researched subject is weakly structured, then the form of representation of the considered role (in the context of correspondence of this separate researched subject to this specific role) must be identical (i.e., in this case – also weakly structured), and vice versa: if the form of representation of the researched subject is strongly structured, then the form of representation of the considered role must also be strongly structured (not otherwise).

Thus, if the above-described mandatory condition for the correctness of the proposed role identification model is met, and the researched subject corresponds to the considered declared role, then at the output of the developed role identification function we will receive the value “0”, while any other, i.e., “non-zero” value will indicate that this separate specific researched subject does not correspond to this separate specific declared role under consideration.

In fact, the developed polycomponent model of HCI subjects’ role identification is represented by the entire batch of expressions (2)–(6) described above and provides the possibility of mathematical formalization and representation of the researched processes.

At the same time, a key feature of the developed model is the availability of two variations of its representation form, namely strongly structured (when the placement order of the dominant impact factors has a significant and fundamental importance), or weakly structured (when the placement order of the dominant impact factors is unimportant and could be just omitted), which provides an expansion of its functional capabilities area in the context of studying the issues of HCI subjects’ role identification, as well as the perception subjectivization of the HCI objects by its subjects.

The next stage in the development of the declared method presented within the framework of this study is, in fact, the development of a specialized algorithm for role identification of HCI subjects based on their multifactor portraits of perception subjectivization of HCI object, the flowchart of which is presented below, in Figure 1.

Description of the blocks of the flowchart is given below. In particular, block “1” is responsible for reading input data about the investigated HCI (i.e., object, subjects, impact factors, roles, etc.). Block “2” is responsible for reading

situational cases for modeling the perception subjectivization of HCI object by all HCI subjects, existing within the framework of the investigated HCI. Block “3” represents the procedure for synthesis of multifactor portraits of the subjects of the investigated HCI based on the results of modeling a relevant situational cases (for each separate subject) using the aforementioned existing impact factors reverse analysis method. Block “4” represents the procedure for synthesis of the patterns for each role, e.g., $DRLx[k].PFsh[j]$ ($j=[1..m];k=[1..npr]$), where m is a total amount of the declared impact factors, while npr is a total amount of the declared role patterns.

Block “5” is a loop limit start, responsible for sequential enumeration of all subjects, e.g., $i=1;i++;i<=nsb$, where nsb is a total amount of the considered subjects within the framework of the investigated HCI, together with the appropriate loop limit end block “9”. Block “6” is responsible for cloning the original multi-factor portrait of current specific subject for j in range (1, m), i.e., $SbC[i][j]=Sb[i][j]$. Block “7” represents the procedure of sorting $SbC[i][1..m]$ by decreasing a share of influence of impact factors 1. m . Block “8” represents the procedure of filling the role in a polycomponent model of the current researched subject $Sbx[i].SbFsh[j]$ ($j=[1..m]$) based on comparison of the position values between the sorted $SbC[i][1..m]$ and the original $Sb[i][1..m]$ multifactor portraits. Block “9” is a loop limit end for loop started at block “5”.

Moving forward, block “10” is a loop limit start, responsible for sequential enumeration of all subjects, e.g., $i=1;i++;i<=nsb$, where nsb is a total amount of the considered subjects within the framework of the investigated HCI, together with the appropriate loop limit end block “20”. While block “11” is a loop limit start, responsible for sequential enumeration of all roles, e.g., $k=1;k++;k<=npr$, where npr is a total amount of the declared role patterns within the framework of the investigated HCI, together with the appropriate loop limit end block “19”. Block “12” represents a branching for the condition formulated as “Are the representation forms of subject and role identical?”: if No (i.e., condition is not met), then algorithm moves to block “13” (which is responsible for the process of form correction, i.e., strongly structured versus weakly structured, or vice versa); if Yes (i.e., condition is met), then algorithm moves forward to block “14” which calculates $ds=Fri(Sbx[i],DRLx[k])$ by means of the afore-mentioned role identification function, presented above by expression (6). Block “15” represents a branching for condition formulated as “ $ds = 0$?”: if No – then algorithm moves to block “16” which is responsible for making decision on non-compliance of the considered subject to the considered role pattern (i.e., $Sb[i] \notin DRLx[k]$); if Yes, then algorithm moves to block “17” which is responsible for making decision on compliance of the considered subject to the considered role pattern (i.e., $Sb[i] \in DRLx[k]$). Block “18” performs saving/storing of the obtained results. Block “19” is a loop limit end for loop started at block “11”. While block “20” is a loop limit end for loop started at block “10”. Finally block “21” performs output of the obtained results.

The functioning of the developed algorithm occurs in the following way. At the initial stage, the input data about the investigated HCI (i.e., object, subjects, impact factors, roles, etc.) are read (block “1”). Right after that, situational cases (for modelling the perception subjectivization of HCI object by HCI subjects) are read as well (block “2”). The next stage is the

implementation/execution of the procedure for synthesis of the multifactor portraits of the subjects of the investigated HCI based on the results of modelling a relevant situational cases (for each separate subject) using the impact factors reverse analysis method (block “3”), and right after that – implementation/execution of another procedure, i.e., for synthesis of patterns for each role (block “4”), is performed. Next, a cycle of sequential enumeration of all researched subjects is performed (limited by loop limit start block “5” and loop limit end block “9”), within which the following operations are implemented step by step, namely such operations as: cloning the original multi-factor portrait of the current specific subject (block “6”); calling the procedure for sorting cloned portrait in descending order of the share of influence of impact factors (block “7”); as well as calling the procedure for filling the role in a polycomponent model of the current researched subject based on the comparison of the position values between the sorted and the original multifactor portraits (block “8”).

Right after that, the algorithm enters the following two cycles/loops: the outer loop of enumerating all the researched subjects (limited by loop limit start block “10” and loop limit end block “20”), and the inner loop to iterate through all the declared roles (limited by loop limit start block “11” and loop limit end block “19”). Already within the inner loop, the following operations are performed step by step, namely condition for verifying the identity of the subject representation form and the role representation form (block “12”), where in case of negative result the representation form of the specific considered role is corrected in order to match the representation form of the corresponding researched subject (block “13”) and returning to the original condition (block “12”) occurs for the revalidation purpose, while in case of positive result the appropriate deviation value is calculated (i.e., $ds = \text{Fri}(\text{Sbx}[i], \text{DRLx}[k])$) by means of the afore-mentioned role identification function, presented above by expression (6) (block “14”) after which the condition of zero deviation value is checked (block “15”), where in case of negative result it is stated and confirmed that the current specific subject does not belong to the current specific role (block “16”), while in case of positive result the current specific considered subject's belonging to the current specific role is ascertained and confirmed (block “17”); and after that the obtained results are saved (block “18”).

Upon completion of the outer loop (enumeration of all the researched subjects limited by loop limit start block “10” and loop limit end block “20”) the algorithm proceeds to the final operation of outputting the obtained results (block “21”), which completes the entire algorithm.

At the same time, the developed specialized algorithm provides the possibility of automation, as well as further software implementation and computer modeling of the studied processes of HCI subjects' role identification based on their multifactor portraits.

Thus, HCI subjects' role identification method is developed, which is based on the multifactor portraits of perception subjectivization of HCI object that is fully based on the corresponding developed model and specialized algorithm, and provides possibility to solve relevant scientific and applied problems in the context of the research into the issues of HCI teams' formation and increasing the level of automation and intellectualization of the constituent components of HCI.

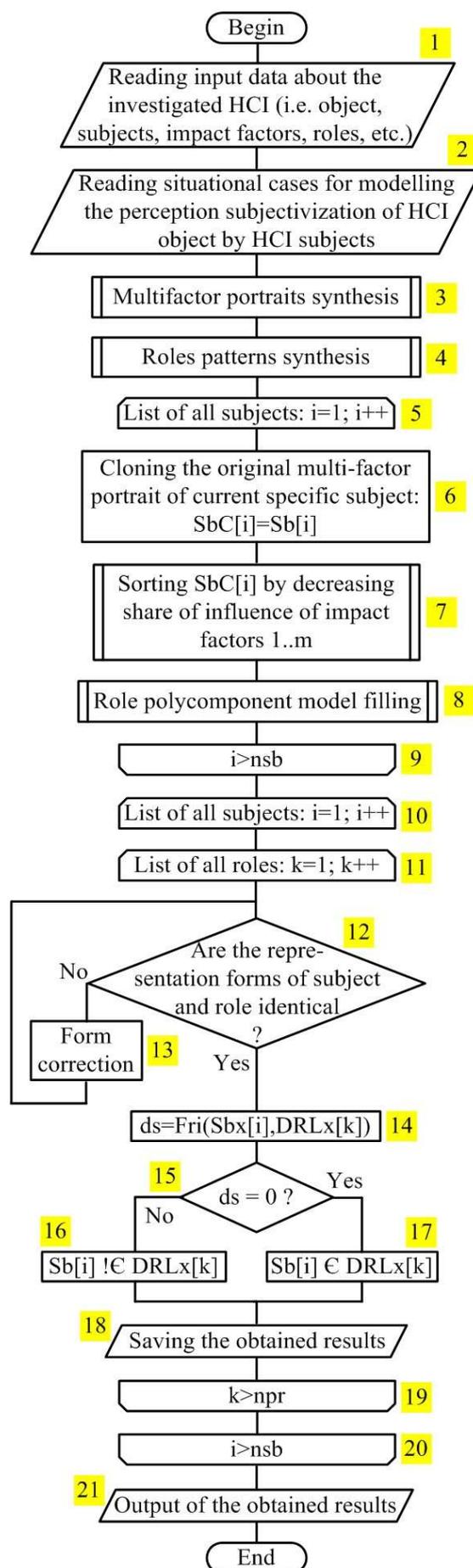


Figure 1. A flowchart of the specialized developed algorithm for HCI subjects' role identification.

III. RESULTS

Thanks to the developed polycomponent model of HCI subjects' role identification, as well as the corresponding specialized algorithm, which together constitute the fundamental basis of the developed method, a practical (software) implementation of the latter has been carried out, as well as its further applied approbation on the example of solving a relevant practical applied task of identifying a potential candidate(s) from among all available into the highly specialized support team of the given software product based on their compliance with the declared role pattern.

In particular, the programming implementation of the developed method is performed using the Python 3.12 [20] programming language and the Thonny 4.1.4 [21, 22] integrated development environment (IDE). The main arguments for choosing this particular configuration of the development environment for software implementation of the declared method were, among other things, such factors as: simple and concise syntax, free access, low resource consumption of hardware of the PC, where it should be installed, compiled and executed, popularity among researchers and scientists in the field of artificial intelligence, as well as the presence of a large number and variety of existing libraries of narrow-profile and specialized tools, and many others.

The developed software implementation of the proposed method fully corresponds to its considered fundamental components (i.e., the model and the algorithm) of functioning, and allows us to obtain a list of the identified subjects of the investigated HCI at the output, which fully correspond to the given subject role, both within the framework of a weakly structured form of representation and within the framework of a strongly structured form of representation. In this case, the following components are used as input data: a set of multifactor portraits of the subjects of investigated HCI, a declared role patterns of HCI subjects, as well as the depth parameter of the polycomponent analysis (the latter is responsible for the number of "top" impact factors that will be taken into account when comparing patterns of the given role(s) and researched subjects). So, let us consider in more details the obtained functioning results of the developed method and its software implementation using the provided example of solving the relevant practical applied task of identifying a potential candidate(s) from among all available into the highly specialized support team of the given software product based on their compliance with the declared role pattern.

The solution to the considered practical applied task begins with the analysis of input data, which are multifactor portraits of all researched subjects of the investigated HCI, which in this separate case, is the interaction between the subjects of support team (of a given software product) and, in fact, this software product itself, in the context of the factors of perception subjectivization of the latter by the former.

In particular, below, in Table 1, the input multifactor portraits of the research subjects (e.g., candidates for the highly specialized support team of a given software product) are displayed, where "Sbj" is a column for designating the researched HCI subjects (S1–S21), while columns F1–F11 represent the corresponding declared impact factors (influencing the perception subjectivization of the common HCI object by each separate HCI subject).

Table 1. Multifactor portraits of researched subjects (candidates)

Sbj	F1	F2	F3	F4	F5	F6	F7	F8	F9	F10	F11
S1	.107	.042	.232	.077	.022	.089	.035	.187	.021	.147	.041
S2	.216	.041	.098	.081	.057	.077	.188	.023	.107	.073	.039
S3	.083	.036	.028	.184	.150	.104	.156	.070	.136	.029	.024
S4	.191	.045	.096	.147	.174	.136	.029	.063	.077	.019	.023
S5	.081	.119	.139	.052	.125	.029	.101	.128	.017	.027	.182
S6	.152	.044	.054	.102	.051	.025	.121	.088	.211	.088	.064
S7	.057	.179	.064	.088	.048	.086	.027	.116	.075	.145	.115
S8	.193	.068	.016	.099	.150	.127	.029	.076	.086	.041	.115
S9	.079	.059	.048	.056	.212	.035	.076	.059	.173	.018	.185
S10	.044	.143	.144	.105	.098	.066	.047	.033	.073	.184	.063
S11	.096	.072	.203	.118	.068	.041	.107	.119	.042	.053	.081
S12	.034	.091	.054	.175	.186	.075	.115	.168	.041	.016	.045
S13	.214	.093	.093	.068	.056	.021	.146	.065	.116	.077	.051
S14	.139	.041	.012	.026	.057	.089	.183	.121	.173	.108	.051
S15	.023	.029	.068	.102	.096	.195	.121	.065	.111	.015	.175
S16	.094	.068	.077	.017	.085	.067	.189	.046	.253	.036	.068
S17	.187	.078	.076	.031	.128	.032	.091	.092	.102	.070	.113
S18	.165	.127	.065	.115	.079	.021	.159	.024	.129	.062	.054
S19	.074	.021	.152	.051	.056	.107	.033	.042	.096	.171	.197
S20	.139	.087	.103	.058	.083	.018	.108	.071	.174	.058	.101
S21	.200	.106	.059	.212	.132	.013	.015	.034	.037	.175	.017

In addition, and as a visual supplement, Figure 2 below represents a graphical visualization of the multifactor portraits of the researched subjects–candidates.

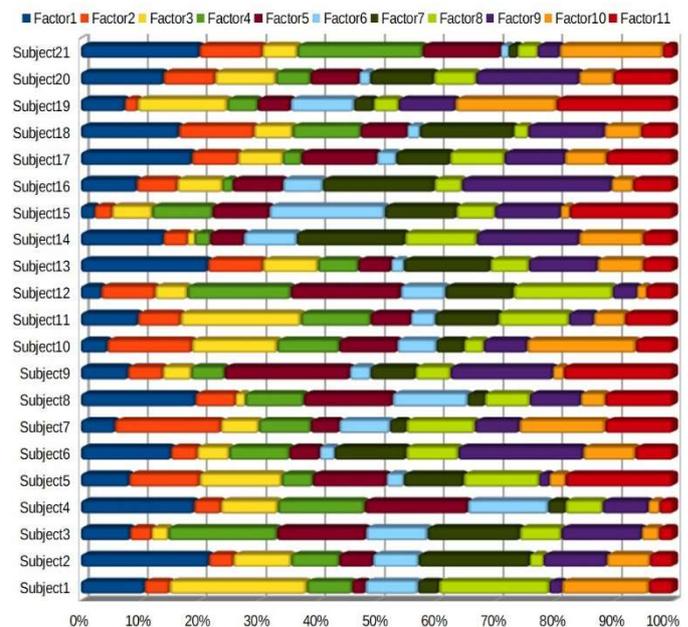


Figure 2. A graphical visualization of the multifactor portraits of the researched subjects–candidates.

At the same time, another, and, in fact, the determining input parameter is the given role pattern, precisely on the basis of which the selection of candidates for the highly specialized support team of a given software product takes place.

In particular, Figure 3 below displays a graphical visualization of the declared role pattern of the considered practical applied task being solved, which, in fact, represents a 3–component role pattern model, where the impact factor F1 is the most dominant among all (since its ordinal number is 1), the impact factor F7 ranks second in the ranking of the most dominant impact factors (hence its ordinal number is 2), and the impact factor F9, actually, closes the ranking of the top 3 most dominant impact factors (and, accordingly, its ordinal number is 3).

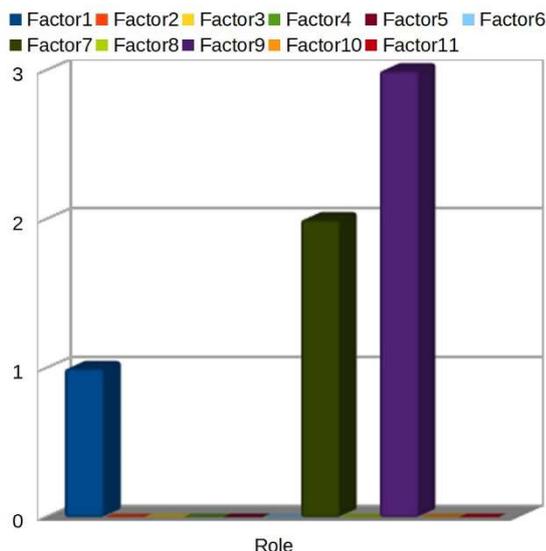


Figure 3. A graphical visualization of the strongly structured form of representation of the declared role pattern.

It should be worth noting right away that the interpretation of the declared pattern of the given role of the considered practical applied task being solved, presented above, corresponds to its strongly structured form of representation, because the ordinal number of its elements is important here in this case.

Whereas, for example, Figure 4 below demonstrates a graphical visualization of another one (the weakly structured) form of representation of exactly the same declared and considered role pattern.

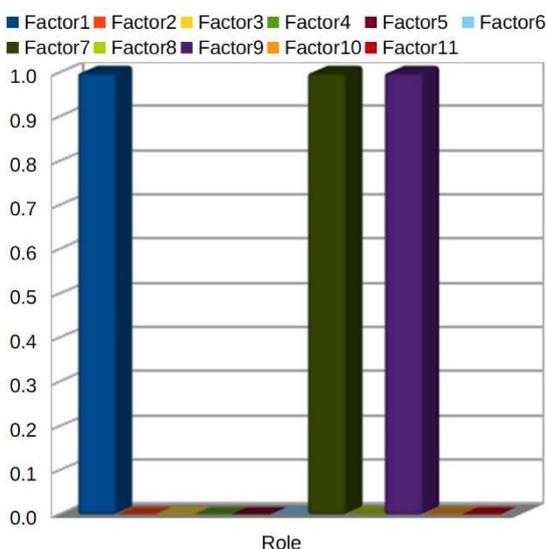


Figure 4. A graphical visualization of the weakly structured form of representation of the declared role pattern.

The next stage in solving the considered practical applied task is identifying the top 3 dominant impact factors in the multifactor portraits of each of the researched subjects – candidates for the highly specialized support team of a given software product, and their comparison with the pattern of the given role.

In particular, Figure 5 below represents a graphical visualization of the results of identifying the top 3 dominant impact factors in the multifactor portraits of each of the researched subjects–candidates.

Sbj	F1	F2	F3	F4	F5	F6	F7	F8	F9	F10	F11
S1	.107	.042	.232	.077	.022	.089	.035	.187	.021	.147	.041
S2	.216	.041	.098	.081	.057	.077	.188	.023	.107	.073	.039
S3	.083	.036	.028	.184	.150	.104	.156	.070	.136	.029	.024
S4	.191	.045	.096	.147	.174	.136	.029	.063	.077	.019	.023
S5	.081	.119	.139	.052	.125	.029	.101	.128	.017	.027	.182
S6	.152	.044	.054	.102	.051	.025	.121	.088	.211	.088	.064
S7	.057	.179	.064	.088	.048	.086	.027	.116	.075	.145	.115
S8	.193	.068	.016	.099	.150	.127	.029	.076	.086	.041	.115
S9	.079	.059	.048	.056	.212	.035	.076	.059	.173	.018	.185
S10	.044	.143	.144	.105	.098	.066	.047	.033	.073	.184	.063
S11	.096	.072	.203	.118	.068	.041	.107	.119	.042	.053	.081
S12	.034	.091	.054	.175	.186	.075	.115	.168	.041	.016	.045
S13	.214	.093	.093	.068	.056	.021	.146	.065	.116	.077	.051
S14	.139	.041	.012	.026	.057	.089	.183	.121	.173	.108	.051
S15	.023	.029	.068	.102	.096	.195	.121	.065	.111	.015	.175
S16	.094	.068	.077	.017	.085	.067	.189	.046	.253	.036	.068
S17	.187	.078	.076	.031	.128	.032	.091	.092	.102	.070	.113
S18	.165	.127	.065	.115	.079	.021	.159	.024	.129	.062	.054
S19	.074	.021	.152	.051	.056	.107	.033	.042	.096	.171	.197
S20	.139	.087	.103	.058	.083	.018	.108	.071	.174	.058	.101
S21	.200	.106	.059	.212	.132	.013	.015	.034	.037	.175	.017

Legend: 1-st dominant 2-nd dominant 3-rd dominant

Figure 5. The results of identifying the top 3 dominant impact factors in the multifactor portraits of each of the researched subjects–candidates.

At the same time, Figure 6 below represents a graphical visualization of the obtained results of identifying potential candidates based on the use of a weakly structured form of representation of the identification model role of the developed method.

Sbj	F1	F2	F3	F4	F5	F6	F7	F8	F9	F10	F11
S1	.107	.042	.232	.077	.022	.089	.035	.187	.021	.147	.041
S2	.216	.041	.098	.081	.057	.077	.188	.023	.107	.073	.039
S3	.083	.036	.028	.184	.150	.104	.156	.070	.136	.029	.024
S4	.191	.045	.096	.147	.174	.136	.029	.063	.077	.019	.023
S5	.081	.119	.139	.052	.125	.029	.101	.128	.017	.027	.182
S6	.152	.044	.054	.102	.051	.025	.121	.088	.211	.088	.064
S7	.057	.179	.064	.088	.048	.086	.027	.116	.075	.145	.115
S8	.193	.068	.016	.099	.150	.127	.029	.076	.086	.041	.115
S9	.079	.059	.048	.056	.212	.035	.076	.059	.173	.018	.185
S10	.044	.143	.144	.105	.098	.066	.047	.033	.073	.184	.063
S11	.096	.072	.203	.118	.068	.041	.107	.119	.042	.053	.081
S12	.034	.091	.054	.175	.186	.075	.115	.168	.041	.016	.045
S13	.214	.093	.093	.068	.056	.021	.146	.065	.116	.077	.051
S14	.139	.041	.012	.026	.057	.089	.183	.121	.173	.108	.051
S15	.023	.029	.068	.102	.096	.195	.121	.065	.111	.015	.175
S16	.094	.068	.077	.017	.085	.067	.189	.046	.253	.036	.068
S17	.187	.078	.076	.031	.128	.032	.091	.092	.102	.070	.113
S18	.165	.127	.065	.115	.079	.021	.159	.024	.129	.062	.054
S19	.074	.021	.152	.051	.056	.107	.033	.042	.096	.171	.197
S20	.139	.087	.103	.058	.083	.018	.108	.071	.174	.058	.101
S21	.200	.106	.059	.212	.132	.013	.015	.034	.037	.175	.017

Legend: 1-st dominant 2-nd dominant 3-rd dominant

Figure 6. Results of identification of potential candidates based on the use of a weakly structured form of representation of role identification of the researched subjects–candidates.

Whereas, Figure 7 below represents the results of solving the considered practical applied task of identifying a potential candidate(s) from among all available into the highly

specialized support team of the given software product based on their compliance with the declared role pattern applying the developed method, in particular based on the usage of a highly structured form of representation of the role identification model of the researched subjects (and the declared role pattern).

Sbj	F1	F2	F3	F4	F5	F6	F7	F8	F9	F10	F11
S1	.107	.042	.232	.077	.022	.089	.035	.187	.021	.147	.041
S2	.216	.041	.098	.081	.057	.077	.188	.023	.107	.073	.039
S3	.083	.036	.028	.184	.150	.104	.156	.070	.136	.029	.024
S4	.191	.045	.096	.147	.174	.136	.029	.063	.077	.019	.023
S5	.081	.119	.139	.052	.125	.029	.101	.128	.017	.027	.182
S6	.152	.044	.054	.102	.051	.025	.121	.088	.211	.088	.064
S7	.057	.179	.064	.088	.048	.086	.027	.116	.075	.145	.115
S8	.193	.068	.016	.099	.150	.127	.029	.076	.086	.041	.115
S9	.079	.059	.048	.056	.212	.035	.076	.059	.173	.018	.185
S10	.044	.143	.144	.105	.098	.066	.047	.033	.073	.184	.063
S11	.096	.072	.203	.118	.068	.041	.107	.119	.042	.053	.081
S12	.034	.091	.054	.175	.186	.075	.115	.168	.041	.016	.045
S13	.214	.093	.093	.068	.056	.021	.146	.065	.116	.077	.051
S14	.139	.041	.012	.026	.057	.089	.183	.023	.107	.073	.039
S15	.023	.029	.068	.102	.096	.195	.121	.065	.111	.015	.175
S16	.094	.068	.077	.017	.085	.067	.189	.046	.253	.036	.068
S17	.187	.078	.076	.031	.128	.032	.091	.092	.102	.070	.113
S18	.165	.127	.065	.115	.079	.021	.159	.024	.129	.062	.054
S19	.074	.021	.152	.051	.056	.107	.033	.042	.096	.171	.197
S20	.139	.087	.103	.058	.083	.018	.108	.071	.174	.058	.101
S21	.200	.106	.059	.212	.132	.013	.034	.037	.175	.017	

Legend: 1-st dominant 2-nd dominant 3-rd dominant

Figure 7. Results of solving the considered practical applied task, obtained based on the usage of a highly structured form of representation of the role identification model of researched subjects–candidates and the declared role pattern.

In addition, Figure 8 below demonstrates the same results of solving the considered practical applied task of identifying a potential candidate(s) from among all available into the highly specialized support team of the given software product based on their compliance with the declared role pattern, obtained using the developed software implementation of the proposed method (i.e., HCI subjects’ role identification method based on their multifactor portraits of perception subjectivization of HCI object), performed on the basis of aforementioned development configuration environment which consists of Python 3.12 programming language and Thonny 4.1.4 IDE.

Thus, using the developed method, namely the HCI subjects’ role identification method based on their multifactor portraits of perception subjectivization of HCI object, the relevant experimental practical applied task of identifying a potential candidate(s) from among all available into the highly specialized support team of the given software product based on their individual multifactor portraits compliance with the declared specific role pattern has been successfully solved, while the obtained results in solving this example task demonstrate the effectiveness and the potential of the proposed approach (method) in solving various similar and/or relevant practical applied tasks and problems.

In the context of discussions and deliberations of the obtained results, as well as comparisons with the outcome of the results of similar existing approaches, the following information is processed and the corresponding conclusions are drawn.

Figure 8. Results obtained due to the functioning of the developed software realization of the proposed method, implemented in Python 3.12 and Thonny 4.1.4 IDE.

In particular, in research [23] the authors investigated the trust factor as one of the relevant HCI factors, based on a comprehensive review of numerous existing researches using the theories of studying the formation and development of trust, which offer a number of insights into the cognitive, social, and relational aspects of trust, emphasizing its multi-dimensional nature, contributing to the understanding of the complexity of trust factor(s) in HCI, emphasizing, among other things, the identification of common features between different trust

models and the assessment of their applicability for technologically complicated and complex systems. At the same time, in another research [24], the authors investigated the impact of HCI on the quality of educational processes based, in particular, on the analysis of various influencing factors, such as the impact of HCI on the quality of teachers, learning management systems, as well as on the quality of the educational content itself, where the methodology of online questionnaires and the practical tools of the existing SPSS software were used as the main tools for analyzing these influence factors. Whereas, study [25] is devoted to the analysis of HCI usability factors based on the example of using existing software products, such as Google Classroom and Microsoft Teams focusing, among other things, on such factors of HCI usability as learning ability, efficiency, memorability, errors, and satisfaction, using appropriate methodological tools for a separate assessment of each of them, including, in particular, the statistical methods of Cronbach's Alpha or Interclass Correlation Coefficients for determining the reliability coefficient, as well as the correlation formula of Pearson's Product Moment to determine the validity of the questionnaire itself. In turn, research [26] explored the integration of emotional, cognitive and interactive processes and impact factors in scope of the development of educational technologies through the prism of HCI, proposing a theoretical holistic framework that integrates usability, emotional intelligence and adaptive interaction, applying cognitive load theory, emotional intelligence theory and self-determination theory to assess their effectiveness, integrating psychological principles to increase engagement, motivation and results of HCI especially in the context of educational technologies. The authors of research [27] investigated the issue of human perception of HCI–interaction with conversational agents, and how the personality of both the conversational agents themselves and the user(s) (e.g., human) can influence the experience of this interaction, also studying whether different manifestations of extraversion in speech style lead to a more anthropomorphized perception (in particular, the perception of humanity and social presence) of the personality of bots (i.e., conversational agents), noting that highly extroverted conversational agents are usually better perceived in terms of social presence and enjoyment of communication, developing the concept of personality-adaptive conversational agents and HCI as a whole.

However, the main and unique feature of the developed method, namely HCI subjects' role identification method based on their multifactor portraits of perception subjectivization of HCI object, in contrast to presently existing similar approaches and solutions, is, in fact, its ability to take into account precisely the factors of perception subjectivization of the objects (or processes, or even other subjects) of HCI, providing the possibility of formalizing the representation and deeper research of this non-trivial irrational component of any intersubjective interaction, thereby revealing the prospects for further research beyond the exclusively HCI field, but, instead, taking into account any intersubjective interaction, in general, regardless of even its context or applied field of application.

IV. CONCLUSIONS

Within the framework of current research, a specialized novel method of HCI subjects' role identification based on their multifactor portraits of perception subjectivization of HCI object is developed and described in details. The developed method provides the possibility of increasing the level of

automation and intellectualization of HCI by additionally taking into account the relevant factor of perception subjectivization of the object of interaction by the subjects of this interaction.

One of the fundamental basis of the proposed method is the developed polycomponent model of HCI subjects' role identification, which can contain any (and necessary) number of previously declared impact factors as its constituent components, and provides the possibility of mathematical formalization and representation of relevant researched processes. At the same time, a key feature of the developed model is the presence of its two main developed variations of the representation form, namely a highly structured (where the placement order of the dominant impact factors has significant and fundamental importance), or a weakly structured (where the placement order of the dominant impact factors is quite unimportant, and could be just omitted), which provide an expansion of its functional capabilities area in the context of studying the issues of HCI subjects' role identification, as well as the perception subjectivization of the HCI objects by its subjects.

Another fundamental basis of the proposed method is the developed specialized algorithm for HCI subjects' role identification based on their multifactor portrait of perception subjectivization of the object of interaction, which provides the possibility of structuring and automation, as well as further software (i.e., programming) implementation and computer modeling of the researched processes (of HCI subjects' role identification).

In addition, as a practical approbation of the developed method, the latter has been used to solve a relevant practical applied task of identifying a potential candidate(s) from among all available into the highly specialized support team of the given software product based on their compliance with the declared role pattern. In particular, within the framework of the resolved practical applied task, a 21 x 11 two-dimensional space has been considered, where 21 is the amount of subjects within the studied HCI, while 11 is the amount of declared roles (or role patterns) within the same studied HCI. In this case, the identification of the correspondence of subjects to roles has been implemented on the basis of a 3-component model taking into account the relevant progressive chain of deep dominance of the 3rd order both for the considered role pattern as well as for all available subjects within the framework of studied HCI. At the same time, in the process of solving the considered practical applied task, the application of both weakly structured and strongly structured variations of the developed role identification model's representation forms has been implemented in practice, which clearly demonstrates their main difference. In general, the obtained results confirm the effectiveness of the developed method, as well as its prospects in the context of further research in the field of automation and intellectualization of relevant components of HCI (as well as any intersubjective interaction in general).

As prospects of further research, the authors see the potential for further application and development of the proposed method, models, solutions and approaches both in the context of the researched issues of investigating the factors influencing the HCI (and, in general for intersubjective interactions of any existing types, variations, or forms) objects' perception subjectivization, and in various applied areas of application, including, in particular, such promising ones as sociotics, cybernetic psychology, neuroengineering, and many

others, where the factor of the researched objects' (or processes') perception subjectivization plays an extremely important and/or significant role.

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