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HMI SUBJECTS' COMPATIBILITY DETERMINING METHOD, BASED ON THEIR PERCEPTION SUBJECTIVIZATION OF INTERACTION OBJECT

Pukach A. I. – PhD, Assistant of Automated Control Systems Department, Institute of Computer Sciences and Informational Technologies, Lviv Polytechnic National University, Lviv, Ukraine. ROR: https://ror.org/0542q3127. ORCID: https://orcid.org/0009-0001-8563-3311.

Teslyuk V. M. – Doctor of Technical Sciences, Professor, Head of Automated Control Systems Department, Institute of Computer Sciences and Informational Technologies, Lviv Polytechnic National University, Lviv, Ukraine. ROR: https://ror.org/0542q3127. ORCID: https://orcid.org/0000-0002-5974-9310.

ABSTRACT

Context. The research is devoted to solving the relevant scientific and applied problem of a background determining and identifying of the compatibility of HMI subjects based on irrational part of their interaction with HMI object(s). **The object of research** is a process of determining the compatibility of HMI subjects based on their perception subjectivization of HMI object. **The subject of research** are methods and means of artificial neural networks, computational intelligence, mathematical modeling, as well as computer programming. **Objective.** The goal of the work is the development of a HMI subjects' compatibility determining method, based on their perception subjectivization of interaction object.

Method. A method for determining the compatibility of subjects of HMI has been developed, which is based on the analysis of subject's polyfactor portraits of perception subjectivization of the object(s) of this interaction, and ensures the possibility of solving the declared scientific and applied problem. The peculiarity of the developed method consists in the application (in the scope of solving the declared problem) of polyfactor portraits representing the perception's subjectivization of the object(s) of HMI – by the subjects of the same interaction, in order to identify the degree/level of compatibility of these subjects specifically in the context of the prism of subjectivization features of their personalized perception of the object(s) (or processes) within the framework of their joint and common HMI. The proposed method is based on the appropriate models, developed and presented in scope of this work, as well as on a specialized algorithm that provides the possibility of automation and software/computer modeling of researched processes.

Results. A basic mathematical model, a specialized algorithm, as well as a software model, have been developed and presented in scope of this research. Additionally, a practical approbation of the developed method has been carried out on the example of solving a relevant specific practical applied problem of identifying potentially interchangeable subjects of the researched HMI team, which confirms the effectiveness and efficiency of developed method in the context of solving relevant practical applied problems.

Conclusions. A method for determining the compatibility of HMI subjects based on their polyfactor portraits of interaction objects' perception subjectivization has been developed, which provides the possibility of solving the relevant scientific and applied problem of determining and identifying the compatibility of HMI subjects, and provides possibility(-ies) for identifying the compatibility of HMI subjects precisely on the basis of their polyfactor portraits of perception subjectivization of the object(s) of this interaction, thereby ensuring the improvement of the qualitative and efficiency indicators of HMI teams due to the possibility of identifying, selecting and joining subjects with a common subjective vision and perception of the object(s) and/or processes of their joint HMI.

KEYWORDS: HMI, subjects' compatibility, polyfactor portrait, perception subjectivization.

ABBREVIATIONS

A-THI is an agreeableness team homogeneity index;
AI is an artificial intelligence;
C-THI is a conscientiousness team homogeneity index;
CHBO is a chaotic heap-based optimizer;
E-THI is an extraversion team homogeneity index;
FFM is a five-factor model;
GAMS is a general algebraic modeling system;
HBO is a heap-based optimizer;
HMI is a human-machine interaction;
IT is an information technology;
N-THI is a neuroticism team homogeneity index;
O-THI is an openness team homogeneity index;
SDLC is a software development life cycle;
TFA is a team formation algorithm;
THI is a team homogeneity index.

NOMENCLATURE

$\left(\sum_{k=1}^{nfc} Fc_{[k]} = 1\right)$ is a mandatory condition that ensures the integrity of the polyfactor portrait of any subject;

$\Delta Sb_{[i][p][q]}$ is a difference in values between the p-th subject and the q-th subject in their perception subjectivization of the i-th object of researched HMI;

$0,\left(\Delta Sb_{[i][p][q]} \notin CRT\right)$ is a result of the range function (of determining the HMI subjects' compatibility levels), representing 0-level compatibility (i.e., incompatibility) of the investigated/comparable HMI subjects, as the difference between polyfactor portraits' values of the investigated/comparable subjects $\Delta Sb_{[i][p][q]}$ doesn't meet the compatibility criterion CRT at all;

CRT is a compatibility criterion variable (which can be represented, for example, by the absolute value of permissible threshold of the difference in values of the impact factors' share of presence between the polyfactor portraits of two investigated/comparable subjects);

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$false, (\Delta Sb_{[i][p][q]} \notin CRT)$ is a logical result “*false*” of the $FcmpbtlL(Sb_{[i][p]}, Sb_{[i][q]}, CRT)$ function, condition for achieving which is the discrepancy in the magnitude of the difference in values of the investigated/comparable subjects’ polyfactor portraits (i.e., $\Delta Sb_{[i][p][q]}$) to the declared compatibility criterion *CRT*.

$Fc_{[k]}$ is a share of presence of the *k*-th impact factor (relatively to all declared/pre-defined impact factors) in the polyfactor portrait of current investigated subject;

$FcmpbtlD(Sb_{[i][p]}, Sb_{[i][q]}, CRT)$ is a range function of determining the compatibility level (i.e., gradation degree of this compatibility) of HMI subjects based on their polyfactor portraits of perception subjectivization of HMI object;

$FcmpbtlL(Sb_{[i][p]}, Sb_{[i][q]}, CRT)$ is a logical function of determining compatibility between the *p*-th subject and the *q*-th subject (of the researched HMI) based on their polyfactor portraits of perception subjectivization of the *i*-th object (of the same researched HMI);

j is a simple counter for enumerating all subjects of the researched HMI;

k is a simple counter for enumerating all defined pre-declared impact factors;

ndr is a total number/amount of the declared distribution segments of the compatibility criterion, represented by corresponding ranges of possible values of the differences between the polyfactor portraits’ values of the investigated/comparable HMI subjects;

nfc is a total number of pre-declared impact factors;

nsb is a total number/amount of subjects within the investigated HMI;

$PbVl_{[1]}, (\Delta Sb_{[i][p][q]} \in CRT = \lfloor Dd_{[1L]}; Dd_{[1H]} \rfloor)$ is a $PbVl_{[1]}$ result (with sequential number “1” from the list of declared possible results) of the range function (of determining the HMI subjects’ compatibility levels), in which the difference between polyfactor portraits’ values of the investigated/comparable subjects $\Delta Sb_{[i][p][q]}$ corresponds to the declared segment of the compatibility criterion *CRT*, represented by the range of values $\lfloor Dd_{[1L]}; Dd_{[1H]} \rfloor$ (with sequential number “1” from the list of possible declared value ranges), where $Dd_{[1L]}$ – is a lower limit of the range, while $Dd_{[1H]}$ – is an upper limit of the range;

$PbVl_{[ndr]}, (\Delta Sb_{[i][p][q]} \in CRT = \lfloor Dd_{[ndrL]}; Dd_{[ndrH]} \rfloor)$ is a $PbVl_{[ndr]}$ result (with sequential number “*ndr*” from the list of declared possible results) of the range function (of determining the HMI subjects’ compatibility levels), in which the difference between polyfactor portraits’ values of the investigated/comparable subjects $\Delta Sb_{[i][p][q]}$ corresponds to the declared segment of the compatibility criterion *CRT*, represented by the range of values $\lfloor Dd_{[ndrL]}; Dd_{[ndrH]} \rfloor$ (with sequential number “*ndr*” from the list of possible declared value ranges), where $Dd_{[ndrL]}$ – is a lower limit of the range, while $Dd_{[ndrH]}$ – is an upper limit of the range, respectively;

$Sb_{[i][j]}$ is a polyfactor portrait of the perception subjectivization of the *i*-th object by the *j*-th subject of the researched HMI;

$Sb_{[i][p]}\{Fc_{[k]}\}$ is a value of the share of presence of the *k*-the impact factor in the perception subjectivization of the *i*-th object by the *p*-th subject of researched HMI;

$Sb_{[i][q]}\{Fc_{[k]}\}$ is a value of the share of presence of the *k*-th impact factor in the perception subjectivization of the *i*-th object by the *q*-th subject of the researched HMI;

$true, (\Delta Sb_{[i][p][q]} \in CRT)$ is a logical result “*true*” of the $FcmpbtlL(Sb_{[i][p]}, Sb_{[i][q]}, CRT)$ function, the mandatory condition for achieving which is the correspondence of the magnitude of the difference in values of the investigated/comparable subjects’ polyfactor portraits (i.e., $\Delta Sb_{[i][p][q]}$) – to the declared criterion *CRT*.

INTRODUCTION

Present IT market is saturated with an extraordinary variety of manifestations of HMI, which, in fact, represent any relations and activities between users (i.e., living people/humans) and software/hardware products (i.e., machines). At the same time, the complexity and scale of many modern IT projects require users to have an appropriate level of proficiency in both special/professional and technical qualifications, as well as a wide range of other properties and characteristics variety. At the same time, one of the key aspects of the quality of HMI is, among other things, the quality of interaction not only of each individual subject (user) with the object (software and/or hardware complex, robotic system, software product, etc.) of this interaction, but also the interaction of these subjects (users, living people/humans) directly with each other, ensuring the proper level of teamwork, and multiplication (under met conditions of coordinated and effective work) of the individual personal efforts (of each separate team member) – by all those team members.

For this purpose, there are appropriate existing specialized methods, models, approaches, and solutions that enable team formation. For example, in a recent study [1] authors confirm the contemporary relevance of the topic of team building nowadays, and an attempt is made by them to develop a coherent theoretical construct that would enable researching, in particular, the issues of the team building effectiveness. At the same time, authors of study [2] confirm the relevance of software development teams’ staffing problem based on the selection of potential candidates, as well as the need to find and apply mechanisms for automating the solution of this problem. Meanwhile, authors of study [3] confirm importance of consideration and taking into account the sociometric analysis of individuals (with different skill sets) for the

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formation of relevant sociotechnical teams, based on usage of relevant mathematical optimization approaches. In addition, the paper [4] considers, among other things, the issues related to managing of already formed teams, and presents the main approaches (as well as their key features) for carrying out this activity, which additionally emphasizes the importance of taking this factor into account and consideration when forming HMI teams.

Thus, the problem of team formation, both in the context of HMI as well as in general, continues remaining relevant and actual nowadays, which is also caused by the emergence of appropriate new/modern challenges. At the same time, determining and identifying the compatibility level(s) of HMI subjects is one of the effective ways to solve this problem, which confirms actuality of current research. Therefore, **the object of research** – is a process of determining the compatibility of HMI subjects based on their perception subjectivization of HMI object. While **the subject of research are** methods and means of artificial neural networks, computational intelligence, mathematical modeling, as well as computer programming. The purpose of the work is to develop a method for determining the compatibility of HMI subjects based on their polyfactor portraits of perception subjectivization of the object(s) of interaction, which will ensure the possibility to resolve the declared scientific and applied problem of a background determining and identifying of the compatibility of HMI subjects based on irrational part of their interaction with HMI object(s).

1 PROBLEM STATEMENT

Let us consider the formalization of the problem of studying the qualitative indicators of HMI as a problem of multiparameter polyfunctional dependence. In this case, the input variables of the problem are sets of parameters and functions that represent a particular, corresponding, area of the researched HMI. While, the output variables of the problem are the corresponding qualitative indicators of the researched HMI. At the same time, one of the most relevant areas of HMI nowadays – is, actually, its irrational component, the key fundamental forming basis of which consists, mainly, in the perception subjectivization of the object of interaction – by the subjects of this interaction. Continuing this hypothesis, let us consider a set of previously agreed and declared impact factors that directly form a polyfactor portrait(s) of the perception subjectivization of HMI object by each of HMI subjects:

$$Sb_{[i][j]} = \{Fc_{[k]}\}. \tag{1}$$

However, such an interpretation takes into account only “vertical” relations (between HMI object and each individual HMI subject), without taking into account the relevant “horizontal” ones – between the subjects themselves, in the context of their perception subjectivization of their common HMI object. Thus, this leads to the emergence of a relevant scientific and applied problem of background definition and identification of the compatibility of HMI subjects based on the irrational component of their interaction with the HMI object(s), to the solution of which, in fact, this study has been devoted, and a specialized method was developed within its framework.

2 REVIEW OF THE LITERATURE

The There are numerous methods, models, and means designed to form HMI teams, taking into account: the subject area of this interaction, organizational features, functional purpose, or any other components. In particular, research [5] proposes two improved swarm-based algorithms (providing faster convergence to the local minimum) for solving the team formation problem, the first of which uses a single crossover operator to improve the performance of the standard HBO algorithm, while the second one – uses the CHBO algorithm. The study [6] is devoted to investigation of team formation problems using AI, in particular, – in the context of the issue of justification the choice of certain/specific already formed/created teams, using the TFA. While the author of another research [7] proposed a combinatorial optimization approach by solving the graph coloring problem based on the use of the integer-programming-model in the GAMS environment, in order to solve (among other things) a team formation problems. The authors of study [8] reviewed and analyzed existing and well-known models/methods of team formation (which depend, among other things, on the characteristics, attributes, and personalities of team members), and identified the most common characteristics of team formation and computational methods used for this purpose. At the same time, within the scope of the study [9] authors investigate the issue of expanding (or replenishing) already formed teams (taking into account the three-component configuration of factors, namely: tasks performed by the team, existing team members, and new candidates for team members), using artificial neural networks and taking into account the aforementioned three-component configuration of factors for simultaneous modeling of the interaction between: the team task(s), team members, and candidates for team members. The study [10] represents the authors’ research in the context of analyzing team formation methods based on two dimensions (namely: conflict management and team effectiveness), finalized in results according to which, in particular, skill-based methods are more likely to create effective teams, but not necessarily less conflictual, while random methods show less conflictual teams that are, at the same time, more effective.

At the same time, authors of the research [11] investigate the problem of forming IT project teams, solved by applying a genetic algorithm, which allows finding a local extremum that will be optimal in the current project conditions for solving a multi-criteria problem (in particular, making a decision on the choice between: the presence of technical competencies of applicants; the ability to work in a team; and the presence of empathy – as a property of feeling empathy to the problems of other subjects of interaction), and also reduce the subjective component in the process of making project decisions, which, in turn,

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will increase the probability of successful completion of IT projects within conditions of uncertainty and dynamic changes. Along with this, results of research [12] confirm the positive effect of using task analysis as a tool for selecting candidates that best fit a specific task role of already formed software development team in order to optimize their skills for the appropriate available roles and, therefore, contribute to the overall success of formed teams. While the research [13] is devoted to the study and formalization of the characteristics necessary for the formation of effective teams, precisely in the context of the currently relevant and widely used Agile software development methodology, the study identified six component characteristics, namely: knowledge, skills, abilities, attitude, experience and personality, as well as another important characteristic which, as it appeared in the process of research, affects the composite characteristics, – and it is, actually, the characteristic of the project itself.

Thus, there are a number of existing methods, models, and means dedicated to forming teams of subjects in various areas, including the areas of IT projects and HMI. Each of the existing solutions is, undoubtedly, effective in its thematic area of specialization. However, a feature (and some drawback/disadvantage) of existing solutions is that, although they take into account a significant part of various factors affecting the formation of teams of the subjects, they completely ignore one extremely important factor of influence, namely: the factor of subjectivization of the perception of object(s) of this interaction (i.e., a "machine", or in general case – a software-hardware complex, a software product, etc.) – by the subjects of this interaction (candidates for acceptance into the formed teams). In other words, in the context of the HMI-specific area: it is going about the perception of the object (i.e., "machine") of this interaction – by the subjects (i.e., "human") of this interaction. In turn, taking into account/consideration this factor (of the HMI object's perception subjectivization) significantly affects the effectiveness of this interaction, as it provides the possibility of identification and achievement of a common vision of the interaction object – by each of the subjects of this interaction, providing the synergy achievement for all relevant components and participants of this interaction.

As a result, a relevant scientific and applied problem arises, which consists in determining and identifying the compatibility level(s) of HMI subjects (based on their polyfactor portraits of interaction objects' perception subjectivization), the solution of which is possible by developing an appropriate method (which is, actually, presented in scope of current research) allowing to take into account/consideration this important factor of HMI objects' perception subjectivization.

3 MATERIALS AND METHODS

The development of the declared method for determining the compatibility of HMI subjects (based on their polyfactor portraits of interaction objects' perception subjectivization) involves the phased development of all its components, namely: 1) development of a basic mathematical model for determining the compatibility of HMI subjects; 2) development of a specialized algorithm for determining the compatibility of HMI subjects; 3) development of a software model for determining the compatibility of HMI subjects; 4) approbation of the developed method on the example of solving a relevant practical applied problem.

However, the basic and fundamental stage of developing the declared method – is the identification of a way(s) for obtaining needed polyfactor portraits (of the interaction objects' perception subjectivization – by the relevant existing subjects of this interaction), because they act as the main input data for the functioning of the declared method (of HMI subjects' compatibility determining based on their polyfactor portraits of interaction objects' perception subjectivization) as well as for all relevant method's components, i.e.: the corresponding models (mathematical and software), as well as the specialized algorithm. Thus, the main source of obtaining a polyfactor portraits of HMI subjects – is the method described in research [14], the essence of which is to determine the weighting coefficients of the shares of influence of each of the previously declared (pre-defined) impact factors onto the perception subjectivization of the interaction object by the interaction subjects, which provides the possibility of obtaining the corresponding (personal/individual, for each of the subjects) polyfactor portraits of these subjects. So later, these subjects' polyfactor portraits could be processed by the proposed method, declared and developed in current research, in order to determine the compatibility level(s) for these subjects.

Development of a basic mathematical model for determining the compatibility of HMI subjects is the first stage of implementing the declared method. The main function of this component of the declared method – is formalizing the representation of the researched processes of determining the compatibility of HMI subjects, as well as providing possibilities for further mathematical (and later – software) modeling of these processes.

In particular, expression (2) below represents the HMI subjects' polyfactor portraits (of the subjectivization of their perception of the interaction object):

$$Sb_{[i][j]} = \left\{ Fc_{[k]}, k = \overline{1, nfc}, \left(\sum_{k=1}^{nfc} Fc_{[k]} = 1 \right) \right\}. \quad (j = \overline{1, nsb}) \qquad (2)$$

At the same time, expression (3) below represents the difference in values of the impact factors' share of presence between the polyfactor portraits of two subjects within the scope of same researched HMI:

$$\Delta Sb_{[i][p][q]}\left(Sb_{[i][p]}, Sb_{[i][q]}\right) = \sum_{k=1}^{nfc} \left| Sb_{[i][p]}\left\{Fc_{[k]}\right\} - Sb_{[i][q]}\left\{Fc_{[k]}\right\} \right|, \left(k = \overline{1, nfc}\right) \qquad (3)$$

Thus, expression (4) below represents the logical function of determining the compatibility of the investi-

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gated HMI subjects based on their polyfactor portraits (of the HMI object's perception subjectivization):

$$FcmpbtlL\left(Sb_{[i][p]}, Sb_{[i][q]}, CRT\right) = \begin{cases} true, \left(\Delta Sb_{[i][p][q]} \in CRT\right) \\ false, \left(\Delta Sb_{[i][p][q]} \notin CRT\right). \end{cases} \quad (4)$$

The introduced *CRT* compatibility criterion acts as a dynamic parameter/variable that can change its values / forms, depending on the needs of each individual task of HMI subjects' compatibility determining. In particular, in addition to the already given above example of presenting this criterion in the form of the absolute value of the permissible threshold (of the difference in values of the impact factors' share of presence between the polyfactor portraits of two comparable subjects), it can also be presented, for example, in the form of a segmented distribution of the value range of this deviation/difference (between comparable subjects), which provides additional possibility of differentiated analysis of the compatibility level(s) of investigated/comparable subjects.

Expression (5) below represents the given example of interpreting the *CRT* compatibility criterion as a segmented distribution of the value ranges to provide a differentiated analysis of the compatibility level(s) of investigated/comparable subjects of researched HMI:

$$FcmpbtlD\left(Sb_{[i][p]}, Sb_{[i][q]}, CRT\right) = \begin{cases} PbVl_{[1]}, \left(\Delta Sb_{[i][p][q]} \in CRT = \left[Dd_{[1L]}; Dd_{[1H]}\right]\right) \\ PbVl_{[2]}, \left(\Delta Sb_{[i][p][q]} \in CRT = \left[Dd_{[2L]}; Dd_{[2H]}\right]\right) \\ \vdots \\ PbVl_{[ndr]}, \left(\Delta Sb_{[i][p][q]} \in CRT = \left[Dd_{[ndrL]}; Dd_{[ndrH]}\right]\right). \\ 0, \left(\Delta Sb_{[i][p][q]} \notin CRT\right) \end{cases} \quad (5)$$

Therefore, expressions (2)–(5) given above, in fact, represent the developed basic mathematical model for determining the compatibility of HMI subjects based on their polyfactor portraits of interaction objects' perception subjectivization, which provides the possibility of both representation formalization of the researched processes (of HMI subjects' compatibility determining) as well as their further mathematical and computer/software modeling.

While the main feature of the developed basic mathematical model (as a component of the declared HMI subjects' compatibility determining method, based on their polyfactor portraits of interaction objects' perception subjectivization) – is its universality, which provides possibilities of its further development, improvement, modification, or usage beyond the limits of exclusively HMI research area/field, but also, in particular, in the context of any intersubjective interaction as a general concept regardless of its applied and/or thematic binding or limitations.

Development of a specialized algorithm (for determining the compatibility of HMI subjects) – is the second stage of implementing the declared method (of HMI subjects' compatibility determining), which provides possibility of algorithmizing the researched processes (of HMI subjects' compatibility determining) in order to allow their further coding (i.e., software/programming implementation).

In particular, Figure 1 below represents a flowchart of the developed algorithm for determining the compatibility of HMI subjects based on their polyfactor portraits of perception subjectivization of the relevant interaction object.

The main feature of the developed specialized algorithm for determining the compatibility of HMI subjects (based on their polyfactor portraits of interaction objects' perception subjectivization) – is that it provides the possibility of algorithmization of the researched processes (of HMI subjects' compatibility determining), and, therefore, as a derivative step – the possibility of coding (i.e., software/programming implementation), and, accordingly, further computer/software modeling of these researched processes, which is possible, besides that, including thanks to the corresponding software model, presented further in the text below.

Development of a software model for determining the compatibility of HMI subjects – is the third stage of implementing the declared method (of HMI interaction subjects' compatibility determining), which provides possibility of computer/software modeling of the researched processes of determining the compatibility of HMI subjects based on their polyfactor portraits of perception subjectivization of the relevant interaction object.

In particular, below, at Figure 2, a corresponding graphical visualization of the proposed software model's structure is presented, which includes such basic components as:

1) input data reading module (i.e., polyfactor portraits of the subjects of researched HMI);

2) model's parameter setting module (*CRT* compatibility criterion, its ranging, range boundaries, threshold value(s), etc.);

3) data processing module;

4) data storage module;

5) results output/visualization module.

Each of the modules of the developed software model represents exclusively a semantic separation of corresponding component(s) of the complex process of HMI subjects' compatibility determining (based on their polyfactor portraits of interaction objects' perception subjectivization), while functionally – absolutely all of these modules are inseparably integrated within the framework of one common, unified and indivisible software model (for determining the compatibility of HMI subjects).

In turn, the proposed structure of the developed software model (of HMI subjects' compatibility determining) can be practically implemented in any arbitrary way by means of any known and/or existing architectures, technologies, platforms, programming languages, integrated development environments, interfaces, etc.

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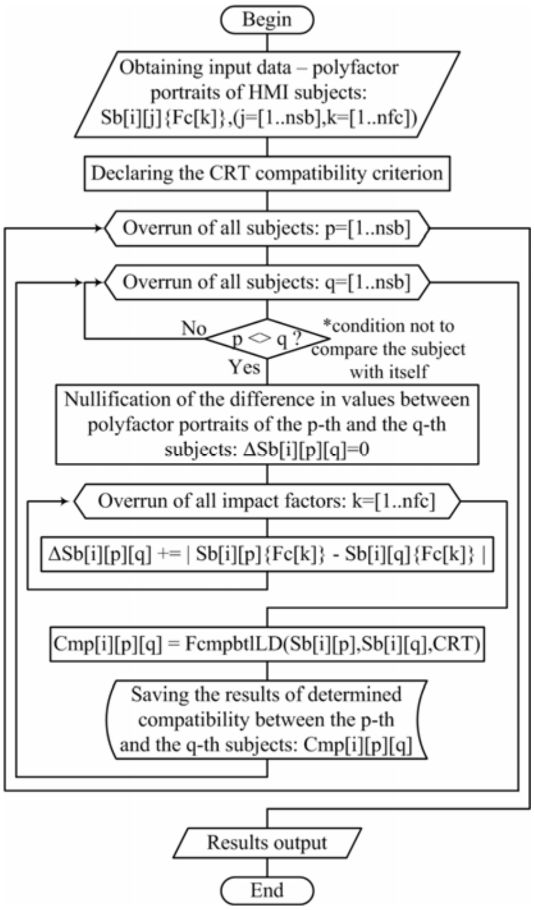

Figure 1 – Flowchart of the developed algorithm for determining the compatibility of HMI subjects

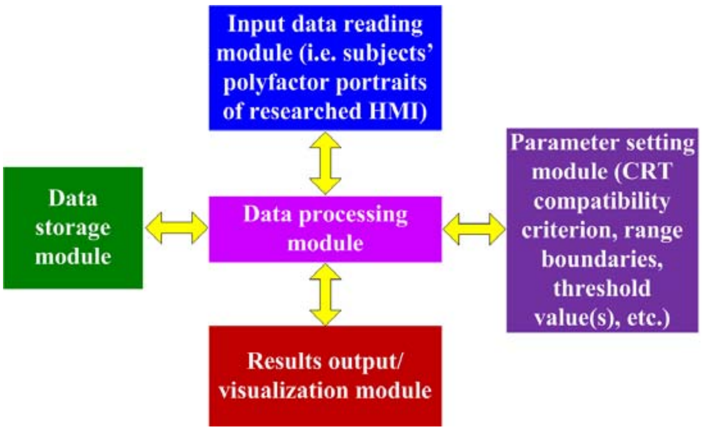

Figure 2 – The structure of the developed software model for determining the compatibility of HMI subjects

In particular, within the scope of current research, the software implementation of the developed software model (of HMI subjects' compatibility determining) has been carried out using the programming language Python 3.12 [15] and integrated development environment Thonny 4.1.4 [16, 17]. The choice of such specific particular software configuration is due to a number of undeniable advantages, including, for example, such as: open access; simplicity, efficiency and ease of use; low consumption level of software and hardware resources; high popularity among professionals, programmers, developers, students, scientists and other enthusiasts; a wide range of existing libraries, including their specialization in modern AI technologies; and many others.

Figure 3 below presents an example of the results obtained by the programming implementation of the developed software model (of HMI subjects' compatibility determining, based on their polyfactor portraits of interaction objects' perception subjectivization).

Main feature of the developed software model (of HMI subjects' compatibility determining) – is the presence of a separate parameter setting module (for setting/defining available model's parameters, including, in particular: the compatibility criterion *CRT*, its ranging,

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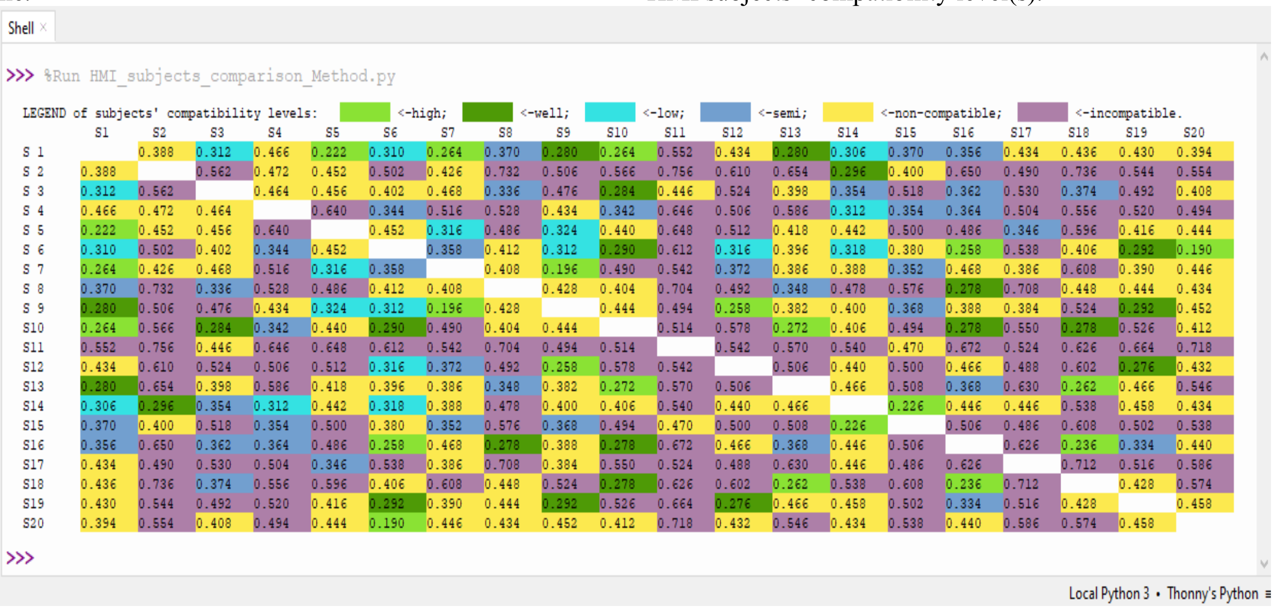
range boundaries, threshold value(s), etc), which provides the possibilities for modeling the same set(s) of input data (i.e., researched HMI subjects' polyfactor portraits) with completely different setting parameters, including the aforementioned compatibility criterion *CRT* as the basic one.

In particular, the example results shown in Figure 3 demonstrate the practical application of the *CRT* compatibility criterion, set as a segmented distribution of the deviation value(s) range, which provides possibility of a differentiated analysis of the investigated/comparable HMI subjects' compatibility level(s).



	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	S12	S13	S14	S15	S16	S17	S18	S19	S20
S 1		0.388	0.312	0.466	0.222	0.310	0.264	0.370	0.280	0.264	0.552	0.434	0.280	0.306	0.370	0.356	0.434	0.436	0.430	0.394
S 2	0.388		0.562	0.472	0.452	0.502	0.426	0.732	0.506	0.566	0.756	0.610	0.654	0.296	0.400	0.650	0.490	0.736	0.544	0.554
S 3	0.312	0.562		0.464	0.456	0.402	0.468	0.336	0.476	0.284	0.446	0.524	0.398	0.354	0.518	0.362	0.530	0.374	0.492	0.408
S 4	0.466	0.472	0.464		0.640	0.344	0.516	0.528	0.434	0.342	0.646	0.506	0.586	0.312	0.354	0.364	0.504	0.556	0.520	0.494
S 5	0.222	0.452	0.456	0.640		0.452	0.316	0.486	0.324	0.440	0.648	0.512	0.418	0.442	0.500	0.486	0.346	0.596	0.416	0.444
S 6	0.310	0.502	0.402	0.344	0.452		0.358	0.412	0.312	0.290	0.612	0.316	0.396	0.318	0.380	0.258	0.538	0.406	0.292	0.190
S 7	0.264	0.426	0.468	0.516	0.316	0.358		0.408	0.196	0.490	0.542	0.372	0.386	0.388	0.352	0.468	0.386	0.608	0.390	0.446
S 8	0.370	0.732	0.336	0.528	0.486	0.412	0.408		0.428	0.404	0.704	0.492	0.348	0.478	0.576	0.278	0.708	0.448	0.444	0.434
S 9	0.280	0.506	0.476	0.434	0.324	0.312	0.196	0.428		0.444	0.494	0.258	0.382	0.400	0.368	0.388	0.384	0.524	0.292	0.452
S10	0.264	0.566	0.284	0.342	0.440	0.290	0.490	0.404	0.444		0.514	0.578	0.272	0.406	0.494	0.278	0.550	0.278	0.526	0.412
S11	0.552	0.756	0.446	0.646	0.648	0.612	0.542	0.704	0.494	0.514		0.542	0.570	0.540	0.470	0.672	0.524	0.626	0.664	0.718
S12	0.434	0.610	0.524	0.506	0.512	0.316	0.372	0.492	0.258	0.578	0.542		0.506	0.440	0.500	0.466	0.488	0.602	0.276	0.432
S13	0.280	0.654	0.398	0.586	0.418	0.396	0.386	0.348	0.382	0.272	0.570	0.506		0.466	0.508	0.368	0.630	0.262	0.466	0.546
S14	0.306	0.296	0.354	0.312	0.442	0.318	0.388	0.478	0.400	0.406	0.540	0.440	0.466		0.226	0.446	0.446	0.538	0.458	0.434
S15	0.370	0.400	0.518	0.354	0.500	0.380	0.352	0.576	0.368	0.494	0.470	0.500	0.508	0.226		0.506	0.486	0.608	0.502	0.538
S16	0.356	0.650	0.362	0.364	0.486	0.258	0.468	0.278	0.388	0.278	0.672	0.466	0.368	0.446	0.506		0.626	0.236	0.334	0.440
S17	0.434	0.490	0.530	0.504	0.346	0.538	0.386	0.708	0.384	0.550	0.524	0.488	0.630	0.446	0.486	0.626		0.712	0.516	0.586
S18	0.436	0.736	0.374	0.556	0.596	0.406	0.608	0.448	0.524	0.278	0.626	0.602	0.262	0.538	0.608	0.236	0.712		0.428	0.574
S19	0.430	0.544	0.492	0.520	0.416	0.292	0.390	0.444	0.292	0.526	0.664	0.276	0.466	0.458	0.502	0.334	0.516	0.428		0.458
S20	0.394	0.554	0.408	0.494	0.444	0.190	0.446	0.434	0.452	0.412	0.718	0.432	0.546	0.434	0.538	0.440	0.586	0.574	0.458	

Figure 3 – An example of the results obtained by the programming implementation of the developed software model for determining the compatibility of HMI subjects

Thus, during the experimental modeling (results of which have been presented at Fig. 3 above) of the programming implementation of the developed software model, six main segmental classifiers of the researched HMI subjects' compatibility levels have been introduced, namely:

1) a "highly compatible" subjects (when the calculated difference in values between polyfactor portraits of comparable subjects does not exceed limit of 1.1X of the declared value of compatibility criterion's permissible threshold);

2) a "well compatible" subjects (when the calculated difference in values between polyfactor portraits of comparable subjects is in the range from 1.1X to 1.2X of the declared value of compatibility criterion's permissible threshold);

3) a "low compatible" subjects (when the calculated difference in values between polyfactor portraits of comparable subjects is in the range from 1.2X to 1.3X of the declared value of compatibility criterion's permissible threshold);

4) a "semi compatible" subjects (when the calculated difference in values between polyfactor portraits of comparable subjects is in the range from 1.3X to 1.5X of the declared value of compatibility criterion's permissible threshold);

5) a "non-compatible" (or, in other works: "rather incompatible than compatible") subjects (when the calculated difference in values between polyfactor portraits of comparable subjects is in the range from 1.5X to 1.9X of the declared value of compatibility criterion's permissible threshold);

6) as well as a (fully/totally) "incompatible" subjects (when the calculated difference in values between polyfactor portraits of comparable subjects exceeds 1.9X-times of the declared value of compatibility criterion's permissible threshold).

The corresponding range values can be adjusted both heuristically (i.e., empirically) and depending on a specific tasks or needs, This property is provided for both the developed basic mathematical model as well as the developed software model as the components of the declared HMI subjects' compatibility determining method based on their polyfactor portraits of interaction objects' perception subjectivization.

4 EXPERIMENTS

The experiment consists of obtaining the polyfactor portraits for all researched subjects – participants of the considered investigated HMI, based on input data related to their perception subjectivization of relevant HMI object.

After that, the obtained polyfactor portraits are cross-compared with each other by means of the developed mathematical model and specialized algorithm (introduced and described in details in scope of previous chapter).

And finally, at the last stage of the experiment, the obtained compatibility results are presented in any arbitrary (convenient) form of representation.

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5 RESULTS

The final stage of implementation of the declared method (of HMI subjects' compatibility determining based on their polyfactor portraits of interaction objects' perception subjectivization) – is its practical approbation on the example of solving a specific experimental practical applied problem, which is, in the context of current research, – the problem of identifying potentially interchangeable subjects of the researched HMI team, that has been considered and resolved by means of the developed method.

Thus, the results of this practical approbation of the developed method – (as relevant) also, in details, and as clearly as possible, demonstrate the results of the entire research in general, and are presented within the scope of this particular section of the research.

A resolution of the declared practical applied problem has been performed/implemented in two basic stages, the first (or "initialization") of which is receiving/obtaining and visualization of input information/data (i.e., subjects' polyfactor portraits of the researched team of investigated HMI), while the second (or "finalization") stage is, in fact, the search, analysis, and identification (by means of the developed method of HMI subjects' compatibility determining based on their polyfactor portraits of interaction objects' perception subjectivization) of potentially interchangeable subjects of the researched HMI team. In other words, the essence of this problem boils down to the fact that for each subject (of the researched HMI team) it is necessary to identify another subject (from the same researched HMI team), the compatibility of which is maximal among all other subjects – members of the researched HMI team.

In particular, below, at Figure 4, a graphical interpretation of the input data is presented – that is, the polyfactor portraits of all subjects – members of the researched HMI team.

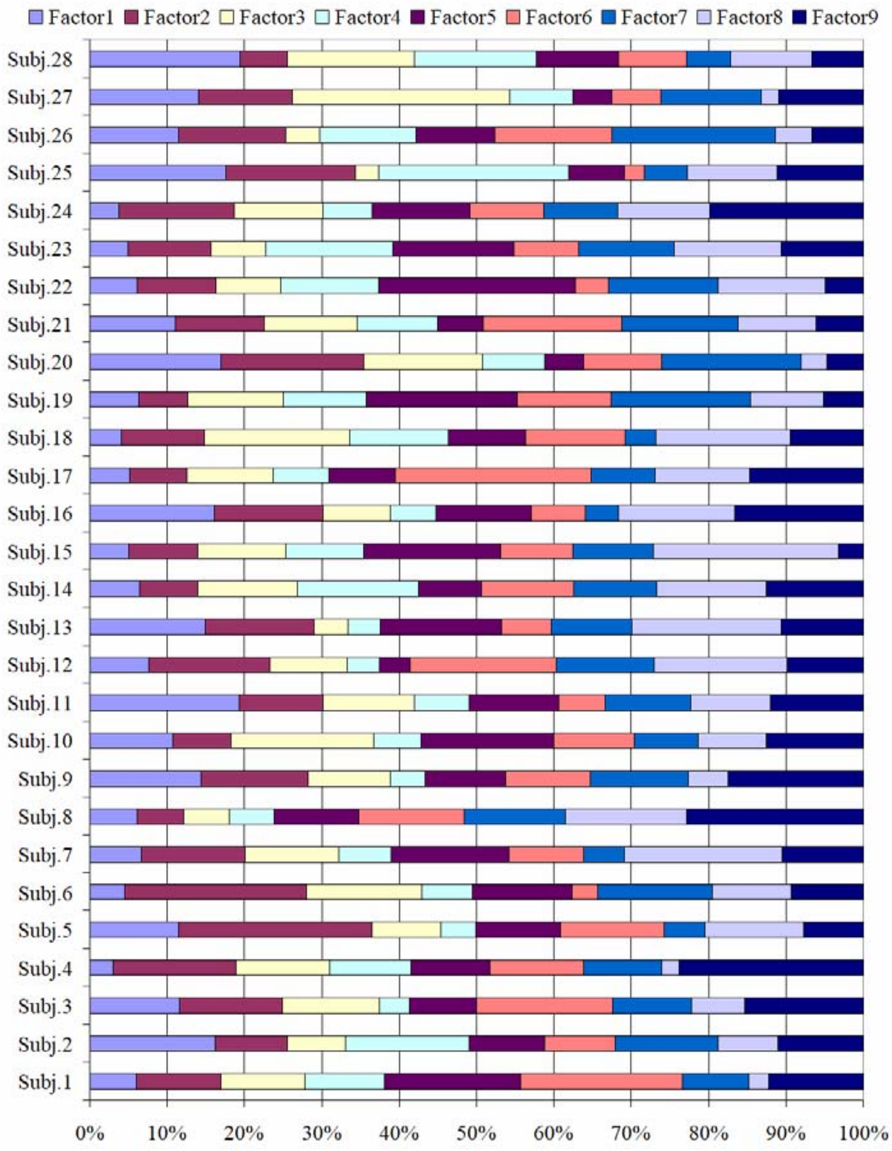

Figure 4 – A graphical interpretation of the input data– the polyfactor portraits of all subjects - members of the researched HMI team

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Figure 5 below demonstrates the results of applying the developed method (of HMI subjects' compatibility determining based on their polyfactor portraits of interaction objects' perception subjectivization) in the context of solving the considered practical applied problem of identifying potentially interchangeable subjects of the researched HMI team.

While, Figure 6 below represents the final result of solving the declared practical applied problem of identifying potentially interchangeable subjects of the researched HMI team.

Shell

```
>>> %Run practical_task_resolution_method_approbation.py
```

LEGEND of subjects' compatibility levels: <-high; <-well; <-low; <-semi; <-non-compatible; <-incompatible.

S#	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
1		0.52	0.37	0.39	0.59	0.61	0.44	0.57	0.46	0.38	0.49	0.50	0.61	0.44	0.48	0.60	0.34	0.51	0.41	0.66	0.42	0.54	0.42	0.45	0.81	0.50	0.62	0.65
2	0.52		0.44	0.55	0.55	0.57	0.55	0.51	0.33	0.44	0.29	0.56	0.44	0.32	0.56	0.43	0.56	0.52	0.48	0.47	0.39	0.49	0.28	0.52	0.43	0.37	0.47	0.31
3	0.37	0.44		0.38	0.41	0.55	0.46	0.47	0.21	0.37	0.36	0.33	0.48	0.40	0.65	0.41	0.33	0.54	0.56	0.51	0.30	0.73	0.57	0.35	0.70	0.43	0.50	0.58
4	0.39	0.55	0.38		0.60	0.54	0.54	0.43	0.34	0.55	0.53	0.58	0.69	0.44	0.63	0.56	0.50	0.52	0.56	0.58	0.53	0.72	0.54	0.26	0.78	0.54	0.60	0.69
5	0.59	0.55	0.41	0.60		0.42	0.40	0.55	0.44	0.51	0.48	0.41	0.45	0.54	0.62	0.37	0.54	0.49	0.62	0.56	0.47	0.65	0.55	0.45	0.60	0.51	0.73	0.54
6	0.61	0.57	0.55	0.54	0.42		0.45	0.62	0.51	0.49	0.41	0.52	0.54	0.53	0.57	0.55	0.61	0.54	0.49	0.49	0.50	0.50	0.46	0.37	0.69	0.62	0.58	0.63
7	0.44	0.55	0.46	0.54	0.40	0.45		0.48	0.48	0.37	0.41	0.40	0.29	0.39	0.29	0.32	0.47	0.32	0.47	0.66	0.52	0.50	0.34	0.30	0.66	0.65	0.66	0.53
8	0.57	0.51	0.47	0.43	0.55	0.62	0.48		0.42	0.50	0.52	0.44	0.51	0.37	0.55	0.45	0.40	0.53	0.51	0.80	0.55	0.58	0.42	0.33	0.82	0.59	0.77	0.68
9	0.46	0.33	0.21	0.34	0.44	0.51	0.48	0.42		0.40	0.30	0.44	0.41	0.47	0.65	0.30	0.49	0.61	0.56	0.41	0.43	0.67	0.52	0.30	0.65	0.41	0.43	0.55
10	0.38	0.44	0.37	0.55	0.51	0.49	0.37	0.50	0.40		0.34	0.59	0.47	0.38	0.47	0.45	0.43	0.43	0.38	0.58	0.48	0.57	0.46	0.39	0.75	0.62	0.49	0.40
11	0.49	0.29	0.36	0.53	0.48	0.41	0.41	0.52	0.30	0.34		0.52	0.34	0.40	0.52	0.29	0.48	0.53	0.50	0.46	0.40	0.52	0.41	0.36	0.50	0.55	0.42	0.33
12	0.50	0.56	0.33	0.58	0.41	0.52	0.40	0.44	0.44	0.59	0.52		0.44	0.43	0.56	0.51	0.40	0.47	0.60	0.55	0.32	0.63	0.49	0.45	0.72	0.54	0.62	0.73
13	0.61	0.44	0.48	0.69	0.45	0.54	0.29	0.51	0.41	0.47	0.34	0.44		0.56	0.45	0.27	0.66	0.59	0.63	0.65	0.60	0.52	0.38	0.45	0.53	0.55	0.61	0.61
14	0.44	0.32	0.40	0.44	0.54	0.53	0.39	0.37	0.47	0.38	0.40	0.43	0.56		0.42	0.51	0.32	0.30	0.38	0.62	0.38	0.47	0.26	0.38	0.59	0.54	0.59	0.38
15	0.48	0.56	0.65	0.63	0.62	0.57	0.29	0.55	0.65	0.47	0.52	0.56	0.45	0.42		0.59	0.55	0.43	0.34	0.71	0.51	0.36	0.35	0.46	0.86	0.67	0.78	0.57
16	0.60	0.43	0.41	0.56	0.37	0.55	0.32	0.45	0.30	0.45	0.29	0.51	0.27	0.51	0.59		0.52	0.51	0.69	0.62	0.59	0.59	0.46	0.31	0.48	0.63	0.61	0.48
17	0.34	0.56	0.33	0.50	0.54	0.61	0.47	0.40	0.49	0.43	0.48	0.40	0.66	0.32	0.55	0.52		0.46	0.53	0.75	0.42	0.67	0.51	0.36	0.78	0.65	0.72	0.60
18	0.51	0.52	0.54	0.52	0.49	0.54	0.32	0.53	0.61	0.43	0.53	0.47	0.59	0.30	0.43	0.51	0.46		0.52	0.69	0.47	0.55	0.40	0.46	0.69	0.60	0.62	0.41
19	0.41	0.48	0.56	0.56	0.62	0.49	0.47	0.51	0.56	0.38	0.50	0.60	0.63	0.38	0.34	0.69	0.53	0.52		0.52	0.34	0.32	0.40	0.51	0.87	0.44	0.70	0.50
20	0.66	0.47	0.51	0.58	0.56	0.49	0.66	0.80	0.41	0.58	0.46	0.55	0.65	0.62	0.71	0.62	0.75	0.69	0.52		0.38	0.72	0.71	0.63	0.68	0.42	0.38	0.52
21	0.42	0.39	0.30	0.53	0.47	0.50	0.52	0.55	0.43	0.48	0.40	0.32	0.60	0.38	0.51	0.59	0.42	0.47	0.34	0.38		0.51	0.48	0.51	0.68	0.32	0.49	0.48
22	0.54	0.49	0.73	0.72	0.65	0.50	0.50	0.58	0.67	0.57	0.52	0.63	0.52	0.47	0.36	0.59	0.67	0.55	0.32	0.72	0.51		0.29	0.56	0.73	0.57	0.75	0.62
23	0.42	0.28	0.57	0.54	0.55	0.46	0.34	0.42	0.52	0.46	0.41	0.49	0.38	0.26	0.35	0.46	0.51	0.40	0.40	0.71	0.48	0.29		0.38	0.55	0.50	0.65	0.49
24	0.45	0.52	0.35	0.26	0.45	0.37	0.30	0.33	0.30	0.39	0.36	0.45	0.45	0.38	0.46	0.31	0.36	0.46	0.51	0.63	0.51	0.56	0.38		0.68	0.62	0.64	0.60
25	0.81	0.43	0.70	0.78	0.60	0.69	0.66	0.82	0.65	0.75	0.50	0.72	0.53	0.59	0.86	0.48	0.78	0.69	0.87	0.68	0.68	0.73	0.55	0.68		0.65	0.73	0.50
26	0.50	0.37	0.43	0.54	0.51	0.62	0.65	0.59	0.41	0.62	0.55	0.54	0.55	0.54	0.67	0.63	0.65	0.60	0.44	0.42	0.32	0.57	0.50	0.62	0.65		0.61	0.59
27	0.62	0.47	0.50	0.60	0.73	0.58	0.66	0.77	0.43	0.49	0.42	0.62	0.61	0.59	0.78	0.61	0.72	0.62	0.70	0.38	0.49	0.75	0.65	0.64	0.73	0.61		0.58
28	0.65	0.31	0.58	0.69	0.54	0.63	0.53	0.68	0.55	0.40	0.33	0.73	0.61	0.38	0.57	0.48	0.60	0.41	0.50	0.52	0.48	0.62	0.49	0.60	0.50	0.59	0.58	

```
>>>
```

Local Python 3 • Thonny's Python

Figure 5 – Results of subjects' compatibility determining of the researched HMI team.

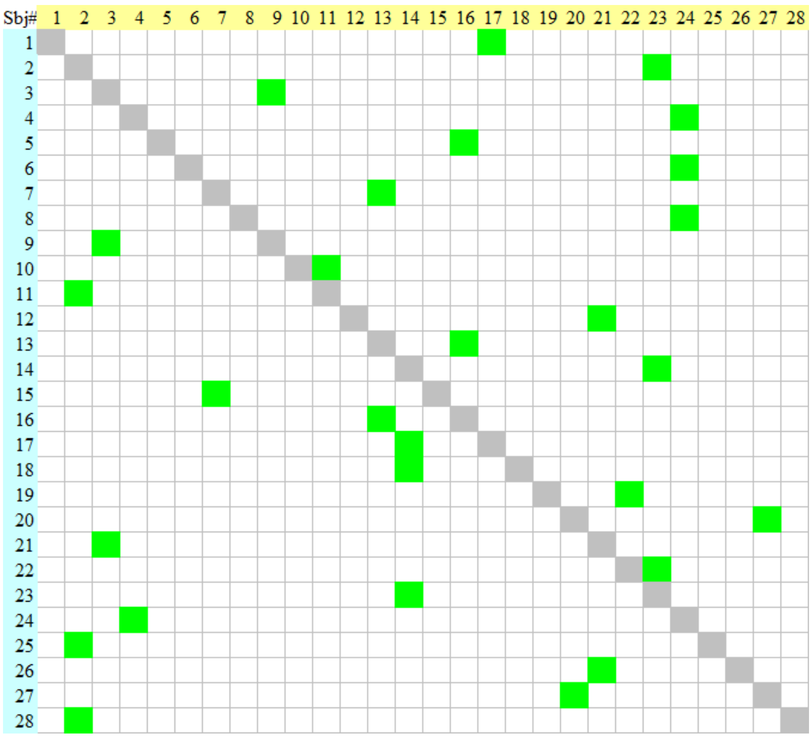

Figure 6 – Identified potentially interchangeable subjects of the researched HMI team

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Thus, by means of the developed method (of HMI subjects' compatibility determining based on their polyfactor portraits of interaction objects' perception subjectivization) – the relevant practical applied problem of identifying potentially interchangeable subjects of the researched HMI team has been successfully resolved.

In turn, the resolution of this specific applied problem opens the way to solving a number of derived subproblems, one of which is, in particular, the identification of subjects (of researched HMI team) that act as the most "universal donor subjects", characterized by a high degree of compatibility level(s) with other subjects – members of the same researched HMI team. For example, based on the results presented above in Figure 6, such subjects are:

– subject 2, which can act as a potentially interchangeable donor for subjects 11, 25 and 28;

– subject 14, which can act as a potentially interchangeable donor for subjects 17, 18 and 23;

– subject 23, which can act as a potentially interchangeable donor for subjects 2, 14 and 22;

– subject 24, which can act as a potentially interchangeable donor for subjects 4, 6, and 8.

As well as a whole batch of other relevant derived practical applied problems, the solution of which is provided by the method developed and represented in scope this research: i.e., HMI subjects' compatibility determining method, based on their polyfactor portraits of interaction objects' perception subjectivization.

6 DISCUSSION

In particular, the research [18] investigates the issues of quantitative analysis of the efficiency and productivity of systems where the main functional elements are living people/human, in particular, the graphical analysis of the nonlinear functional relationship between team productivity and team size, in the context of which the problem of human compatibility (in teams) is being studied as well. It has been determined that the area of functional dependence of team productivity on its size – has more diffuse characteristics, and this fact is, actually, caused by the problem of human compatibility (of the researched team's members). In addition, a curve model of the low human compatibility mode is presented, when each new team member contributes to the advancement of the project to some extent due to his experience, new knowledge and skills, but with lower productivity, since this new team member, in addition to increasing the time spent on internal contacts, – is also somehow incompatible with other team members. Also, the model of building a project team is presented, where the average productivity of people (i.e., team members) increases or decreases with the addition of each new team member, depending on how compatible the newcomer is with the rest of already existing team members.

In scope of research [19], a relevant framework is developed that attempts to integrate human and machine performance metrics during interaction in such a way as to provide a robust, human-compatible system that requires the participation of three main functional elements (which form a relevant three-component interaction model) in interaction based on: engineering design (i.e., product life cycle software developers), operating systems developers (including users and managers), and system design architects.

The research [20] is devoted to the investigation of the quantitative assessment of the abstract concept of team homogeneity and the measurement of its impact on software quality and team productivity, which is implemented on the basis of a specially developed metric called the THI, built on the basis of a six-step process of calculating the THI of a software development team, and the obtained research results, actually, confirm a direct relationship between the quality of the results of intersubjective interaction and the corresponding indicator of the proposed THI. At same time, the research [21] represents a study in context of issue of the influence of social and human factors in the field of software development, which provides the possibility of quantifying the abstract concept of team homogeneity based on the FFM, namely: O-THI, C-THI, E-THI, A-THI and N-THI. The impact of these five indicators is assessed by conducting experiments in academic and industrial environments for three different phases of SDLC, i.e.: analysis and design, implementation, and testing. And the obtained results, actually, indicate and confirm that those proposed and introduced five indicators (i.e., O-THI, C-THI, E-THI, A-THI and N-THI) can be used to help both managers and scientists to create a productive team(s) that, in turn, can create the higher-quality software.

While, the research [22] presents a method of remote selection of candidates for a team, based on socionic analysis of their content in a social networks, where a key role is assigned to the psychological compatibility of the interaction between the members of the formed team(s), assessing, first of all, the "soft skills" of the candidates (which include: high communication skills, language skills, cognitive or emotional empathy, leadership traits), using Jung's basis with the help of four pairs of dichotomous signs, which (with a high probability) determine the psyche of a person and, on this basis, assess its ability to be involved in performing a certain type(s) of work, proposing an algorithm for using visual and verbal methods for forming teams, assessing their cohesion and determining the optimal leader.

At the same time, the advantage of the developed method of HMI subjects' compatibility determining based on their polyfactor portraits of interaction objects' perception subjectivization, presented within the scope of current research, – is that, unlike existing approaches and solutions, the proposed method provides the possibility of processing polyfactor portraits of perception subjectivization of the HMI object by each of the subjects of this interaction, which makes it possible to determine the compatibility of subjects precisely according to the key criterion of their affinity in subjective vision and perception of the object of their joint interaction, thereby ensuring the possibility of identifying subjects with a common vision of the object of interaction, and, accordingly, increasing

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the level of efficiency of their interaction due to, precisely, this common vision and mutual understanding, as well as minimizing any destructive components/effects caused by differences in this vision of the object(s) or the processes of their joint interaction.

Therefore, based on the results of performed research, the scientific novelty and practical significance of the research have been formulated and given below. Scientific novelty of the obtained research results – for the first time, a method of determining the HMI subjects' compatibility based on their polyfactor portraits of interaction objects' perception subjectivization has been developed, which makes it possible to identify the compatibility of HMI subjects precisely on the basis of their polyfactor portraits of perception subjectivization of the object(s) of interaction, thereby ensuring an improvement in the qualitative and efficiency indicators of HMI teams due to the possibility of identifying, selecting and joining subjects with a common subjective vision and perception of the object(s) and processes of their joint HMI. Practical significance of the obtained research results – a software model (of determining the compatibility of HMI subjects based on their polyfactor portraits of interaction objects' perception subjectivization) has been developed, as well as its programming implementation (using the Python programming language), which provides the possibility(-ies) of computer/software modeling of the researched processes of HMI subjects' compatibility determining based on their polyfactor portraits of interaction objects' perception subjectivization; a practical approbation of the developed method (of determining the compatibility of HMI subjects based on their polyfactor portraits of interaction objects' perception subjectivization) has been carried out on the example of solving a relevant practical applied problem of identifying potentially interchangeable subjects of the researched HMI team, which provides opportunities for solving a whole batch of other relevant derived practical applied problems in the context of HMI-subjects' compatibility based on their personal subjectivization of the perception (i.e., understanding, vision) of relevant HMI-object(s).

CONCLUSIONS

The relevant scientific and applied problem of a background determining and identifying of the compatibility of HMI subjects based on irrational part of their interaction with HMI object(s), ensuring the improvement of the qualitative and efficiency indicators of HMI teams due to the possibility of identifying, selecting and joining subjects with a common (e.g.: "close", or similar) subjective vision and perception of the object(s) and/or processes of their joint HMI.

The scientific novelty of obtained results consists in the following: for the first time, a method of determining the HMI subjects' compatibility based on their polyfactor portraits of interaction objects' perception subjectivization has been developed, which makes it possible to identify the compatibility of HMI subjects precisely on the basis of their polyfactor portraits of perception subjectivization of the object(s) of interaction, thereby ensuring an improvement in the qualitative and efficiency indicators of HMI teams due to the possibility of identifying, selecting and joining subjects with a common subjective vision and perception of the object(s) and processes of their joint HMI.

The practical significance of obtained results consists in the following: a software model (of determining the compatibility of HMI subjects based on their polyfactor portraits of interaction objects' perception subjectivization) has been developed, as well as its programming implementation (using the Python programming language), which provides the possibility(-ies) of computer/software modeling of the researched processes of HMI subjects' compatibility determining based on their polyfactor portraits of interaction objects' perception subjectivization; a practical approbation of the developed method (of determining the compatibility of HMI subjects based on their polyfactor portraits of interaction objects' perception subjectivization) has been carried out on the example of solving a relevant practical applied problem of identifying potentially interchangeable subjects of the researched HMI team, which provides opportunities for solving a whole batch of other relevant derived practical applied problems in the context of HMI-subjects' compatibility based on their personal subjectivization of the perception (i.e., understanding, vision) of relevant HMI-object(s).

Prospects for further research are potential development(s) and improvement(s) of both the developed method and its relevant component models (in particular – the software model) in the context of researching the issues of: HMI objects' and processes' perception subjectivization, automation and intellectualization of HMI and its components, as well as the formation, creation, replenishment, or correction of teams (intersubjective associations, groups, joints, forms, environments, etc.), both in the field/area of HMI as well as in other relevant and/or related fields, in particular, such as: socionics, social engineering, cybernetic psychology, and intersubjective interaction in general.

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This research is proactive. It was carried out as a part of the scientific activity of the authors outside of the working hours at their main positions.

DECLARATIONS

Conflict of interest: The authors declare that they have no conflict of interest in relation to this research, whether financial, personal, authorship, or otherwise, that could affect the research and its results presented in this paper.

Authors' contributions: Andrii Pukach: the HMI subjects' compatibility determining method, methodology, resources, data curation, project administration, modeling, visualization, correspondence; Vasyl Teslyuk: conceptualization, supervision.

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Data availability: The original contributions presented in this study are included in the article.

Software availability: The manuscript has no associated software.

Use of artificial intelligence tools: The authors confirm that they did not use artificial intelligence technologies in creating the submitted work.

REFERENCES

1. Perwira L. T., Widarnandana G. D. Are Team Building Interventions Still Relevant?. *Psikostudia Jurnal Psikologi,* 2022, Vol. 11, No. 4, pp. 520–531. DOI: 10.30872/psikostudia.v11i4.8723
2. Melnyk K., Borysova N., Kochuieva Z. et al. Towards Designing of Recommendation System for Recruiting of Software Development Teams [Electronic resource]. *CMIS-2021: The 4th International Workshop on Computer Modeling and Intelligent Systems,* 2021, Vol. 2864, paperID 20, pp. 1–12. Mode of access: https://ceurspt.wikidata.dbis.rwth-aachen.de/Vol-2864/paper20.pdf (date of access: 26.01.2026). – Title from screen.
3. Campêlo M. B., Tatiane F. F., Silva A. The sociotechnical teams formation problem: a mathematical optimization approach. *Annals of Operations Research,* 2018, Vol. 286(1–2), pp. 201–216. DOI: 10.1007/s10479-018-2759-5
4. Drogobytskij I. N. Systematicity of organizational management. *Sistemni Doslidzennia Ta Informacijni Tehnologii*, 2020, Vol. 0(3), pp. 51–65. DOI: 10.20535/srit.2308-8893.2020.3.04
5. Nageh N., Elshamy A., Wahab A. S. H. et al. Enhanced Heap-Based Optimizer Algorithm for Solving Team Formation problem. *Computers, Materials & Continua,* 2022, Vol. 73, No. 3, pp. 5245–5268. DOI: 10.32604/cmc.2022.030906
6. Georgara A., Rodriguez-Aguilar J.A., Sierra C. Building Contrastive Explanations for Multi-Agent Team Formation [Electronic resource]. *In Proc. of the 21st International Conference on Autonomous Agents and Multiagent Systems (AAMAS 2022), IFAAMAS*, 2022, pp. 1–9. Mode of access: https://iiia.csic.es/media/filer_public/ce/41/ce4113c7-499a-4fd5-9f3b-65ceb9494e9d/fp464-georgara.pdf (date of access: 26.01.2026). Title from screen.
7. Šeda M. Integer Programming Approach to Graph Colouring Problem and Its Implementation in GAMS. *Wseas Transactions on Systems,* 2023, Vol. 22, pp. 532–537. DOI: 10.37394/23202.2023.22.53
8. Stavrou G., Adamidis P., Papathanasiou J. et al. Team Formation Characteristics and Methods: A Short Review [Electronic resource]. *Proceedings of the EWG-DSS 2021 International Conference On Decision Support System Technology on Decision Support Systems, Analytics and Technologies in response to Global Crisis Management*, 2021, pp. 1–8. Mode of access: https://www.researchgate.net/profile/Georgios-Stavrou/publication/355827046_Team_Formation_Characteristics_and_Methods_A_Short_Review/links/61803327a767a03c14dd721c/Team-Formation-Characteristics-and-Methods-A-Short-Review.pdf (date of access: 26.01.2026). Title from screen.
9. Zhao L., Yao Y., Guo G. et al. Team Expansion in Collaborative Environments. *Lecture Notes in Computer* Science, 2018, pp. 713–725. DOI: 10.1007/978-3-319-93040-4_56
10. Balawi S., Youssef A., Elmasry Y. Impact of team formation methodology on Team's conflict and effectiveness. *Proceedings of the 2023 ASEE Gulf-Southwest Annual Conference*, 2023, pp. 1–9. DOI: 10.18260/1-2-1153-46335
11. Blyznyukova I., Teslenko P. Formation of a minimum viable IT project team using the genetic algorithm. *Technology Audit and Production Reserves*, 2023, Vol. 2, No. 70, pp. 6–10. DOI: 10.15587/2706-5448.2023.277930
12. Otokiti K., Chiemeke S. C., Ukaoha K. C. Towards Selecting Software Development Team Members using Task Analysis [Electronic resource]. *African Journal Of Management Information System,* 2020, Vol. 2, Iss. 1, pp. 55–65. Mode of access: https://www.researchgate.net/profile/Kareem-Otokiti/publication/363223924_Towards_Selecting_Software_Development_Team_Members_using_Task_Analysis_Reference_Format/links/6311fd3bacd814437ff9c1be/Towards-Selecting-Software-Development-Team-Members-using-Task-Analysis-Reference-Format.pdf (date of access: 26.01.2026). – Title from screen.
13. Zainal D. A. P., Razali R., Mansor Z. Team Formation for Agile Software Development: A Review. *International Journal on Advanced Science, Engineering and Information Technology,* 2020, Vol. 10, No. 2, pp. 555–561. DOI: 10.18517/ijaseit.10.2.10191
14. Pukach A. I., Teslyuk V. M. Method of forming multifactor portraits of the subjects supporting software complexes, using a multilayer perceptron. *Radio Electronics, Computer Science, Control,* 2025, Vol. 1, pp. 130–141. DOI: 10.15588/1607-3274-2025-1-12
15. Python Release Python 3.12.0. [Electronic resource], Python.org. Mode of access: https://www.python.org/downloads/release/python-3120/ (date of access: 26.01.2026). – Title from screen.
16. Thonny, Python IDE for beginners [Electronic resource], Thonny.org. Mode of access: https://thonny.org/ (date of access: 26.01.2026). Title from screen.
17. Thonny, Release Version 4.1.4 GitHub [Electronic resource]. Mode of access: https://github.com/thonny/thonny/releases/tag/v4.1.4 (date of access: 26.01.2026). – Title from screen.
18. Quantitative analysis of the efficiency and productivity of the activity of human systems. Part 1: Graphical analysis of the nonlinear functional relationship between team productivity and team size [Electronic resource]. *PM World Journal*, 2021, Vol. X, Iss. III, pp. 1–13. Mode of access: https://pmworldlibrary.net/wp-content/uploads/2021/03/pmwj103-Mar2021-Barseghyan-quantitative-analysis-of-efficiency-and-productivity-of-human-systems-part-1.pdf (date of access: 26.01.2026). – Title from screen.
19. Raghunathan R., Srinath R. Review of Recent Developments in Ergonomic Design and Digital Human Models. *Industrial Engineering & Management*, 2016, Vol. 5, No. 2, pp. 1–7. DOI: 10.4172/2169-0316.1000186
20. Qamar N., Malik A. A. Birds of a Feather Gel Together: Impact of Team Homogeneity on Software Quality and Team Productivity. *IEEE Access,* 2019, Vol. 7, pp. 96827–96840. DOI: 10.1109/access.2019.2929152
21. Qamar N., Malik A. A. A Quantitative Assessment of the Impact of Homogeneity in Personality Traits on Software Quality and Team Productivity. *in IEEE Access,* 2022,

DOI 10.15588/1607-3274-2026-2-16

Vol. 10, pp. 122092–122111. DOI: 10.1109/ACCESS.2022.3222845
22. Morushko O., Khymytsia N., Teslyuk V. Remote Selection of Staff Based on Socionic Analysis of Social Network Content [Electronic resource]. *COLINS-2022: 6th International Conference on Computational Linguistics and Intelligent Systems*, 2022, Vol. 3171, pp. 1–12. Mode of access: https://ceur-ws.org/Vol-3171/paper15.pdf (date of access: 26.01.2026). Title from screen.

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МЕТОД ВИЗНАЧЕННЯ СУМІСНОСТІ СУБ’ЄКТІВ ЛЮДИНО-МАШИННОЇ ВЗАЄМОДІЇ НА ОСНОВІ ЇХ СУБ’ЄКТИВІЗАЦІЇ СПРИЙНЯННЯ ОБ’ЄКТА ВЗАЄМОДІЇ

Пукач А. І. – канд. техн. наук, асистент кафедри автоматизованих систем управління інституту комп’ютерних наук та інформаційних технологій Національного університету «Львівська Політехніка», Львів, Україна. ROR: https://ror.org/0542q3127. ORCID: https://orcid.org/0009-0001-8563-3311.

Теслюк В. М. – д-р техн. наук, професор, завідувач кафедри автоматизованих систем управління інституту комп’ютерних наук та інформаційних технологій Національного університету «Львівська Політехніка», Львів, Україна. ROR: https://ror.org/0542q3127. ORCID: https://orcid.org/0000-0002-5974-9310.

АНОТАЦІЯ

Актуальність. Дослідження присвячено вирішенню актуальної науково-прикладної проблеми фонового визначення та ідентифікації сумісності суб’єктів людино-машинної взаємодії (ЛМВ) на основі ірраціональної компоненти їх взаємодії з об’єктом(ами) ЛМВ. **Об’єктом дослідження** є процес визначення сумісності суб’єктів ЛМВ на основі суб’єктивізації сприйняття ними об’єкта ЛМВ. **Предметом дослідження** є методи та засоби штучних нейронних мереж, обчислювального інтелекту, математичного моделювання, а також комп’ютерного програмування.

Мета роботи – розроблення методу визначення сумісності суб’єктів ЛМВ, що базується на суб’єктивізації сприйняття ними об’єкта ЛМВ.

Метод. Розроблено метод визначення сумісності суб’єктів ЛМВ, який ґрунтується на аналізі їх поліфакторних портретів суб’єктивізації сприйняття об’єкта(ів) цієї взаємодії, та забезпечує можливість вирішення вищезадекларованої науково-прикладної задачі. Особливість розробленого методу полягає у застосуванні (у рамках вирішення заявленої проблеми) поліфакторних портретів, що репрезентують суб’єктивізацію сприйняття об’єкта(ів) ЛМВ – суб’єктами цієї ж взаємодії, з метою виявлення ступеня/рівня сумісності цих суб’єктів саме в контексті призми суб’єктиваційних особливостей їх персоніфікованого сприйняття об’єкта(ів) (або процесів) в рамках їх спільної ЛМВ. Запропонований метод базується на відповідних моделях, розроблених і представлених у рамках даної роботи, а також на спеціалізованому алгоритмі, що забезпечує можливість автоматизації та подальшого програмно-комп’ютерного моделювання досліджуваних процесів.

Результати. В рамках цього дослідження: розроблено та представлено базову математичну модель, спеціалізований алгоритм, а також програмну модель задекларованого методу. Додатково, проведено практичну апробацію розробленого методу на прикладі розв’язання релевантної прикладної практичної задачі визначення потенційно взаємозамінних суб’єктів досліджуваного колективу ЛМВ, що підтверджує дієвість та ефективність розробленого методу в контексті вирішення подібних та пов’язаних релевантних прикладних практичних задач.

Висновки. Розроблено метод визначення сумісності суб’єктів ЛМВ за їх поліфакторними портретами суб’єктивізації сприйняття об’єктів ЛМВ, який забезпечує можливість вирішення релевантної актуальної науково-прикладної задачі визначення та ідентифікації сумісності суб’єктів ЛМВ, а також надає можливість ідентифікувати сумісність суб’єктів ЛМВ саме на основі їх поліфакторних портретів суб’єктивізації сприйняття об’єкта(ів) цієї взаємодії, забезпечуючи, тим самим, підвищення якісних і ефективних показників команд ЛМВ саме за рахунок можливості виявлення, відбору та об’єднання суб’єктів (людей) із спільним суб’єктивним баченням і сприйняттям об’єкта(ів) та/або процесів їх спільної взаємодії.

КЛЮЧОВІ СЛОВА: людино-машинна взаємодія, сумісність суб’єктів, поліфакторний портрет, суб’єктивізація сприйняття.

ЛІТЕРАТУРА

1. Perwira L. T. Are Team Building Interventions Still Relevant? / L. T. Perwira, G. D. Widarnandana // Psikostudia Jurnal Psikologi. – 2022. – Vol. 11, No. 4. – P. 520–531. DOI: 10.30872/psikostudia.v11i4.8723
2. Towards Designing of Recommendation System for Recruiting of Software Development Teams [Electronic resource] / K. Melnyk, N. Borysova, Z. Kochuieva et al. // CMIS-2021: The 4th International Workshop on Computer Modeling and Intelligent Systems. – 2021. – Vol. 2864, paperID 20. – P. 1–12. – Mode of access: https://ceurspt.wikidata.dbis.rwth-aachen.de/Vol-2864/paper20.pdf (date of access: 26.01.2026). – Title from screen.
3. Campêlo M. B. The sociotechnical teams formation problem: a mathematical optimization approach / M. B. Campêlo, F. F. Tatiane, A. Silva // Annals of Operations Research. – 2018. – Vol. 286(1–2). – P. 201–216. DOI: 10.1007/s10479-018-2759-5
4. Drogobytskij I. N. Systematicity of organizational management / I. N. Drogobytskij // Sistemni Doslidzennia Ta Informacijni Tehnologii. – 2020. – Vol. 0(3). – P. 51–65. DOI: 10.20535/srit.2308-8893.2020.3.04
5. Enhanced Heap-Based Optimizer Algorithm for Solving Team Formation problem / [N. Nageh, A. Elshamy, A. S. H. Wahab et al.] // Computers, Materials & Continua. – 2022. – Vol. 73, No. 3. – P. 5245–5268. DOI: 10.32604/cmc.2022.030906

DOI 10.15588/1607-3274-2026-2-16

6. Building Contrastive Explanations for Multi-Agent Team Formation [Electronic resource] / A. Georgara, J. A. Rodriguez-Aguilar, C. Sierra // In Proc. of the 21st International Conference on Autonomous Agents and Multiagent Systems (AAMAS 2022), IFAAMAS. – 2022. – P. 1–9. – Mode of access: https://iiia.csic.es/media/filer_public/ce/41/ce4113c7-499a-4fd5-9f3b-65ceb9494e9d/fp464-georgara.pdf (date of access: 26.01.2026). – Title from screen.
7. Šeda M. Integer Programming Approach to Graph Colouring Problem and Its Implementation in GAMS / M. Šeda // Wseas Transactions on Systems. – 2023. – Vol. 22. – P. 532–537. DOI: 10.37394/23202.2023.22.53
8. Team Formation Characteristics and Methods: A Short Review [Electronic resource] / G. Stavrou, P. Adamidis, J. Papathanasiou et al. // Proceedings of the EWG-DSS 2021 International Conference On Decision Support System Technology on Decision Support Systems, Analytics and Technologies in response to Global Crisis Management. – 2021. – P. 1–8. – Mode of access: https://www.researchgate.net/profile/Georgios-Stavrou/publication/355827046_Team_Formation_Characteristics_and_Methods_A_Short_Review/links/61803327a767a03c14dd721c/Team-Formation-Characteristics-and-Methods-A-Short-Review.pdf (date of access: 26.01.2026). – Title from screen.
9. Team Expansion in Collaborative Environments / [L. Zhao, Y. Yao, G. Guo et al.] // Lecture Notes in Computer Science. – 2018. – P. 713–725. DOI: 10.1007/978-3-319-93040-4_56
10. Balawi S. Impact of team formation methodology on Team’s conflict and effectiveness / S. Balawi, A. Youssef, Y. Elmasry // Proceedings of the 2023 ASEE Gulf-Southwest Annual Conference. – 2023. – P. 1–9. DOI: 10.18260/1-2-1153-46335
11. Blyznyukova I. Formation of a minimum viable IT project team using the genetic algorithm / I. Blyznyukova, P. Teslenko // Technology Audit and Production Reserves. – 2023. – Vol. 2, No. 70. – P. 6–10. DOI: 10.15587/2706-5448.2023.277930
12. Towards Selecting Software Development Team Members using Task Analysis [Electronic resource] / K. Otokiti, S. C. Chiemeke, K. C. Ukaoha // African Journal Of Management Information System. – 2020. – Vol. 2, Iss. 1. – P. 55–65. – Mode of access: https://www.researchgate.net/profile/Kareem-Otokiti/publication/363223924_Towards_Selecting_Software_Development_Team_Members_using_Task_Analysis_Reference_Format/links/6311fd3bacd814437ff9c1be/Towards-Selecting-Software-Development-Team-Members-using-Task-Analysis-Reference-Format.pdf (date of access: 26.01.2026). – Title from screen.
13. Zainal D. A. P. Team Formation for Agile Software Development: A Review / D. A. P. Zainal, R. Razali, Z. Mansor // International Journal on Advanced Science, Engineering and Information Technology. – 2020. – Vol. 10, No. 2. – P. 555–561. DOI: 10.18517/ijaseit.10.2.10191
14. Pukach A. I. Method of forming multifactor portraits of the subjects supporting software complexes, using a multilayer perceptron / A. I. Pukach, V. M. Teslyuk // Radio Electronics, Computer Science, Control. – 2025. – Vol. 1. – P. 130–141. DOI: 10.15588/1607-3274-2025-1-12
15. Python Release Python 3.12.0. [Electronic resource] / Python.org. // – Mode of access: https://www.python.org/downloads/release/python-3120/ (date of access: 26.01.2026). – Title from screen.
16. Thonny, Python IDE for beginners [Electronic resource] / Thonny.org. // – Mode of access: https://thonny.org/ (date of access: 26.01.2026). – Title from screen.
17. Thonny, Release Version 4.1.4 GitHub [Electronic resource]. – Mode of access: https://github.com/thonny/thonny/releases/tag/v4.1.4 (date of access: 26.01.2026). – Title from screen.
18. Barseghyan P. Quantitative analysis of the efficiency and productivity of the activity of human systems. Part 1: Graphical analysis of the nonlinear functional relationship between team productivity and team size [Electronic resource] / P. Barseghyan // PM World Journal. – 2021. – Vol. X, Iss. III. – P. 1–13. – Mode of access: https://pmworldlibrary.net/wp-content/uploads/2021/03/pmwj103-Mar2021-Barseghyan-quantitative-analysis-of-efficiency-and-productivity-of-human-systems-part-1.pdf (date of access: 26.01.2026). – Title from screen.
19. Raghunathan R. Review of Recent Developments in Ergonomic Design and Digital Human Models / R. Raghunathan, R. Srinath // Industrial Engineering & Management. – 2016. – Vol. 5, No. 2. – P. 1–7. DOI: 10.4172/2169-0316.1000186
20. Qamar N. Birds of a Feather Gel Together: Impact of Team Homogeneity on Software Quality and Team Productivity / N. Qamar, A. A. Malik // IEEE Access. – 2019. – Vol. 7. – P. 96827–96840. DOI: 10.1109/access.2019.2929152
21. Qamar N. A Quantitative Assessment of the Impact of Homogeneity in Personality Traits on Software Quality and Team Productivity / N. Qamar, A. A. Malik // in IEEE Access. – 2022. – vol. 10. – P. 122092–122111, DOI: 10.1109/ACCESS.2022.3222845
22. Morushko O. Remote Selection of Staff Based on Socionic Analysis of Social Network Content [Electronic resource] / O. Morushko, N. Khymytsia, V. Teslyuk // COLINS-2022: 6th International Conference on Computational Linguistics and Intelligent Systems. – 2022. – Vol. 3171. – P. 1–12. – Mode of access: https://ceur-ws.org/Vol-3171/paper15.pdf (date of access: 26.01.2026). – Title from screen.

DOI 10.15588/1607-3274-2026-2-16