

METHOD FOR HCI USERS IDENTIFICATION BASED ON THEIR "POLYFACTOR PORTRAITS" OF PERCEPTION SUBJECTIVIZATION OF HCI OBJECT

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Abstract. This paper addresses the critical problem of user identification within the framework of human-computer interaction (HCI). A novel identification method is proposed based on users' "polyfactor portraits." These portraits effectively reflect how individuals subjectively perceive specific HCI objects. The primary objective of this approach is to model the irrational components of human behavior, thereby improving system automation and intellectualization. Structurally, the developed method integrates a specialized identification algorithm with a core supporting mathematical model. To validate the efficiency of the proposed approach, a comprehensive practical experiment was conducted. This experiment involved the identification of technical support team members based on the dominant features of their interaction with a specific supported software product. The experimental results confirm the applicability of the method. Finally, the paper outlines future research directions aimed at potential improvements, technical enhancements, and broader practical applications of this identification method in real-world systems.

Keywords: human-software interaction, irrational component of human-software interaction, irrational influence factors, HCI automation, HCI intellectualization

METODA IDENTYFIKACJI OPERATORÓW HCI W OPARCIU O ICH "PORTRETY WIELOCZYNNIKOWE" SUBIEKTYWIZACJI POSTRZEGANIA OBIEKTU HCI

Streszczenie. W niniejszym artykule poruszono kluczowy problem identyfikacji operatorów w kontekście interakcji człowiek-komputer (HCI). Zaproponowano nowatorską metodę identyfikacji opartą na "portretach wieloczynnikowych" użytkowników. Portrety te skutecznie odzwierciedlają sposób, w jaki poszczególne osoby subiektywnie postrzegają konkretne obiekty HCI. Głównym celem tego podejścia jest modelowanie irracjonalnych elementów ludzkiego zachowania, co ma na celu poprawę automatyzacji i intelektualizacji systemu. Pod względem strukturalnym opracowana metoda łączy wyspecjalizowany algorytm identyfikacji z podstawowym modelem matematycznym. W celu zweryfikowania skuteczności proponowanego podejścia przeprowadzono kompleksowy eksperyment praktyczny. Eksperyment ten polegał na identyfikacji członków zespołu wsparcia technicznego na podstawie dominujących cech ich interakcji z konkretnym obsługiwanym oprogramowaniem. Wyniki eksperymentu potwierdzają przydatność tej metody. Na zakończenie w artykule nakreślono kierunki przyszłych badań mające na celu potencjalne ulepszenia, udoskonalenia techniczne oraz szersze praktyczne zastosowania tej metody identyfikacji w rzeczywistych systemach.

Słowa kluczowe: interakcja człowiek-oprogramowanie, irracjonalny składnik interakcji człowiek-oprogramowanie, irracjonalne czynniki wpływu, automatyzacja HCI, intelektualizacja HCI

Introduction

A relevant trend in global IT market nowadays is the emphasis on automation and intellectualization of human-machine, human-computer, and human-software interaction, as well as all possible types and species of their manifestations, one of which is, in particular, a comprehensive support of software products, and all its constituent parts and components, like: architectural solutions; development/coding; testing; configuration management; environments synthesis; compilation; deployment; debugging; delivery; customer services; technical support; business analytics; system engineering; social engineering; marketing; and others.

It should be worth noting right away that a significant part of the considered processes of a comprehensive support of software products (for example, automated testing, automated deployment of environments, automated product assembly, automated registration and processing of internal/external requests, and many others) is being already quite well automated in the context of rational component of this manifestation of HCI.

While, in the context of irrational component of HCI (one of the most striking and significant manifestations of which is, actually, the personified perception of the common object of HCI by various HCI subjects), there is a noticeable gap in the context of relevant existing both scientific-applied as well as practical-applied researches.

Thus, the HCI object(s) perception subjectivization (where the human component acts as the subject of this interaction, while the computer component, represented, including, by the supported software product(s), acts as the object of this interaction) plays one of the key roles in the efficiency and the effectiveness of such intersubjective interaction, because any differences in the subjective vision (or perception) of a common object of interaction between different subjects of this same interaction – lead to misunderstandings, disagreements, and lack of coordination

between these subjects, directly negatively affecting the results of their joint efforts in the context of interaction with this common object.

At the same time, in the context of the above-described issues, it is extremely important to understand the specifics of the personalized perception of the object of interaction – by each of the subjects of this same interaction, moderating and combining the subjects with each other in such a way so that ensure maximum efficiency and effectiveness from their symbiosis and cooperation.

As a result, we get the need to ensure the possibility of identifying HCI subjects based on their polyfactor portraits of perception subjectivization of HCI object. Hence, a relevant scientific and applied problem arises.

Object of research – is the process of identification the HCI subjects based on their polyfactor portraits of perception subjectivization of HCI object.

Subject of research – methods and means of artificial intelligence (AI), in particular artificial neural networks of a multilayer perceptron type, as well as methods and means of algorithmic, mathematical, and computer modelling, as well as software programming.

The goal of the research – is the development of a method for identifying HCI subjects based on their polyfactor portraits of perception subjectivization of HCI object.

To achieve this goal, the following main research objectives have been identified:

- performing an analysis of the subject area of HCI, its manifestations, as well as features in the context of problematics of automation and intellectualization of a comprehensive support of software products (as one of the most relevant manifestations of HCI);
- development of an algorithm for HCI subjects identification based on their polyfactor portraits of perception subjectivization of HCI object;



- development of a basic mathematical model for identifying HCI subjects based on their polyfactor portraits of perception subjectivization of HCI object;
- development of the software implementation of the developed method;
- performing a practical approbation of the developed method on the example of solving a relevant experimental practical applied problem.

This research represents a full cycle of development and practical approbation of a method designed to solve the declared scientific and applied problem of HCI subjects identification based on their polyfactor portraits of perception subjectivization of the object of this interaction.

1. Analysis of recent researches and publications

The analysis of recent researches and publications has been carried out both in the context of field of HCI, as well as the specifics of automation and intellectualization of a comprehensive support of software products as one of the most vivid, relevant and widespread manifestations of HCI.

In particular, in the research [4], the author reveals the fundamental principles of the HCI generalized concept, as well as the influence of human factors engineering principles, including those particular one performing relevant impact on this type of interaction.

While, another research [15] defines HCI as a sequence of protocols, dialogues, and actions in scope of which humans participate to communicate (interact) with machines (computers), all of which involve data input and/or control through a graphical (user) interface to achieve a desired result.

At the same time, we would like to note that nowadays the main efforts of HCI researchers and developers are aimed precisely at using alternative methods of communication and interaction (between humans and computers/machines), which, unlike the classic graphical user interface (GUI), are more natural for humans, that is, for example:

- natural human language recognition, represented in researches [29, 30];
- gesture recognition, considered in scope of relevant researches [6, 12, 16];
- even interactions based on the conversion of human brain signals [24];
- as well as many other possible alternatives to the "classic" GUI concept.

At the same time, all the principles of HCI operate, in particular, within the framework of a comprehensive support of software products, as one of the most vivid, relevant and widespread implementations and/or manifestations of this type of interaction.

Let's note right away that by comprehensive support of software products we mean the entire range of activities aimed at maintaining the viability of these software products as well as their correct functioning.

Thus, this concept includes the development of software products, their testing, the formation of deployment environments, the formation of functional and non-functional requirements, customer and technical support, systems engineering, and the entire complex spectrum of modern software development life cycle (SDLC) processes.

At the same time, the main efforts of researchers of each of these components of a comprehensive support for software products are focused on ensuring the maximum level of automation and intellectualization of the latter.

In particular, work [1] represents the authors' research in the context of a relevant topic regarding the possibilities of future cooperation between humans and AI in the field of software development, the implementation of which is actually being carried out in front of our eyes, even within the framework of the present.

The confirmation of the previous hypothesis is, in particular, the work [2], where authors have investigated and described the positive effect of reducing the time of software development with the help of appropriate AI-tools, which ensure the improvement of human-AI cooperation in this area.

At the same time, another work [7] represents the authors' research on the impact and role of AI in the context of software testing automation area. Meanwhile, work [9] expands and complements the list of such components as: AI, machine learning, and the Internet of Things (IoT), to revolutionize software testing.

In addition, work [28] explores the evolution of AI in the field of software testing – from its very initial stage in the form of simple automation scripts, to, in fact, AI capable of providing not only the automation of routine processes, but also a certain level of its intellectualization.

Besides that, research [13] develops this direction further, studying the features of AI-based automation of chatbot testing (which, in turn, are themselves a form of AI, i.e. the main "paradox" here in this situation is, actually, the use of AI for testing AI in the context of developing and testing intelligent software products).

At the same time, another research [3] considers DevOps and AIOps as the main catalysts of digital transformation in the era of automated operations in the context of software development and comprehensive support.

While, in scope of another research [8], the authors consider integrating AI with DevOps as a way to improve continuous delivery, automation, and predictive analytics for high-performance software development.

In addition, authors of another research [17] explore future forecasts regarding the prospects for the development of continuous integration, continuous delivery, and automation in software infrastructure management, by integrating AI into DevOps pipelines.

In turn, the research [25] is devoted to the authors' review of new challenges in the context of AI in software engineering, while another research [22] considers and analyses software engineering and AI in the context of improving the entire SDLC.

While the authors of another research [10] have conducted investigation of issue related to increasing the efficiency of resolving technical support requests using AI-driven learning and adaptation models, in particular in the context of implementing generative AI in technical support systems.

Thus, based on the conducted comprehensive analysis of recent researches and publications in the context of considered problematics, we clearly state the relevance of the issue of automation and intellectualization of both HCI (as a whole), as well as the constituent components of a comprehensive support for software products (as one of the most relevant and full-fledged manifestations of HCI).

A fairly popular and proven effective way to ensure, implement and increase this automation and intellectualization (of HCI, and all its relevant manifestations) – are precisely AI technologies, which make it possible to automate the relevant processes with the appropriate level of their intellectual (or, more truthfully, pseudo-intellectual) component.

At the same time, existing solutions for automation and intellectualization of HCI, and, in particular, a comprehensive support of software products, provide the ability to take into account mainly rational factors of influence (for example, such as: cost, speed, profitability, bandwidth, etc.), as well as only some limited variation of factors from the category of irrational components, for example, such as social and human factors described in research [14].

Additionally, we should emphasize that, absolutely all existing solutions, unfortunately, do not provide any possibilities for taking into account such an extremely and critically important irrational factor of HCI as the factor of perception subjectivization of the common object of interaction by various subjects of this same interaction.

After all, it is the perception subjectivization of the common object of interaction by different participants (subjects) in this team interaction (regardless whether it is comprehensive support of software products, human-computer interaction, human-machine interaction, or any other type of intersubjective interaction in general) that directly affects the efficiency and effectiveness of this interaction. Since the difference(s) in subjective vision and perception of a single common object between different subjects of this interaction can lead to such negative components as, for example:

- uncoordination of these subjects,
- misunderstandings between them,
- incorrectness and inaccuracies in mutual understanding of each other,
- misunderstandings of user workflows,
- misunderstandings of business needs,
- incorrect interpretation of task priorities,
- irrational use of resources (especially human and time resources, which often could be highly limited and quite non-renewable),
- or even to the emergence of conflict situations between these subjects,
- and each of these above-mentioned components destructively affecting the entire interaction in general.

Fortunately, the approach described in the research [19] provides the possibility to take into account and quantify the factors of perception subjectivization of not only the objects of a comprehensive support of software products (for which this approach has been mainly conceived), but also objects of any intersubjective interaction in general.

While another method proposed in research [18] allows forming a multifactor portraits for the subjects of a comprehensive support of software products, based on their personalized perception of the support object (both human-computer, or any intersubjective interaction in general), and through the use of encapsulated artificial neural networks of a multilayer perceptron type, which provide automation, as well as a significant increase in the level of intellectualization of relevant processes for the components of a comprehensive support of software products (in particular, including human-computer interaction (in general), and any intersubjective interaction (as a whole).

At the same time, another extremely urgent and related problem – is to ensure the possibility of identifying the subjects of HCI precisely by their personalized perception of the common object of this interaction, which will contribute to a better study of an irrational component(s) of this interaction, including in the context of improving the automation and intellectualization of the latter, and also reveals additional possibilities for the potential of using the obtained identification results as an additional component of a multifactor identification and verification of HCI subjects, including, in particular, the establishment of an unauthorized or an unidentified subjects.

Thus, the main problematics of this research has been formulated, while both solutions considered in the two abovementioned studies (i.e., [19] and [18]), represented in the previous paragraph, create a fundamental basis for ensuring the possibility of generating the input data necessary for solving the declared scientific and applied problem of HCI subjects identification based on their polyfactor portraits of perception subjectivization of HCI object.

2. Method development

The initial stage and the first-priority step in solving the declared scientific and applied problem (of HCI subjects identification based on their polyfactor portraits of perception subjectivization of HCI object) – is the development of an appropriate identification algorithm, which is mandatory and necessary to ensure the formalization and structuring of the studied

processes, as well as the possibility of their further automation and software implementation.

In particular, Figure 1 below represents a flowchart of the developed specialized algorithm for HCI subjects identification based on their polyfactor portraits of perception subjectivization of HCI object.

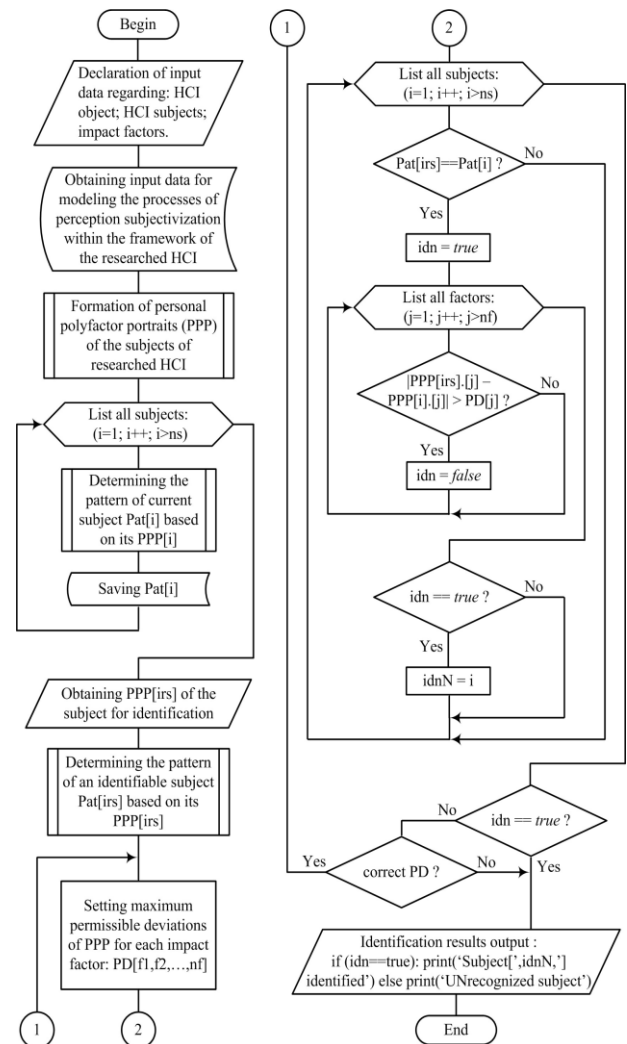


Fig. 1. Flowchart of the developed algorithm for HCI subjects identification based on their polyfactor portraits of perception subjectivization of HCI object

In addition, Figures 2 and 3 below represent flowcharts of two following procedures, namely:

- the procedure for formation of personal polyfactor portraits (PPP) of HCI subjects regarding their perception subjectivization of the interaction object (provided at Figure 2);
- and the procedure for determination of the subject's pattern (Pat[i]) based on its personal polyfactor portrait (PPP[i]) (provided at Figure 3).

The main essence of the developed algorithm and the procedure for forming personal polyfactor portraits (PPP) of HCI subjects regarding their perception subjectivization of the interaction object – is to obtain averaged normalized values of the shares of presence of each factor from the declared set of impact factors influencing the perception subjectivization of the common HCI object by each separate individual HCI subject, based on the processing of specific data obtained during modelling a relevant situational cases, which, in fact, represent this perception subjectivization of the common object by separate specific subject within the framework of the researched HCI.

While the main essence of the developed algorithm and the procedure for determination of the subject's pattern (Pat[i]) based on its personal polyfactor portrait (PPP[i]) consists in positioning the impact factors (within the personal polyfactor

portrait of a separate individual subject of the researched HCI) according to their priority/dominance (within the same personal polyfactor portrait): starting from the most priority/dominant impact factor (the share of presence of which in the considered personal polyfactor portrait is maximal among shares of presence of all impact factors) with position #1, and ending with the least priority/dominant impact factor (the share of presence of which in the considered personal polyfactor portrait is minimal among shares of presence of all impact factors) with position # nf (where nf – is a total number of the pre-declared impact factors).

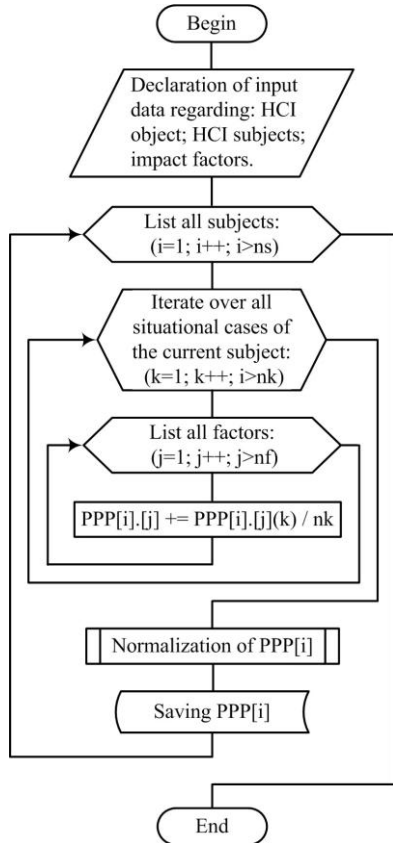


Fig. 2. Flowchart of the developed procedure for formation of personal polyfactor portraits (PPP) of HCI subjects regarding their perception subjectivization of the interaction object

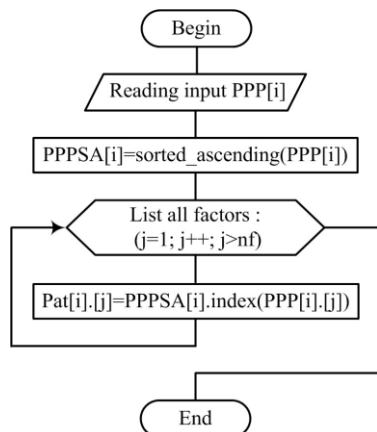


Fig. 3. Flowchart of the developed procedure for determination of the subject's pattern (Pat[i]) based on its personal polyfactor portrait (PPP[i])

A key feature of the developed algorithm for HCI subjects identification based on their polyfactor portraits of perception subjectivization of HCI object – is introducing and implementation of the proposed two-stage identification principle, according to which:

- at the first stage, the comparison is done not directly between the polyfactor portraits of the subjects themselves, but instead

between their patterns, and only in the case of identity of the latter – the transition to the second stage of identification is carried out;

- at the second stage of identification, the direct comparison of polyfactor portraits (namely: the shares of presence of appropriate impact factors, forming these portraits) of the comparable subjects (within the framework of the researched HCI) – is being already carried out.

Implementation of such a two-stage identification principle ensures optimization of the computational complexity of the developed algorithm, because in this case the algorithm will avoid comparing knowingly inappropriate subjects whose personal polyfactor portrait patterns do not appropriately correspond to each other.

However, it should be additionally worth noting that in some cases (primarily, we are talking about cases when: within one separate polyfactor portrait there are values of different impact factors, the magnitudes of which are close to each other, so the positions of these factors can alternate with each other within the pattern of this same considered polyfactor portrait) the first stage (of the proposed two-stage identification principle) can be simply omitted, and the main identification, in such cases, is, actually, carried out exclusively on the basis of the second stage (i.e., the direct comparison of polyfactor portraits of the comparable subjects).

The next designing stage for the declared method of HCI subjects identification based on their polyfactor portraits of perception subjectivization of HCI object – is the development of the corresponding basic mathematical model, consisting of a set of expressions (1)–(3), presented and described in detail below in the text.

In particular, expression (1) below represents the proposed formalization model for a personal polyfactor portrait of HCI subject in the context of its perception subjectivization of the object of same HCI:

$$PPP_{[i]} = \{Psrp_{[ij]}, (j = \overline{1, nf})\}, i \in [1, ns] \quad (1)$$

where $PPP_{[i]}$ – a personal polyfactor portrait of the i -th subject of researched HCI; i – the indicator variable of the current subject of researched HCI; $Psrp_{[ij]}$ – the share of presence of the j -th impact factor within a framework of the personal polyfactor portrait of currently considered subject of the researched HCI; j – the indicator variable of currently considered impact factor (from the set of previously declared impact factors, within the framework of researched HCI); nf – the total number of pre-declared impact factors which form a personal polyfactor portrait of each subject of the researched HCI; ns – the total number of subjects within a framework of the researched HCI.

Expression (2) below represents the pattern model for a personal polyfactor portrait of HCI subject:

$$Pat_{[i]} = \{PPPSA_{[i]}.index(PPP_{[i]}[Psrp_{[ij]}])\} \\ (j = \overline{1, nf}, i \in [1, ns]) \quad (2)$$

where $Pat_{[i]}$ – a pattern of a personal polyfactor portrait of the i -th subject of researched HCI; i – the indicator variable of the current subject of researched HCI; $PPP_{[i]}$ – a personal polyfactor portrait of the i -th subject of researched HCI; $PPPSA_{[i]}$ – a sorted personal polyfactor portrait of the i -th subject (of the researched HCI), impact factors within which are sorted in descending order of their magnitude; $Psrp_{[ij]}$ – the share of presence of the j -th impact factor within a framework of the personal polyfactor portrait of currently considered subject of the researched HCI; j – the indicator variable of currently considered impact factor (from the set of previously declared impact factors within the framework of researched HCI); $PPPSA_{[i]}.index(PPP_{[i]}[Psrp_{[ij]}])$ – an index (position) of the j -th impact factor (of a personal polyfactor portrait of the i -th subject) within a framework of a sorted personal polyfactor portrait of the same subject; nf – the total number of pre-declared impact factors which form a personal polyfactor portrait of each subject of the researched HCI; ns – the total number of interaction subjects within a framework of the researched HCI.

Expression (3) below, actually, represents a proposed model of the specialized function for identifying HCI subjects based on their polyfactor portraits of perception subjectivization of relevant HCI object:

$$fSbjIdn \left(\begin{matrix} PPP_{[irs]} \\ PPP_{[i]} \end{matrix} \right) = \begin{cases} 1, \{ (Pat_{[irs]} = Pat_{[i]}) \wedge \\ \wedge (PPP_{[irs]} \cdot Psrcp_{[j]} = PPP_{[i]} \cdot Psrcp_{[j]}) \\ (\forall j = \overline{1, nf}), (i \in \overline{1, ns}) \} \\ 0, \{ otherwise \} \end{cases} \quad (3)$$

where $fSbjIdn(PPP_{[irs]}, PPP_{[i]})$ – a logical function (which means that it can only acquire a logical meaning «1» – «true», or logical meaning «0» – «false») for identifying HCI subjects based on their polyfactor portraits of perception subjectivization of relevant HCI object, the arguments of which are the identifiable subject and the current known subject (from among those already previously identified within the framework of the researched HCI); $PPP_{[irs]}$ – a personal polyfactor portrait of the identifiable subject (within the framework of researched HCI); irs – an indicator of the identifiable subject; $PPP_{[i]}$ – a personal polyfactor portrait of the i -th subject of researched HCI; i – the indicator variable of the current subject (from among already known, previously identified subjects) of researched HCI; $Pat_{[irs]}$ – a pattern of a personal polyfactor portrait of the identifiable subject (within the framework of researched HCI); $Pat_{[i]}$ – a pattern of a personal polyfactor portrait of the i -th subject of researched HCI; $Psrcp_{[j]}$ – the share of presence of the j -th impact factor within a framework of the personal polyfactor portrait of currently considered subject of the researched HCI; j – the indicator variable of currently considered impact factor (from the set of previously declared impact factors, within the framework of researched HCI); nf – the total number of pre-declared impact factors which form a personal polyfactor portrait of each subject of the researched HCI; ns – the total number of subjects within a framework of the researched HCI; $\{otherwise\}$ – a set/union which combines all other cases (when the complex condition for the logical meaning "1" of the identification function is not met) in which the identification function automatically acquires the logical meaning "0".

Thus, expressions (1)–(3), provided above, represent the developed basic mathematical model for identifying HCI subjects based on their polyfactor portraits of perception subjectivization of HCI object.

Additionally noting, the developed basic mathematical model fully corresponds to the previously presented developed specialized algorithm, and together with the latter – forms the declared method dedicated for solving the relevant considered scientific and applied problem of HCI subjects identification based on their polyfactor portraits of perception subjectivization of HCI object.

3. Research results, and discussions

At the same time, the final development stage for the declared method – is its practical approbation on the example of solving the given experimental practical applied problem of identifying the subject of the technical support team of defined supported software product based on the dominant features of subject's polyfactor portrait of perception subjectivization of this particular specific supported software product.

The resolving of the declared experimental practical applied problem is carried out in few stages:

- the first of which is the formation of personal polyfactor portraits of all subjects – participants of the considered supported software product's technical support team;
- the second stage – is the formation of an appropriate patterns of a personal polyfactor portraits of these subjects (i.e., the considered supported software product's technical support team members);
- while the third (and, at the same time, the final) stage is, in fact, the identification of the subject(s) (of the considered

supported software product's technical support team) based on the dominant features of its relevant personal polyfactor portrait.

In particular, Table 1 below contains data on the formed personal polyfactor portraits of the subjects of considered software product's technical support team (marked as "S1"–"S30" in the table), as well as the identifiable subjects (marked as "IRS1"–"IRS3" in the table).

The methodology for determining and normalizing influential factors (F1–F8) that form polyfactor portraits is based on the use of the impact factors reverse analysis method (described in detail in scope of research [19]), which allows to distinguish the shares of presence of each of previously declared impact factors (meanwhile, the choice of factors may vary depending on the specifics of particular tasks being solved, and may include various sets of cognitive-perceptual factors) that affect the perception subjectivization of the object of interaction by the subject of interaction within the framework of a partial situational case representing an "instant slice" of this interaction. Thus, applying aforementioned method for all available situational cases of interaction between the object and the partial researched subject, will obtain a set of values (of the shares of presence of each of the declared impact factors), averaging and normalizing which – will obtain, respectively, a personal polyfactor portrait of this particular researched subject of considered interaction. Thus, in a similar way, a personal polyfactor portraits of all the researched subjects of considered team have been obtained.

Table 1. Data on the formed personal polyfactor portraits of the subjects of considered software product's technical support team ("S1"–"S30"), as well as the identifiable subjects ("IRS1"–"IRS3")

	F1	F2	F3	F4	F5	F6	F7	F8
S1	0.044	0.171	0.055	0.025	0.221	0.140	0.135	0.209
S2	0.051	0.045	0.213	0.111	0.137	0.094	0.237	0.112
S3	0.118	0.058	0.073	0.148	0.246	0.116	0.074	0.167
S4	0.085	0.170	0.053	0.158	0.244	0.055	0.031	0.204
S5	0.067	0.132	0.135	0.118	0.159	0.121	0.224	0.044
S6	0.133	0.124	0.178	0.108	0.113	0.054	0.197	0.093
S7	0.108	0.123	0.099	0.073	0.223	0.115	0.057	0.202
S8	0.111	0.086	0.141	0.102	0.147	0.163	0.205	0.045
S9	0.047	0.190	0.064	0.114	0.221	0.145	0.087	0.132
S10	0.133	0.143	0.060	0.135	0.232	0.041	0.037	0.219
S11	0.059	0.169	0.085	0.023	0.215	0.071	0.165	0.213
S12	0.094	0.034	0.133	0.217	0.111	0.087	0.168	0.156
S13	0.151	0.136	0.128	0.095	0.115	0.052	0.214	0.109
S14	0.109	0.164	0.067	0.131	0.196	0.056	0.111	0.166
S15	0.059	0.123	0.088	0.108	0.206	0.171	0.113	0.132
S16	0.056	0.159	0.021	0.123	0.281	0.031	0.086	0.243
S17	0.162	0.131	0.118	0.113	0.082	0.032	0.146	0.216
S18	0.102	0.119	0.047	0.092	0.279	0.107	0.113	0.141
S19	0.108	0.069	0.173	0.031	0.123	0.148	0.213	0.135
S20	0.164	0.143	0.043	0.156	0.121	0.179	0.063	0.131
S21	0.115	0.141	0.111	0.122	0.212	0.043	0.103	0.153
S22	0.118	0.108	0.058	0.116	0.139	0.124	0.174	0.163
S23	0.084	0.126	0.094	0.053	0.296	0.105	0.135	0.107
S24	0.125	0.135	0.067	0.122	0.223	0.124	0.031	0.173
S25	0.109	0.070	0.123	0.102	0.228	0.146	0.067	0.155
S26	0.183	0.131	0.042	0.212	0.139	0.114	0.145	0.034
S27	0.055	0.042	0.193	0.162	0.087	0.113	0.231	0.117
S28	0.134	0.115	0.172	0.066	0.192	0.177	0.043	0.101
S29	0.068	0.152	0.043	0.117	0.253	0.074	0.106	0.187
S30	0.075	0.146	0.102	0.098	0.236	0.065	0.110	0.168
IRS1	0.117	0.144	0.113	0.125	0.207	0.044	0.101	0.149
IRS2	0.105	0.067	0.169	0.033	0.126	0.151	0.217	0.132
IRS3	0.168	0.146	0.042	0.152	0.119	0.184	0.061	0.128

In addition, Figure 4 represents a graphical interpretation of the formed personal polyfactor portraits of the subjects of considered software product's technical support team ("S1"–"S30"), as well as the identifiable subjects ("IRS1"–"IRS3").

The next stage in resolution of the given practical applied problem – is the formation of patterns for personal polyfactor portraits of the subjects of considered software product's technical support team ("S1"–"S30"), as well as patterns for identifiable subjects ("IRS1"–"IRS3"), the corresponding graphical interpretation of which is presented below at Figure 5.

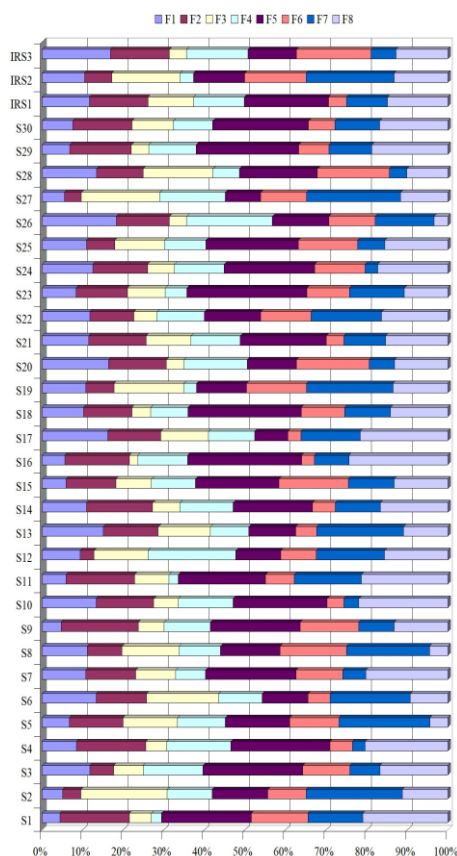


Fig. 4. A graphical interpretation of the formed personal polyfactor portraits of the subjects of considered software product's technical support team ("S1"–"S30"), as well as the identifiable subjects ("IRS1"–"IRS3")

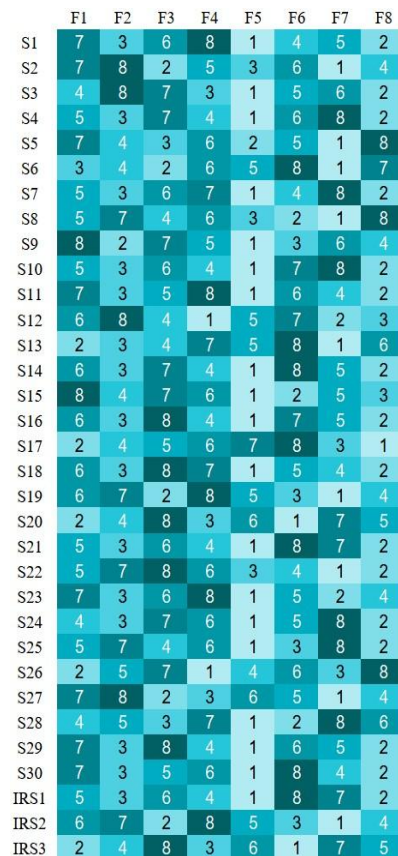


Fig. 5. A graphical interpretation of the formed patterns for personal polyfactor portraits of the subjects of considered software product's technical support team ("S1"–"S30"), as well as the identifiable subjects ("IRS1"–"IRS3")

IRS1 identification:																														
Dominant Factors	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	S12	S13	S14	S15	S16	S17	S18	S19	S20	S21	S22	S23	S24	S25	S26	S27	S28	S29	S30
chains / combinations																														
1	X		X	X			X		X	X			X	X	X		X			X	X	X	X	X				X	X	X
1&2	X		X	X			X		X	X			X	X	X		X			X	X	X	X	X				X	X	X
1&2&3	X			X			X			X	X		X	X	X		X			X	X	X	X	X				X	X	X
1&2&3&4				X						X			X	X	X					X	X	X	X	X					X	
1&2&3&4&5				X						X				X	X					X	X	X	X	X						
1&2&3&4&5&6										X										X	X	X	X	X						
1&2&3&4&5&6&7										X										X	X	X	X	X						
IRS2 identification:																														
Dominant Factors	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	S12	S13	S14	S15	S16	S17	S18	S19	S20	S21	S22	S23	S24	S25	S26	S27	S28	S29	S30
chains / combinations																														
1		X			X	X		X				X						X		X		X					X			
1&2		X			X	X		X				X						X		X		X					X			
1&2&3		X			X	X		X				X						X		X		X					X			
IRS3 identification:																														
Dominant Factors	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	S12	S13	S14	S15	S16	S17	S18	S19	S20	S21	S22	S23	S24	S25	S26	S27	S28	S29	S30
chains / combinations																														
1																				X										

Fig. 6. Results of subjects identification for considered software product's technical support team

The final stage in solving the declared practical applied problem is, in fact, the identification of the subject(s) of considered software product's technical support team – according to the dominant features of their relevant personal polyfactor portraits.

In particular, within the framework of this stage, another extremely useful and extraordinary feature of the proposed two-stage identification approach has been revealed and demonstrated, which involves achieving the final identification result already at the first stage of comparing the subjects' patterns without a need to execute the second stage of proposed two-stage identification approach.

Indeed, as can be seen from the results of solving the given applied practical problem (presented below at Figure 6), the patterns of subjects' personal polyfactor portraits themselves can already be their unique identifiers. For example, in case

of the considered particular exemplary practical applied problem being solved in scope of this research:

- an unambiguous defining of the identifiable subject IRS1 has been achieved at the stage of comparing the pattern of its personal polyfactor portrait with the patterns of personal polyfactor portraits of known subjects, i.e. members of considered software product's technical support team, while comparing a consecutive combination of 7 dominant impact factors;
- an unambiguous defining of the identifiable subject IRS2 has been achieved at the stage of patterns comparison while comparing a consecutive combination of already 3 dominant impact factors;
- while an unambiguous defining of the identifiable subject IRS3 has been achieved at the stage of patterns comparison while comparing the consecutive combination of only 1 particular dominant impact factor, since, as it turned out,

among all the subjects of the considered software product's technical support team, only one specific subject "S20" has factor "F6" as the key dominant feature (i.e., the most dominant impact factor).

Thus, the obtained results of the final stage of solving the declared practical applied problem (i.e., identifying the subject of the technical support team of defined supported software product based on the dominant features of subject's polyfactor portrait of perception subjectivization of this particular specific supported software product) are presented below at Figure 6.

At the same time, it is worth noting that the final result has been achieved at the first stage (of the proposed two-stage identification approach) of partial comparison of the patterns of identifiable subjects' personal polyfactor portraits, that is, without involving the second stage (i.e., the "factor-by-factor" comparison of subjects' polyfactor portraits themselves).

In addition, Figure 7 below displays the results of the second stage of subjects' identification, that is based on the comparison of personal polyfactor portraits of the identifiable subjects (themselves) with those specific subjects, patterns of personal polyfactor portraits of which have already been previously matched with the relevant identifiable one(s) (i.e., "IRS1" with "S21", "IRS2" with "S19", "IRS3" with "S20"), and the comparison of factor-by-factor differences (marked as "dF1"–"dF8") between these relevant subjects – with the previously declared maximum permissible deviation values (marked as "RefVal") for each particular impact factor.

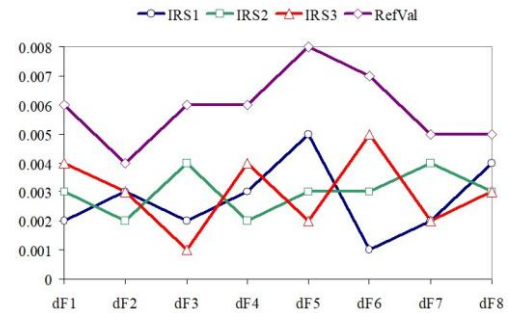


Fig. 7. Results of direct comparison of personal polyfactor portraits of the identifiable and pre-identified subjects (i.e., "IRS1" with "S21", "IRS2" with "S19", "IRS3" with "S20"), and their comparison with the previously declared maximum permissible deviation values (RefVal)

Modelling the operation of the developed method, performed on the example of solving the declared practical applied problem, has been carried out using the relevant specialized developed software realization of this method, implemented on the basis of the Python 3.13.7 programming language [20] and the Thonny 4.1.7 integrated development environment (IDE) [27].

The operating results, obtained by means of this specialized developed software, are presented below at Figure 8, and, in fact, fully correspond to already previously presented results of solving the declared practical applied problem, since the latter were, actually, based on the former.

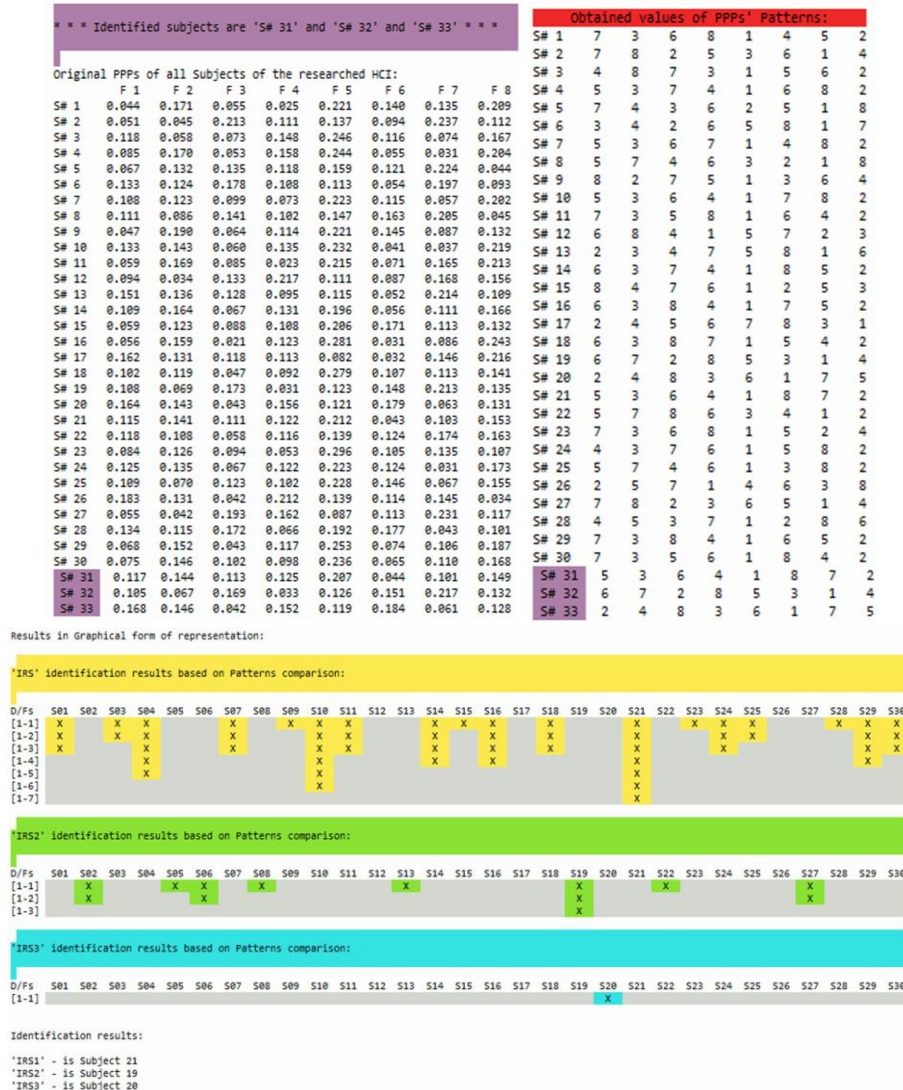


Fig. 8. Operating results obtained by modeling the developed specialized software realization of proposed method, implemented on the basis of the Python 3.13.7 and Thonny 4.1.7 IDE

Thus, using the developed specialized software realization of the proposed method (for HCI subjects identification based on their polyfactor portraits of perception subjectivization of HCI object), implemented on the basis of Python 3.13.7 programming language and Thonny 4.1.7 IDE, the given practical applied problem (of identifying the subject of the technical support team of defined supported software product based on the dominant features of subject's polyfactor portrait of perception subjectivization of this particular specific supported software product) has been successfully resolved.

Additionally, a stress testing of the developed approach has been performed on a significantly larger dataset of polyfactor portraits with a dimension of 10,000 records, the distribution statistics of which is presented below at Figure 9.

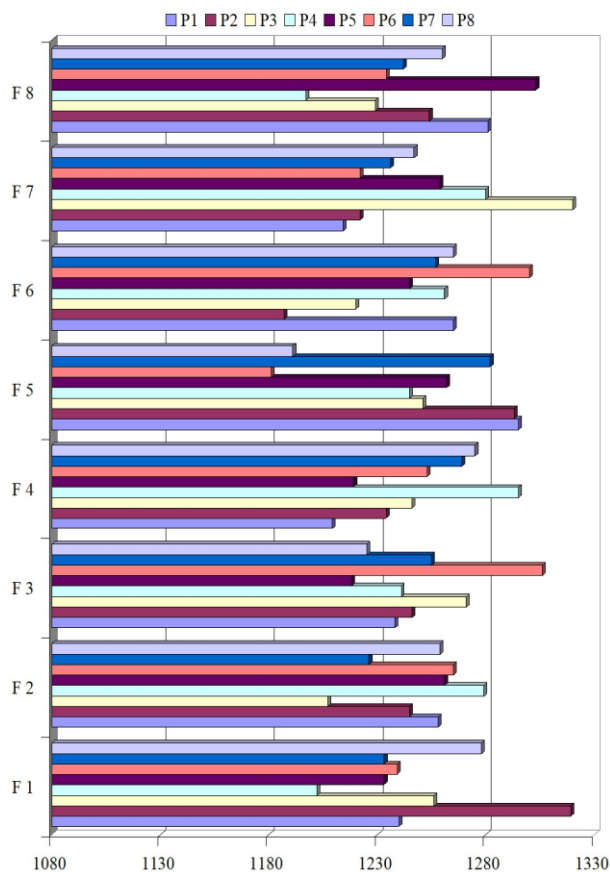


Fig. 9. A distribution statistics of the dataset for stress testing of the developed approach (where F1-F8 are impact factors, while P1-P8 are their positions of dominance)

After that, using the developed approach, random 100 subjects (from the considered dataset with a dimension of 10,000 records) were identified. Meanwhile, the main task of performed testing was to determine the number of matches between the patterns of polyfactor portraits of: the considered random 100 patterns and all 10,000 input patterns. In this case, the comparison of patterns was carried out step by step:

- starting from the coincidence of the position of only the most dominant factor (indicated as "D[1]");
- continuing with a pair of the most dominant factor and the next to it (indicated as "D[1-2]");
- continuing with a trio combination of the most dominant factor, the second in dominance rating, and the third in dominance rating (indicated as "D[1-3]");
- and so on ... ;
- ending with a complete (8-factor) coincidence of patterns (indicated as "D[1-8]").

Figure 10 below shows the dynamics of the arithmetic mean values of matches determined at each step.

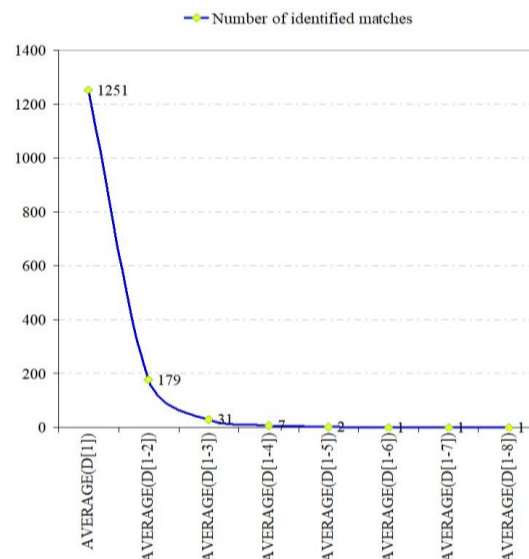


Fig. 10. The dynamics of the arithmetic mean values of matches determined in result of a step by step comparison of polyfactor portraits patterns between the considered random 100 patterns and all 10,000 input patterns

Thereby, based on above Figure 10, we can observe a clear exponential-regressive trend of a significant decrease in the number of potential subjects-candidates (out of total 10,000) for the final comparison.

Besides that, Figure 11 below demonstrates a positive trend in the number of unambiguous undisputed identifications of a single subject out of 10,000, according to which:

- starting with the quadratic combination of dominant factors (indicated as "D[1-4]") – we see unambiguous undisputed identification of one partial subject (out of 100 randomly identified among 10,000 total input patterns);
- for the quintal combination (indicated as "D[1-5]") – already 23 out of 100 (i.e. 23%) subjects have been unambiguously undisputedly identified;
- for the hexal combination (indicated as "D[1-6]") – this indicator reached already 63%;
- while for the hectal and octal combinations (indicated as "D[1-7]" and "D[1-8]", respectively) – 79% of subjects could be unambiguously undisputedly identified among 10,000 of candidates, which is an extremely good indicator.

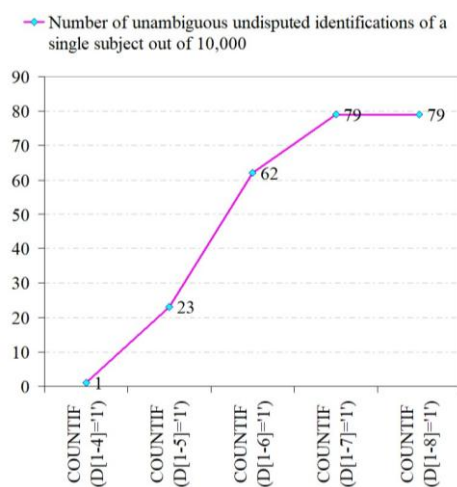


Fig. 11. Obtained trend in the number of unambiguous undisputed identifications of a single subject out of 10,000

At the same time, in all cases, we are talking about unambiguous undisputed identification, that is, identification without any loss of accuracy, which is also a significant advantage of the developed approach.

Thus, performed practical approbation of the proposed method demonstrates its effectiveness and efficiency in solving a class of relevant practical applied problems of identifying HCI subjects based on their perception subjectivization of common HCI object, both in the context of issues related to a comprehensive support of software products, as well as in the context of any inter-subjective interaction in general.

3.1. Discussions and comparison with outcome of similar existing approaches

This section of the conducted research represents the discussions of comparison the developed method (for HCI subjects identification based on their polyfactor portraits of perception subjectivization of HCI object) with outcome of similar existing approaches. For example, in scope of research [21], the authors have developed a unique approach for identifying HCI users based on the study of computer mouse movements' patterns. By applying targeted feature engineering methods to an appropriate computer mouse tracking dataset(s), and respectively training a random forest classifier, the authors have demonstrated that mouse-based user identification is surprisingly effective, indicating the plausibility of its implementation. In particular, the model developed by the authors achieved an accuracy of 28% and a ROCAUC(OvR) of 0.932 for the classification task of 566 users. As traditional methods for users' identification become increasingly regulated, behavioural identification methods and approaches (such as already mentioned computer mouse tracking) can offer new vectors for user(s) profiling that are harder to detect and prevent.

A similar study is also presented in another research [11], which is more about an overview, where the authors carried out a comprehensive review and classification of different types of features and approaches addicted to users' identification based on the movements of a computer mouse during its operating by these users. Thus, the approach of users' identification based on their interaction with a computer mouse, proposed in both above-considered researches, is surprisingly effective in terms of providing the simplest possible solution for depersonalized user identification. Unfortunately, such approach does not provide a comprehensive solution for identifying HCI users in context of an irrational component of perception subjectivization of the object of interaction, and can serve, for example, as one of the potential identifiers (at the same time, by the way, quite informative one) of the impact of this subjectivization.

At the same time, the authors of another research [7] proposed a personalized method for identifying users of smart-systems based on pressing buttons on the touch screen of control devices. The key idea of this approach is to use users' button-pressing habits in order to identify these users. For this purpose, the authors investigate features from time series data on user(s) interaction with a touchscreen, with the subsequent implementation of the possibility of users' identification using supervised learning. Experimental evaluations, obtained by the authors of this research, demonstrate that their user identification method provided the ability to verify/identify users with an accuracy of around 94.4%. Given the limited amount of training data obtained in 10 trials, the accuracy was 92.8% when the authors used the most relevant training data, confirming the feasibility of this specific user identification method. However, as in the previous considered cases, this approach also does not provide a comprehensive solution in the context of studying the perception subjectivization of the system by users, so it can be used as a partial identifier of the impact of this subjectivization.

In addition, the authors of the other research [23] have presented an extremely interesting approach to user identification by taking into account multiple aspects of the behaviour of different users when interacting with their personal passwords, including, in particular, such one as: password style, input errors, and time spent entering password(s). The approach, proposed by authors of this particular considered research, includes a set

of strategies and tools that use, among others, the longest common subsequence (LCS) algorithm, focusing additionally on password(s) modification patterns and comparing user actions during these changes. The proposed solution improves the confidence range algorithm approach, related to the concept of electronic personal synthesis behaviour (EPSB), by introducing the LCS usage within the latter. Thus, the above-considered approach uses a cognitive analysis of users during their interaction with their own personal passwords (for accessing software products or services), actually studying and researching the specific area of the subjectivization of users' perception of their personalized confidential passwords, however, regardless of the software products or services (for accessing which these passwords are, actually, used) themselves, which makes this approach extremely narrowly specialized, making it impossible to fully scale and adapt it to application in the context of the researched issue of HCI objects' (in particular, supported software products) perception subjectivization. However, this approach can be used as one of extraordinary and effective additional mechanisms for increasing cybersecurity standards while identifying HCI subjects.

At the same time, the authors of research [26] investigate a method of user identification based on the "keystroke dynamics" of a computer keyboard as one of the promising and cost-effective behavioural biometrics. The approach, proposed by authors of the considered research, uses the transfer learning classification method, which has proven itself well while processing various tasks with a small training dataset and the presence of noisy data, which, by the way, is extremely inherent in the keystroke dynamics. In their study, the authors use AlexNet and ResNet, two separate types of pre-trained convolutional neural network models that are commonly used to apply deep transfer learning concepts to image-based systems. That is why the authors apply the transformation of "keystroke" type data into a relevant "image" type data, and then generate artificial image data by expanding the available data, which is a key point of whole this approach. At the same time, pre-trained models are used by applying an extra fine-tuning (of relevant parameters in some specific layers) and are used by the authors as an end-to-end training and classification system. A feature extraction method (i.e., classification support vector machine) with pre-trained models is also applied to the keystroke dataset(s). A relative analysis of both approaches is presented, and finally, the best of them is used in the recognition-based system (proposed by the authors of considered research), which, in the end, made it possible to obtain a high accuracy of successful recognition. Despite that, as in previous cases of already considered similar and alternative existing solutions for user identification, this particular approach of user(s) identification based on the computer keyboard keystrokes' dynamics is, by its nature, based more on the rational component (but not the irrational one) of HCI users' interaction, using a rational dynamics metrics. In this regard, the application of this particular specific approach for identifying the irrational component(s) of HCI, unfortunately, does not provide the possibility of obtaining the desired results, especially in the context of the considered researched issue of HCI subjects identifying based on their personalized (i.e., individualistic, and, in most cases, quite unique) perception subjectivization of the relative HCI object(s).

While, unlike the overviewed existing similar approaches discussed above, the results obtained by means of the proposed method, developed and represented in scope of this research, provide an adapted and complex solution precisely in the context of a highly specialized scientific and applied problem of HCI subjects identification based on their polyfactor portraits of perception subjectivization of the object of same interaction, taking into account the specifics, features, and potential difficulties in solving most possible derived subproblems of a wider range of issues related to researching the irrational component of HCI as well as any type of intersubjective interactions in general. Therefore, unlike the considered existing similar approaches

for ensuring the possibility of "passive" identification of HCI subjects, the absolute majority of which are intended mainly for processing, analysing and taking into account primarily and exclusively rational factors of influence during the interaction between a human and computer products (for example, such as: PC mouse movement trajectories, pressing buttons on the touch screen, styles of users' personal passwords and time spent on their entry, dynamics of pressing keys on the PC keyboard, etc.), the method of identifying HCI subjects developed within the framework of this study provides the possibility of taking into account the irrational component of this interaction, namely such its fundamental component as the perception subjectivization of HCI object – by HCI subjects. Moreover, the proposed approach is quite non-standard from the point of view of "usual" study of HCI subjects (based on more rational components of this interaction), and is probably more typical for applied psychology (which, however, is more focused on the interaction between living people) so, in fact, the developed method, to a certain extent, lays the foundations for integration of these two global fields of science. Nevertheless, based on the obtained results, we state the effectiveness of the developed solution (both the identification method itself as a whole, as well as its individual constituent components: the algorithm, the model, and the software implementation) in the context of solving the declared scientific and applied problem of HCI subjects identification based on their polyfactor portraits of perception subjectivization of the object of this interaction, which is part of a cluster of more global scientific and applied problematics of research into the irrational component of HCI, in the context of improving the automation and intellectualization of the latter. While the obtained results of practical approbation of the developed method confirm the applied potential of the proposed innovation in both: the research field of global scientific and applied issues for automation and intellectualization of a comprehensive support of software products (as one of the most relevant and full-fledged manifestations of HCI); the related areas; as well as any kind and/or type of intersubjective interaction in general.

The scientific novelty, which is based on the obtained research results, consists in the following: for the first time, a method for HCI subjects identification based on their polyfactor portraits of perception subjectivization of HCI object has been developed, which provides the possibility of solving the declared scientific and applied problem of the same name, within the framework of a more global scientific and applied problematics of studying the irrational component(s) of HCI (as well as its all relative practical forms and manifestations), in the context of improving the automation and intellectualization of the latter.

While the practical significance of the research results consists in the following:

- a two-stage algorithm for identifying HCI subjects based on their polyfactor portraits of perception subjectivization of HCI object has been developed;
- an appropriate programming/software realization of the developed method has been implemented based on Python 3.13.7 and Thonny 4.1.7 IDE;
- and a practical approbation of the developed method has been carried out on the example of solving an experimental practical applied problem, the results of which confirm the effectiveness of the proposed approach in solving a class of relevant practical applied problems of identifying HCI subjects based on their perception subjectivization of common HCI object.

As a prospect(s) for further research, we see opportunities in a combined synthesis of the proposed approach with other similar and/or related existing solutions and approaches which provide the possibility of a "passive" identification of HCI subjects without involving any personalized information about these subjects (such as, for example: biometric data, accounts, personal identifier numbers/codes, etc., which directly indicate a connection with their unique owner), and instead – relying only

on the possibility of processing mostly a depersonalized information (about studied / identifiable subjects) primarily of a cognitive nature (behavioural characteristics, unique behavioural traits, features of personalized perception or vision of object or processes, static or kinetic behavioural features of interaction, etc.).

4. Conclusions

This research is dedicated to the development of a specialized method for identifying HCI subjects based on their polyfactor portraits of perception subjectivization of relevant HCI object, which is part of a cluster of more global scientific and applied problematics of research into the irrational component(s) of HCI, in the context of improving the automation and intellectualization of the latter.

As one of a fundamental components of the proposed method, a corresponding specialized algorithm for identifying HCI subjects has been developed, a key feature of which is implementation of the proposed two-stage identification principle, according to which:

- at the first stage, the comparison is done not directly between the polyfactor portraits of the subjects themselves, but instead between their patterns, and only in the case of identity of the latter – the transition to the second stage of identification is carried out;
- while at the second stage of identification, the direct factor-by-factor comparison of polyfactor portraits of the comparable subjects (within the framework of the researched HCI), patterns on which correspond to each other (according to the results, obtained at the abovementioned first stage), is already carried out.

Moreover, the obtained results of a conducted practical approbation of the developed method confirm the effectiveness of the proposed two-stage identification, demonstrating the possibility of extremely fast (and at the same time correct and unambiguous) identification of researched subjects already at the first stage, which, in some cases, may be reduced solely to the identification of the most dominant impact factor influencing in scope of a personal polyfactor portrait of the identifiable subject(s).

As another fundamental component of the proposed method, a basic mathematical model for HCI subjects identification based on their polyfactor portraits of perception subjectivization of HCI object has been developed, which fully corresponds to the developed specialized algorithm and, both together with it, ensures the correct functioning of the proposed method, as well as its further software/programming realization, the results of implementation (based on Python 3.13.7 and Thonny 4.1.7 IDE) and modelling of which are also presented within the framework of this research.

As the final development stage of the declared method, its practical approbation has been carried out on the example of solving the given experimental practical applied problem of identifying the subject of the technical support team of defined supported software product based on the dominant features of subject's polyfactor portrait of perception subjectivization of this particular specific supported software product.

The obtained results of practical approbation confirm the effectiveness of the developed method in the context of solving both relevant scientific and applied, as well as practical applied problems, in the context of a global scientific and applied problematics of increasing level of automation and intellectualization for a comprehensive support of software products, as well as the related relevant problem(s) of taking into account and consideration the irrational component(s) of both HCI, as well as any other types or manifestations of an intersubjective interaction in general.

The prospects for further research directions regarding possible ways of potential improvement(s) and/or enhancement(s), as well as practical application, of the developed method

(for HCI subjects identification based on their polyfactor portraits of perception subjectivization of HCI object), have been considered, which consist, among other things, in further development of additional algorithmic and software supply in order to expand the capabilities of computer modelling of relevant researched processes.

Additional direction of the prospects for further research lays in ensuring opportunities in a combined synthesis of the proposed approach with other similar and/or related existing solutions and approaches which provide the possibility of a "passive" identification of HCI subjects without involving any personalized information about these subjects.

References

- [1] Ali, M. N., & Ali, M. M. (2024). The Future Of Human-Ai Collaboration In Software Development: A Narrative Exploration. *Academic Journal on Innovation, Engineering & Emerging Technology*, 174–185. <https://doi.org/10.69593/ajiet.v1i01.151>
- [2] Anumakonda, R. C. (2025). Reducing Development Time with AI Tools: Enhancing Human-AI Collaboration in Software Development. *European Modern Studies Journal*, 9(3), 503–517. [https://doi.org/10.59573/emsj.9\(3\).2025.45](https://doi.org/10.59573/emsj.9(3).2025.45)
- [3] Chittala, S. (2024). AIops and DevOps: Catalysts of Digital Transformation in the Age of Automated Operations. *International Journal of Scientific Research in Computer Science, Engineering and Information Technology*, 10(6), 155–166. <https://doi.org/10.32628/CSEIT24106163>
- [4] Dubey, P. (2023). Principles of human factors engineering. Alexis Press.
- [5] Gomathy, C. K., & Meyrina, D. (2025). The Role of Artificial Intelligence in Automating Software Testing. *International Journal of Innovative Research in Science, Engineering and Technology*, 14(03). <https://doi.org/10.15680/IJRSET.2025.1403119>
- [6] Gori, R. (2025). Virtual Mouse: Integrating Eye, Hand and Voice Controls for Enhanced Human-Computer Interaction. *International Journal for Research in Applied Science and Engineering Technology*, 13(7), 494–501. <https://doi.org/10.22214/ijraset.2025.72994>
- [7] Ishida, S., Suda, K., & Inamura, H. (2024). User Identification via Touch-screen Button Operation for Smart Home. *Sensors and Materials*, 36(10), 4501. <https://doi.org/10.18494/SAM5211>
- [8] Jain, S. (2023). Integrating Artificial Intelligence with DevOps: Enhancing continuous delivery, automation, and predictive analytics for high-performance software engineering. *World Journal of Advanced Research and Reviews*, 17(3), 1025–1043. <https://doi.org/10.30574/wjarr.2023.17.3.0087>
- [9] Jeremić, V., Bucea-Manea-Tonis, R., Vesić, S., & Stefanović, H. (2023). Revolutionizing Software Testing: The Impact of AI, ML, and IoT. *EdTech Journal*, 3(1), 12–15. <https://doi.org/10.18485/edtech.2023.3.1.1>
- [10] Kannan, S., & Saradhi, K. S. (2023). Generative AI in technical support systems: Enhancing problem resolution efficiency through AI-driven learning and adaptation models. *Nanotechnology Perceptions*, 19(S1), 198–217.
- [11] Karim, M., & Hasanuzzaman, Md. (2020). A Study on Mouse Movement Features to Identify User. *Scientific Research Journal*, 08(04), 77–82. <https://doi.org/10.31364/SCIRJ/v8.i4.2020.P0420766>
- [12] Khan, I., Kanchan, V., & Bharambe, S. (2024). Gesture Controlled Virtual Mouse with Voice Assistant. *International Research Journal of Multidisciplinary Scope*, 05(01), 26–35. <https://doi.org/10.47857/irjms.2024.v05i01.0127>
- [13] Khankhoje, R. (2023). AI - Based Test Automation for Intelligent Chatbot Systems. *International Journal of Science and Research (IJSR)*, 12(12), 1302–1309. <https://doi.org/10.21275/SR231216065308>
- [14] Machuca-Villegas, L., Gasca-Hurtado, G. P., Morillo Puente, S., & Restrepo Tamayo, L. M. (2021). An Instrument for Measuring Perception about Social and Human Factors that Influence Software Development Productivity. *JUCS - Journal of Universal Computer Science*, 27(2), 111–134. <https://doi.org/10.3897/jucs.65102>
- [15] Mahadewi, E. P., Mo, S., Timotius, E., Tungkup, D. L., & Ilham, C. I. (2021). Understanding Human-Computer Interaction Patterns: A Systematic Analysis of Past and Future Innovations. *Webology*, 18(2), 261–272. <https://doi.org/10.14704/WEB/V18I2/WEB18320>
- [16] Mukthineni, V., Mukthineni, R., Sharma, O., & Narayanan, S. J. (2020). Face Authenticated Hand Gesture Based Human Computer Interaction for Desktops. *Cybernetics and Information Technologies*, 20(4), 74–89. <https://doi.org/10.2478/cait-2020-0048>
- [17] Pattanayak, S., Murthy, P., & Mehra, A. (2024). Integrating AI into DevOps pipelines: Continuous integration, continuous delivery, and automation in infrastructural management: Projections for future. *International Journal of Science and Research Archive*, 13(1), 2244–2256. <https://doi.org/10.30574/ijrsa.2024.13.1.1838>
- [18] Pukach, A. I., & Teslyuk, V. M. (2025). Method of Forming Multifactor Portraits of the Subjects Supporting Software Complexes, Using a Multilayer Perceptron. *Radio Electronics, Computer Science, Control*, (1), 130–141. <https://doi.org/10.15588/1607-3274-2025-1-12>
- [19] Pukach, A., Teslyuk, V., Lysa, N., & Sikora, L. (2025). Development of Impact Factors Reverse Analysis Method for Software Complexes' Support Automation. *Designs*, 9(3), 58. <https://doi.org/10.3390/designs9030058>
- [20] Python.org. (2025). *Python release* Python 3.13.7. <https://www.python.org/downloads/release/python-3137/>
- [21] Rose, L., et al. (2025). Exploring mouse-based user identification, 1–7. https://github.com/nicolelucas03/mouse-based_user_identification/blob/main/MouseBasedIdentification.pdf
- [22] Saeed, S., & Varol, A. (2021). Software Engineering and Artificial Intelligence: Re-Enhancing the Lifecycle. *Computing Advances & Trends*, 33–44. <https://doi.org/10.5121/csit.2021.112403>
- [23] Shannaq, B., & Shakir, M. T. (2024). Enhancing Security through Multi-Factor User Behavior Identification: Moving Beyond the Use of the Longest Common Subsequence (LCS). *Informatica*, 48(19). <https://doi.org/10.31449/inf.v48i19.6270>
- [24] Sharma, V., Jain, K. S., Kaur, A., & Singh, A. (2020). Human-Computer Interaction with Special Emphasis on Converting Brain Signals to Speech. *International Journal of Innovative Technology and Exploring Engineering*, 9(6), 523–529. <https://doi.org/10.35940/ijtee.F3650.049620>
- [25] Srihith, I. V. D., Varaprasad, R., Mohan, Y. R., Srinivas, T. A. S., & Sravanthi, Y. (2022). A Review on New Challenges in AI and Software Engineering. *International Journal of Advanced Research in Science, Communication and Technology*, 34–42. <https://doi.org/10.48175/IJARSCT-7137>
- [26] Tewari, A., & Verma, P. (2022). An Improved User Identification based on Keystroke-Dynamics and Transfer Learning. *Webology*, 19(1), 5369–5387. <https://doi.org/10.14704/WEB/V19I1/WEB19360>
- [27] Thonny.org. (2025). *Thonny 4.1.7, Python IDE for beginners*. <https://thonny.org/>
- [28] Ugwa, S. (2024). From Scripts to Intelligence: How AI is Reshaping the Future of Software Testing. *World Journal of Advanced Engineering Technology and Sciences*, 13(1), 1167–1179. <https://doi.org/10.30574/wjaets.2024.13.1.0449>
- [29] Vemuri, V. (2024). The Evolution of Human-Computer Interaction: From Command Lines to Conversational Interfaces Powered by Large Language Models. *Journal of Artificial Intelligence, Machine Learning and Data Science*, 2(1), 2257–2266. <https://doi.org/10.51219/JAIMLD/venkata-padma-kumar-vemuri/494>
- [30] Vijayakumar, K. (2023). Performance Optimization of Speech Processing for Natural Language Understanding in Enhancing Human-Computer Interaction. *ICTACT Journal on Data Science and Machine Learning*, 4(3), 452–455. <https://doi.org/10.21917/ijdsml.2023.0103>

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