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METHOD OF SEARCHING FOR INFORMATION OBJECTS IN UNIFIED INFORMATION SPACE

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Abstract. The article discusses the concept and principles of building unified information space and presents a scheme for its formation. The article considers formation of unified information space using a specialized information computer system, which is actually a hardware and software basis for supporting unified information space. The stages of information object identification in unified information space are considered. The article suggests a method for finding missing features of an incoming object by implementing the information objects interaction with each other within unified information space.

Keywords: unified information space, information object, signs, object identification, search method.

INTRODUCTION

Unified information space is an information model of a complex subject area. It includes information objects, connections between them, environment of the space and processes accompanying creation of unified information space [1–5].

Unified information space is formed as a result of processing information about an object, received from various sources.

Here is the contradiction, which is as follows: in order to obtain information features of objects, the heterogeneous data sources there are used, and these sources are characterized by varying degrees of accuracy and different formats for data presenting. At the same time, for the formation of unified information space, the unification of data obtained from heterogeneous sources is required. The implementation of a converting mechanism for such formats also is required. So, the contradiction arises between the heterogeneous nature of sensors for collecting features of objects and the requirement for a unified data presentation. In this case, the same object, the parameters of which are obtained from different sensors, must be uniquely identified anyway.

In the process of forming unified information space, an information computer system collects information from various data sources presented in different forms and / or formats, while the processing of incoming data can be carried out by heterogeneous computer systems [6–8].

To form unified information space, it is required to implement a unified data entry, store data in uniform formats and exchange information between all infor-

mation objects [5, 9, 10]. An information object is a mathematical description of an initial object by its main parameters. It can be represented as a tuple of parameters of a real object, and all values of the parameters are determined by the characteristics of the real object.

Information about objects in unified information space changes dynamically [11–12].

Creation of unified information space is intended to provide a unified description of information objects for all users, so that all users of unified information space perceive the same information object in the same way. This characteristic is the main feature of unified information space [1, 2].

Thus, unified information space is a complex of tools that support the unity of presentation, processing and interpretation of information about information objects. Creation of unified information space is aimed to provide access to general information without limiting the place and time [13–19].

The information computer system, on the basis of which unified information space is formed, performs the following main functions:

- transformation of information about objects and formation of unified information space;
- providing users with information about objects.

The goal of the research is to consider the concept and principles of building unified information space and present a scheme for its formation using a specialized information computer system; describe the stages of identifying an information object in unified information space; propose a method for finding missing features of an incoming object.

SCHEME OF UNIFIED INFORMATION SPACE FORMATION

Fig. 1 shows a general scheme for unified information space formation. An important task of unified information space is to transform the input information in such a way that each information object in unified information space is presented uniquely.

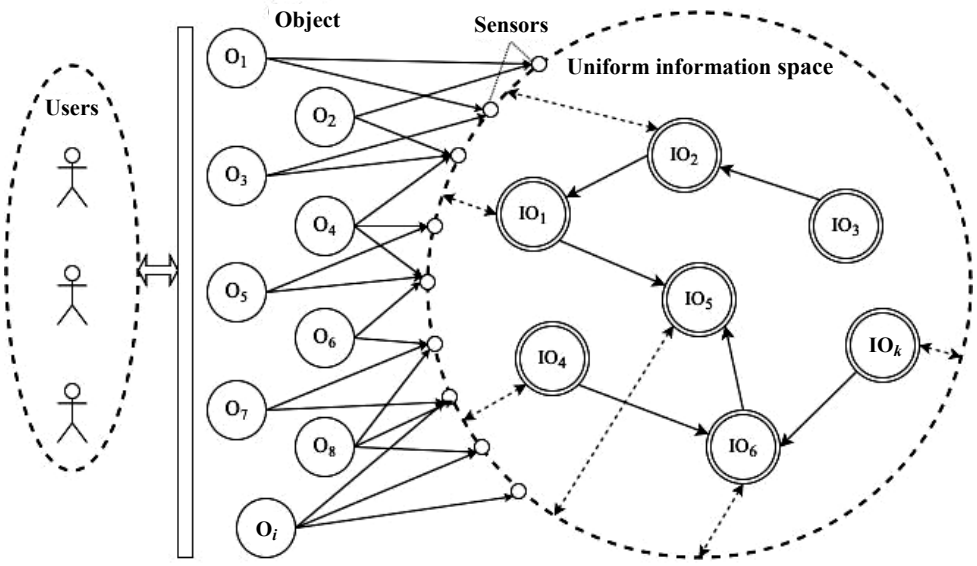

Fig. 1. General scheme of unified information space

In unified information space, the attributes of information objects must be defined in a single format and their number must be the same. Information objects should also be perceived unambiguously by users of unified information space. In fact, the input information in unified information space is heterogeneous in its presentation.

The task of internal mechanisms of an information computer system is to transform heterogeneous information coming in different formats and from different sources into a single set of information object attributes, by which unified information space users can uniquely identify an information object.

STAGES OF INFORMATION OBJECT IDENTIFICATION IN UNIFIED INFORMATION SPACE

Identification of an information object in unified information space makes it possible to unambiguously define it by the corresponding features. To identify objects, an identification method can be used which is based on a step-by-step analysis of the characteristics of an object using requests to the object in order to provide an opportunity to make decisions about its identification.

As it shows Fig.1 the external sources of information for unified information space generally represent objects $O_1, O_2, \ldots, O_m$ in different ways, where *m* is the number of objects operated by unified information space. Information about such objects is received as a set of feature values by reading them using sensors.

Also here is presented the users of unified information space, who's goal is to get some information about the objects there.

There are many information objects $IO_1, IO_2, \ldots, IO_k$, each of which has a set of features $P_1, P_2, \ldots, P_n$, where k is number of information objects, and *n* is number of an information object features, i.e., IO_k $(P_1, P_2, \ldots, P_n)$.

In this case, it is considered that the same maximum number of features is set for each information object. Still the number of features for each specific object may be less than the maximum — some features may be absent (correspond to the NONE value), i. e. this object may simply not have this feature.

In unified information space each IO_k information object is different, that is, there are no two absolutely identical information objects:

$$IO_1 \neq IO_2 \neq, IO_3 \neq \ldots \neq IO_k .$$

Therefore, unified information space should work as a kind of reference system. For this you need to go through several stages:

1. To form unified information space. It will consist of a set of information objects, each of which is characterized by a set of features. Such information objects will differ from each other, that is, they will be unique. Information objects have connections, so they interact with each other. A connection is understood as the presence of parameters of another information object in the certain object, which are obtained as a result of their interaction with each other. Connections between information objects correspond to the "interaction trajectory", which is determined by the pre-history of the of objects interactions with each other.

Unified information space is constantly being updated and trained. Formation of unified information space is the procedure of its training, that is, recognition of incoming objects without reference to a specific object.

2. Read the characteristics of the incoming object using sensors, which are a kind of meters. But it happens that sensors may not read some signs of information objects, for example, there will be no access, there will be no information (corresponds to the NULL value).

3. Classification (recognition) of an object. The system receives an object O_m with a set of features, the sensors should read their values, and unified information space should unambiguously answer the question of whether there is an information object in a unified information space with such feature values, or a new information object will be formed.

METHOD OF SEARCHING FOR MISSING FEATURES IN THE INFORMATION OBJECT

Information objects have a local feature memory. When a unique identification of an incoming object occurs, the values of its parameters are added to the memory of corresponding attributes of the information object. Then, from a set of values of each information object attribute, statistical characteristics that describe this attribute are determined — the mathematical expectation M and the variance D, and the more input objects are identified by unified information space, the more accurate they become.

Method of searching for missing features in an information object:

1. Formation of the objects interaction history. Information objects store history of interactions with each other and an information object can answer the question whether it interacted with another information object before, and if so, whether the trajectory of its interaction contains the needed feature. If a given information object does not have an answer to this question, then it refers to other information objects of unified information space.

2. Comparison on the basis of features. An object O_i with a set of parameters $(P_1, P_2, \ldots, P_n)$ comes to the input. If the value of each parameter falls within the permissible range of values for the corresponding attribute of a certain information object $(M - D \le P_i \le M + D)$, then unified information space uniquely identifies the incoming object, that is, $\mathrm{O}_i = \mathrm{IO}_k$.

3. Search for missing features. To search for missing features, an information object interacts with every other information object from unified information space. For this, a feature search will be used. This search is based on the trajectory of the objects interaction, and their combination allows gradually narrow the search area for the missing parameters of the objects. And so on, until all the missing features are filled in so that unified information space can uniquely identify the object O_i.

4. Clarification (recognition) of missing features. If there are not enough signs, then it is necessary to turn to other information objects of unified information space and request the necessary missing features based on the trajectory of information objects interaction. For this, it is necessary that each information object retains the trajectory of interaction, i.e. it actually has a kind of global

memory. With such unified information space formation, all trajectories of all information objects interaction are placed in a single data warehouse.

5. The result is displaying the found object, group of objects or establishing the fact that the analyzed object is new.

In brief, the method is the next: the identification of an information object is made according to certain external or internal characteristics of an information object, taking into account the interaction of an information object in a unified information space. To support these actions, each information object is supplied with a set of features that characterize the object to a certain extent. Due to this, the procedure for identifying an information object is reduced to a simple comparison of the characteristics of the information object with the characteristics of the incoming object. If the parameters of an information object in a necessary and sufficient degree coincide with the parameters of the incoming real object, then this object is considered as has been identified.

ORGANIZATION AND CONDUCTING EXPERIMENTAL RESEARCH

We will analyze efficiency of incoming objects search in unified information space.

For the experiments, unified information space of 20,000 information objects was formed.

The percentage of missing parameters in information objects (NONE) was 6%. After that, a single information space is rebuilt by eliminating duplicate information objects. A series of 20 experiments each was carried out, at certain probabilities (25, 20, 15, 10 and 5%, respectively) that the parameter would not be read by the sensors (NULL).

Experiment 1. Let's consider the case when each of 20,000 information objects is described by 7 parameters. Below is a snippet of 10 information objects (Table 1).

Table 1. Fragment of 10 information objects from unified information space

IO	P						
	P_1	P_2	P_3	P_4	P_5	P_6	P_7
IO_1	4 ± 0,5	3 ± 0,9	6 ± 0,7	7 ± 0,1	6 ± 0,9	9 ± 0,4	11 ± 0,6
IO_2	5 ± 0,1	6 ± 0,6	6 ± 0,9	7 ± 0,4	6 ± 0,6	6 ± 0,1	9 ± 0,2
IO_3	1 ± 0,3	6 ± 0,9	3 ± 0,2	5 ± 0,2	NONE	10 ± 0,4	8 ± 0,4
IO_4	1 ± 0,7	6 ± 0,7	7 ± 0,3	6 ± 0,4	6 ± 0,5	NONE	10 ± 0,8
IO_5	4 ± 0,4	6 ± 0,6	4 ± 0,4	7 ± 0,2	8 ± 0,3	6 ± 0,5	8 ± 0,4
IO_6	5 ± 0,4	4 ± 0,8	6 ± 0,4	4 ± 0,5	5 ± 0,7	8 ± 0,8	9 ± 0,7
IO_7	2 ± 0,3	3 ± 0,6	7 ± 0,4	NONE	7 ± 0,6	9 ± 0,7	8 ± 0,6
IO_8	3 ± 0,4	5 ± 0,5	5 ± 0,4	6 ± 0,2	9 ± 0,6	NONE	7 ± 0,5
IO_9	2 ± 0,9	2 ± 0,5	3 ± 0,2	4 ± 0,9	8 ± 0,2	6 ± 0,5	11 ± 0,2
IO_{10}	1 ± 0,2	6 ± 0,7	6 ± 0,4	8 ± 0,7	9 ± 0,3	8 ± 0,3	11 ± 0,5

In this case, the interval length for each parameter was 5 units, for example, for the parameter P_1 [1; 6).

The following variants of the results were obtained:

1. When the sensors read all the values of the parameters of the incoming object and its unique identification has occurred:

New object:

5,8 6,5 6,2 4,8 9,6 9,5 9,7

Search object:

IO 06106 5 ± 0,3 6 ± 0,4 6 ± 0,7 4 ± 0,9 9 ± 0,4 9 ± 0,6 9 ± 0,2

2. When the sensors read all the values of the incoming object parameters and its identification did not occur, there was no information object in unified information space that would describe this incoming object:

New object:

4,9 3,3 4,5 7,9 5,2 6,5 11,7

Object is absent!

In this case, this incoming object becomes a new information object and can be added to unified information space.

3. When the sensors did not read the values of all parameters of the incoming object (NULL), but due to the interaction of information objects with each other in unified information space, a unique identification of the incoming object took place:

New object:

5,2 Null 6,4 6,3 5,5 10,1 9,9

Search object:

IO 02727 5 ± 0,1 4 ± 0,4 6 ± 0,5 6 ± 0,8 5 ± 0,6 10 ± 0,8 9 ± 0,2
IO 13394 5 ± 0,6 2 ± 0,2 6 ± 0,8 6 ± 0,4 5 ± 0,2 10 ± 0,1 9 ± 0,9
IO 14824 5 ± 0,1 5 ± 0,3 6 ± 0,9 6 ± 0,9 5 ± 0,4 10 ± 0,2 9 ± 0,4

ReCreateObject:

5,2 4,1 6,4 6,3 5,5 10,1 9,9

Search object:

IO 02727 5 ± 0,1 4 ± 0,4 6 ± 0,5 6 ± 0,8 5 ± 0,6 10 ± 0,8 9 ± 0,2

4. When the sensors did not read the values of all parameters of the incoming object and, despite the interaction of information objects with each other in unified information space, identification of the incoming object did not occur:

New object:

2,1 4,5 3,5 Null 9,6 9,2 Null

Search object:

IO 08264 2 ± 0,3 4 ± 0,2 3 ± 0,7 None 9 ± 0,6 9 ± 0,7 10 ± 0,4
IO 08473 2 ± 0,6 4 ± 0,6 3 ± 0,3 6 ± 0,8 9 ± 0,2 9 ± 0,5 8 ± 0,4
IO 16500 2 ± 0,9 4 ± 0,7 3 ± 0,1 8 ± 0,4 9 ± 0,4 9 ± 0,6 8 ± 0,4

ReCreateObject:

2,1 4,5 3,5 Null 9,6 9,2 8,5

Search object:

IO 08473 2 ± 0,6 4 ± 0,6 3 ± 0,3 6 ± 0,8 9 ± 0,2 9 ± 0,5 8 ± 0,4
IO 16500 2 ± 0,9 4 ± 0,7 3 ± 0,1 8 ± 0,4 9 ± 0,4 9 ± 0,6 8 ± 0,4

ReCreateObject:

2,1 4,5 3,5 5,1 9,6 9,2 8,5

Object absent!

5. When the sensors did not count values of one or several parameters and, after the interaction of information objects with each other in unified information space, it was found that this object does not have this feature (NONE).

New object:

2,7 4,7 4,1 8,3 5,5 Null 7,6

Search object:
IO 12602 2 ± 0,5 4 ± 0,4 4 ± 0,3 8 ± 0,7 5 ± 0,8 10 ± 0,9 7 ± 0,8
ReCreateObject:
2,7 4,7 4,1 8,3 5,5 Null 7,6
ReCreateObject:
2,7 4,7 4,1 8,3 5,5 Null 7,6
ReCreateObject:
2,7 4,7 4,1 8,3 5,5 None 7,6
Object absent!

Generalization of the experiments results made it possible to conclude about search efficiency of incoming objects in unified information space with 7 parameters and an interval length of 5 units, which is presented in Table 2.

Table 2. Search efficiency of incoming objects in unified information space with 7 parameters and an interval length of 5 units

Probability that the parameter will not be read by sensors (NULL),%	Probability of an incoming object identification,%
5	20
10	10
15	25
20	15
25	15

Table 2 shows that search efficiency of incoming objects in unified information space with 7 parameters and an interval length of 5 units is low.

Therefore, it was decided to reduce number of parameters that describe the object, and conduct similar experiments with 4, 5 and 6 parameters with the same initial data. The results of the experiments are presented in Table 3.

Table 3. Search efficiency of incoming objects in unified information space with 4, 5 and 6 parameters and an interval length of 5 units

Probability that the parameter will not be read by sensors (NULL), %	Probability of an incoming object identification depending on the number of parameters, %		
	4	5	6
5	100	100	65
10	100	100	45
15	100	90	85
20	100	100	75
25	100	100	50

Based on the data in Tables 2 and 3, a graph was built for comparing search efficiency of incoming objects in unified information space with 4, 5, 6 and 7 parameters and an interval length of 5 units (Fig. 2).

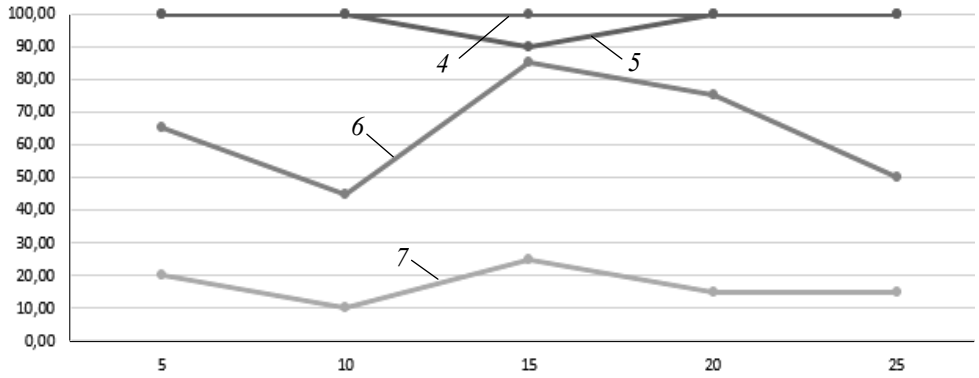

Fig. 2. Comparative graph of search efficiency of incoming objects in unified information space with 4, 5, 6 and 7 parameters and an interval length of 5 units

From Fig. 2, we can conclude that search efficiency of incoming objects in unified information space with an interval length of 5 units was on average: with 4 parameters — 100%, with 5 parameters — 98%, with 6 parameters — 64% and with 7 parameters — 17%.

Accordingly, a decrease in the number of parameters leads to a sharp increase in search efficiency of incoming objects in unified information space.

Experiment 2. When analyzing the conclusions of experiment 1, it was decided to change the lengths of the values intervals of the parameters of the incoming objects in unified information space with a constant value of parameters number.

Let us consider the case when each of 20,000 information objects is described by 7 parameters, but with different interval lengths of parameter values of 3, 4, and 5 units. The results of the experiments are presented in table 4.

Table 4. Search efficiency of incoming objects in unified information space with 7 parameters and an interval length of 3, 4 and 5 units

Probability that the parameter will not be read by sensors (NULL),%	**Probability of an incoming object identification depending on the interval length, %**		
	3	4	5
5	100	75	20
10	100	40	10
15	95	50	25
20	100	65	15
25	100	50	15

Based on the data in Table 4, a graph was built for comparing search efficiency of incoming objects in unified information space with 7 parameters and an interval length of 3, 4, and 5 units (Fig. 3).

From Fig. 3, we can conclude that search efficiency of incoming objects in unified information space with 7 parameters on average was: with an interval length of 3 units — 99%, 4 units — 56%, 5 units — 17%.

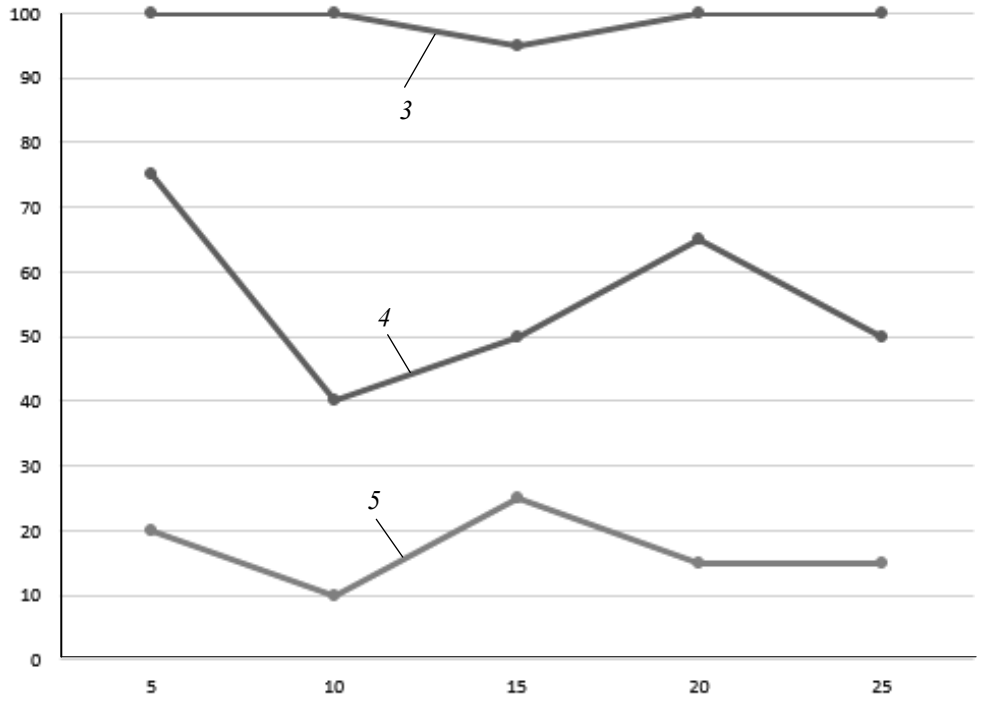

Fig. 3. Comparative graph of search efficiency of incoming objects in unified information space with 7 parameters and an interval length of *3*, *4* and *5* units

Accordingly, an increase in the interval length leads to a sharp decrease in search efficiency of incoming objects in unified information space.

Experiment 3. When analyzing the conclusions of experiment 2, it was decided to conduct similar experiments with a small interval length, but a larger number of incoming objects parameters in unified information space.

Let us consider the case when each of 20,000 information objects is described by 8, 9, and 10 parameters with a length of parameter value intervals being 3 units. The results of the experiments are presented in Table 5.

Table 5. Efficiency of searching for incoming objects in unified information space with 8, 9 and 10 parameters with a length of parameter value intervals of 3 units

Probability that the parameter will not be read by sensors (NULL),%	**Probability of an incoming object identification depending on the number of parameters,%**			
	7	8	9	10
5	100	85	35	25
10	100	80	40	5
15	95	90	35	10
20	100	90	45	25
25	100	95	40	15

Based on the data in Tables 4 and 5, a graph was constructed for comparing searching efficiency of incoming objects in unified information space with 7, 8, 9 and 10 parameters and the length of the parameter values interval of 3 units (Fig. 4).

From Fig. 4, we can conclude that search efficiency of incoming objects in unified information space with length of parameter value interval of 3 units on average was: with 7 parameters — 99%, with 8 parameters — 88%, with 9 parameters — 39%, and with 10 parameters — 16%.

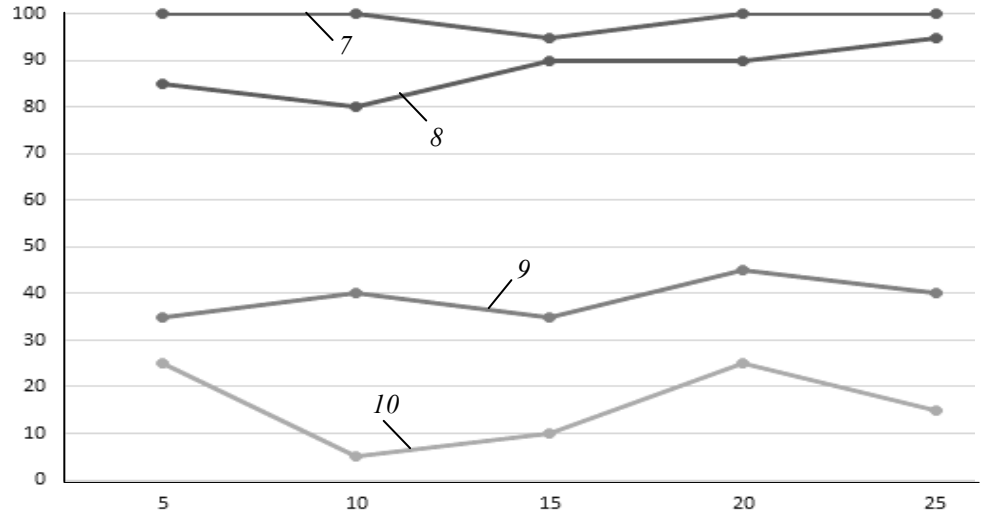

Fig. 4. Comparative graph of search efficiency of incoming objects in unified information space with 7, 8, 9 and 10 parameters and length of the parameter value interval of 3 units

Accordingly, search efficiency of incoming objects in unified information space is the highest with 7 and 8 parameters and with length of the parameter values interval of 3 units.

CONCLUSIONS

The article discusses formation of unified information space using a specialized information computer system, which is actually a hardware and software basis for supporting a single information space.

The stages of information object identification in unified information space are considered. The article proposes the method of searching for missing features of the incoming object by implementing information objects interaction with each other within unified information space.

The experiments described in the article make it possible to evaluate search efficiency of incoming objects in unified information space when the number of incoming parameters and interval of their values change. The experiments have shown that the identification probability depends significantly on the number of parameters of the original object, as well as on the length of the intervals describing values of the object parameters themselves. At the same time, with an increase in number of original object parameters and the interval length of object parameters, search efficiency of incoming objects in unified information space significantly decreases.

Thus, a promising direction of research is the development of specialized methods for identifying objects in unified information space, which will improve object identification efficiency in conditions of an increase in number of the original object parameters and the interval length of object parameters.

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МЕТОД ПОИСКА ИНФОРМАЦИОННЫХ ОБЪЕКТОВ В ЕДИНОМ ИНФОРМАЦИОННОМ ПРОСТРАНСТВЕ / А.Г. Додонов, В.Е. Мухин, В.В. Завгородний, Я.И. Корнага, А.А. Завгородняя

Аннотация. Рассмотрены понятие и принципы построения единого информационного пространства и представлена схема его формирования. Рассмотрено формирование единого информационного пространства с использованием специализированной информационной компьютерной системы, которая фактически является аппаратно-программным базисом для поддержки единого информационного пространства, а также этапы идентификации информационного объекта в едином информационном пространстве. Предложен метод поиска недостающих признаков входящего объекта путем реализации взаимодействия информационных объектов между собой внутри единого информационного пространства.

Ключевые слова: единое информационное пространство, информационный объект, признаки, идентификация объекта, метод поиска.

МЕТОД ПОШУКУ ІНФОРМАЦІЙНИХ ОБ'ЄКТІВ В ЄДИНОМУ ІНФОРМАЦІЙНОМУ ПРОСТОРІ / О.Г. Додонов, В.Є. Мухін, В.В. Завгородній, Я.І. Корнага, Г.А. Завгородня

Анотація. Розглянуто поняття і принципи побудови єдиного інформаційного простору і подано схему його формування. Розглянуто формування єдиного інформаційного простору з використанням спеціалізованої інформаційної комп'ютерної системи, яка фактично є апаратно-програмним базисом для підтримання єдиного інформаційного простору, а також етапи ідентифікації інформаційного об'єкта в єдиному інформаційному просторі. Запропоновано метод пошуку відсутніх ознак вхідного об'єкта шляхом реалізації взаємодії інформаційних об'єктів між собою всередині єдиного інформаційного простору.

Ключові слова: єдиний інформаційний простір, інформаційний об'єкт, ознаки, ідентифікація об'єкта, метод пошуку.

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