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SITUATIONAL-EVENT MODEL OF THE HYBRID PATTERNS RECOGNITION FOR HETEROGENEOUS DATA PROCESSING IN COMPLEX SYSTEMS

Abstract. *In the article represented the new situational-event model of hybrid patterns recognition. This model based on representation a heterogeneous data of a complex system in the form of patterns set, sets of external conditions characteristics as manifestations of a current situation, a static component of a situation – in the form of stationary informativity characteristics, a dynamic component in the form of a nonstationary informativity characteristics and the set of classes as recognitions result. The developed model using provides a priory level of classification reliability, based on analysis of a smaller set but the most informative signs.*
Keywords: *hybrid patterns recognition, making-decision methods, data classification reliability, time-complexity of recognition algorithms, data processing in complex systems, program engineering, information systems and technologies.*

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Introduction

For data analysis in complex systems, methods and means of pattern recognition are traditionally used [1-5]. This is due to the impossibility of complete formalization and mathematical model`s representation of such systems [1, 3, 4, 6]. At the same time, the situation becomes complicated because the large quantity of data, that characterizing a complex system also are heterogeneity [7, 8]. For data processing in complex systems the combined recognition is widely used [1, 7, 9-15]. However, the analysis shows, that with heterogeneous data, this approach is not effective. For combined recognition with a large amount of data, obtaining a reliable result is associated with a large time complexity [11-14]. That makes practical application of such algorithms much more difficult. In addition, combined recognition is not effective with dynamic interference and distortion of the external environmental condition for the complex system [8, 16, 17].

Hybrid recognition [18], which in some sources is also called multi-parameter combined recognition [16, 17, 19, 20], are using for data processing in complex systems, where information patterns have a different nature of origin. It creates a possibility for getting high-reliability classification result at the changing of different interferences and distortion in environmental condition for recognition object. But, for decreasing time-complexity and maximizing accuracy result, the decision-making should be received by less quantity of information signs. For complex systems, its aspect is complicated by the heterogeneous data, that to be processed, also different physical nature of interference and distortion in environmental condition and dynamical changing their intensity level.

Existing approaches to solving that trouble are related with increasing quantity of informative signs of complex systems. It finds confirmation by the Vapnik-Chervonenkis deep probabilistic theory of patterns recognition, which is called also VC-theory [21, 22]. Thus, increasing quality of information signs leads to the level of reliability is grow. But if the complex system characterized by heterogeneous data and their informativity level depends on interference and distortion – reliable classification level will not grow unequivocally with an increase in the number of signs. The signs affected by interference and distortion will be significant source of classification errors. Thus, the heterogeneous data of complex systems should be had maximal informativity level for current interferences and distortion, that have been present in environmental condition.

According to the aforesaid, creating the new approach to increasing classification reliability and minimizing time-complexity of heterogeneous data analysis have a relevance for modern science and technology. The solution to this problem is seen in the development of a new model of hybrid image recognition.

1. Subject area analysis and statement of the problem

For the heterogeneous data processing in complex systems, is widely used that model [1, 10]:

$$P = \{X\}^d \cup \{X\}^p \cup \{X\}^l \cup \{X\}^s, \qquad (1)$$

where $\{X\}^d$ – set of deterministic, probabilistic, logic and structure (linguistics) in complex systems signs.

Based on model (1), at the heterogeneous data processing, both direct and reverse recognition task can have implemented [1, 3, 23]:

$$\forall C \in \{C\}, C \Leftrightarrow \left\{ \{X\}^d \cup \{X\}^p \cup \{X\}^l \cup \{X\}^s \right\}, \qquad (2)$$

where $\{C\}$ – classes alphabet, where everyone class C is characterizing the compliance status of complex system.

The heterogeneous data processing is carried out in the following sequence.

1) The system of the reference set of the algorithm is determined. From signs set $\{X\}$, selecting subsets $S_1 \ldots S_q$ had becomes.

2) Calculates the proximity measure of recognition object O_r and everyone representative object with known classification result, and total estimate is determined:

$$\begin{cases} \Gamma(O_r, C_1) = \Gamma_{S1}(O_r, C_1) + \ldots + \Gamma_{Sq}(O_r, C_1), \\ \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \\ \Gamma(O_r, C_m) = \Gamma_{S1}(O_r, C_m) + \ldots + \Gamma_{Sq}(O_r, C_m), \end{cases} \qquad (3)$$

where $\Gamma_{Sq}(O_r, C_m)$ – compliance estimate for object O_r and class C_m by signs subset S_q.

3) Next, the rules are specified by which a classification decision can be made in the following sequence:

– the similarity rules of the reference and analyzed object, which allow according to a measure estimate to calculate a value that is an estimate for pairs of objects;

– the rules of estimates forming for each class according to a fixed reference set based on estimates of pairs for objects;

– the rules of summary estimates forming for each class according to all reference set;

– the decision-making rules that, based on the estimates for classes, ensure that the recognition object is classed to one of the classes or, conversely, deny such classification.

However, for complex systems, the main information is not in individual characteristics, but in their different combinations [23]. Since in complex systems it is not always known which combinations are informative, in algorithms of calculation of estimates the measure of similarity of objects is calculated not by sequential comparison of individual characteristics, but by comparison of all possible characteristics that describe a complex system [23].

Thus, combined recognition for analysis of non-uniform data in complex systems is associated with a large power of reference sets. As results – the large number of computational operations. In addition, combined recognition does not take into account the fact that various interferences and distortions result in not all patterns having the same information value and allow for a reliable solution. In addition, it should be noted that the effect of interference and distortion, and thus the information of signs, is dynamic.

Hybrid recognition can take into account the effects of interference and distortion by describing a complex system with a set of patterns that have different nature origins [18, 23].

Hybrid recognition uses two approaches: joint patterns analysis [17] and separate patterns analysis [16].

In joint analysis, all patterns signs of different nature are combined into one pattern together. After that, the data processing is performed by classical methods of combined recognition [17]. The positive effect in such a case is to use more independent numbers of signs on which the interferences and distortions have different effects.

The maximum benefit of hybrid recognition can be obtained using separate analysis. In this case, patterns are not merged into a single global pattern and are processed until the a priori specified recognition reliabilities is obtained to one or more patterns [16, 18, 23]. This variant is natural for multithreaded data processing. Given the heterogeneity of the data, different algorithms can be applied in different stream to match the characteristics and calculate the degree patterns proximity to representative descriptions of classes for the complex system. The classification decision-making based on searching of patterns groups with identical classifications [18]. Since it is a priori known that each image of a complex system must point to the same class, in the case of an ideal display system and no interferences and distortion of signs, absolutely reliable result will be obtained. At the same time, the presence of interference and distortion leads to the facts that part of the patterns to indicate erroneous classification variants.

In these circumstances, the possibility of obtaining the most reliable solution in the minimum time is solely due to the need to exclude from processing less informative images that have been subject to maximum distortion and transformation.

Thus, an important scientific and technical task is formed – ensuring a reliability classification decision-making in hybrid recognition based on analysis of a smaller set of the most informative signs.

2. Solving problem

For solving task of maximizing recognition reliability and reduction quantity of less-informativity signs of patterns was developed the new situational-event model of hybrid patterns recognition which gives possibility for the patterns selecting with most informativity and create classification result based on matching fewer data. Thus, the set of data to be processed, varies according to the changes state of the environmental condition, interferences and distortion level. This model is represented on cortege such view

$$SEMHPR = \langle P, EC, SICh, NSICh, C \rangle, \tag{4}$$

where P – a patterns set of complex system, which forms on the multiple information sources different nature origin;
EC – an environmental condition set that characterized a current situation;
$SICh$ – a patterns stationary informativity characteristics of complex systems;
$NSICh$ – a patterns nonstationary informativity characteristics of complex systems;
C – a classes set, that complex systems characterized.

According to this model, the current state of a complex system is defined on the basis of receiving set of its images which signs have the different nature of origin. Besides, receive the external conditions characteristics set allows to define degree of informational content for each pattern and to provide accept reliable the decision. For this purpose, on the basis of set EC provide determining of stationary and non-stationary informativity characteristics for everyone a pattern from $\{P\}$.

If to present that pattern of recognition object P is described by some function $P = f(x, y)$, where x, y – arguments, that define characteristic of object, which is in some space Ω. Then reflection of this object I defined as $I = g(x', y')$, where x', y' – arguments that define patterns characteristic which is in some information space Ω'. In the case of an ideal reflective system, for any point of space the condition satisfied: $g = f$. In reality, that condition cannot be fully executed. This is due to the reflection distortion that have a presence. According to relation between objects space and their patterns space, the reflection of space point will be defined as:

$$g'(x', y') = h(x', y', \alpha, \beta, f'(\alpha, \beta)), \tag{5}$$

where (α, β) – point of space\`s coordinate
$h(x', y', x, y)$ – function, that described the spatial relation between an object and its reflection.

Obviously, for other source that have same placement

$$g''(x',y') = h(x',y',\alpha,\beta,f''(\alpha,\beta)). \quad (6)$$

On the common situation, ratio of objects space and patterns space for nonlinear system will have a next form:

$$g(x',y') = \iint_{x\in X, y\in Y} h(x',y',f(x,y))dxdy. \quad (7)$$

For a linear system:

$$g(x',y') = \iint_{x\in X, y\in Y} h(x',y')f(x,y)dxdy. \quad (8)$$

As at hybrid patterns recognition the signs have the different nature of origin, value x and y do not correlate with each other and function h will have an appearance:

$$h(x',y',x,y) = h'(x',x)h(y',y). \quad (9)$$

This function takes into account the distortion of the object in the pattern space, and the resulting pattern will be represented as:

$$P = \iint_{x\in X, y\in Y} h(x',y',x,y)f(x,y)dxdy + \xi(x',y'), \quad (10)$$

where $\xi(x',y')$ – the distortions distribution characteristic of objects in pattern space.

Taking into account (4) and on the basis of (10), at hybrid recognition, the complex system description model will have an appearance

$$\begin{cases} P_1 = \iint_{x\in X, y\in Y} h_1(x',y',x,y)f_1(x,y)dxdy + \xi_1(x',y'), \\ P_2 = \iint_{x\in X, y\in Y} h_2(x',y',x,y)f_2(x,y)dxdy + \xi_2(x',y'), \\ \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots \\ P_k = \iint_{x\in X, y\in Y} h_k(x',y',x,y)f_k(x,y)dxdy + \xi_k(x',y'). \end{cases} \quad (11)$$

Based on model (1), the stationary informativity characteristic for each patterns of complex system are determined so:

$$SICh_k = \frac{1}{h_k(x',y',x,y)}, \quad (12)$$

where h_k – directly, is characteristics of information displaying means (an accuracy characteristic of sensors for complex systems parameters registration and also accuracy of data transferring interfaces). As the structure of information system do not changing in system life-time, these characteristics need only a priori definitions and are constants in the course of further operation cycles of non-uniform data.

The nonstationary informativity characteristics for each from k patterns are determined so:

$$NSICh_k = \frac{1}{\xi_k(x', y')}, \qquad (13)$$

where ξ_k – is characteristics of the current interferences and distortion for each patterns of complex system. These characteristics change throughout systems life-cycle in depending on the current environmental conditions. This characteristics set is non-stationary and demands constant control on each cycle of classification decision-making.

The general informativity characteristic of each patterns will be defined as multiplication of two components: stationary and nonstationary. The most reliable solution Rd is obtained behind the result of patterns analysis, that satisfies informational criterion:

$$\exists P_k \in \{P\}, \max ICh_k \Rightarrow Rd. \qquad (14)$$

The patterns that, on current observation conditions for recognitions object, have an information characteristic less than a priori caused – mast keep from recognition. Thus, implementation the situational analysis conception by selected data that having higher informativity level behind current situations, allowed to solve task – ensuring the reliability classification decision-making in hybrid recognition based on analysis of a smaller set of the most informative signs.

The situational-event model of the hybrid patterns recognition, that have been represented, had find the using on three different applied solution. It was: information systems of temperature's spatial distribution monitoring for coke pie [24], information system of ultrasonic linear distance measurement for automation systems [25] and information system of text-unique level analysis [26]. In these solutions, mean an 18% reduction in the amount of data processed was obtained for a priori given level of recognition reliability of 85%. This effect is clarified by the use of situational processing of the most informative data under current environmental conditions. Thus, the main problem was solved.

Conclusion

The main results presented in it work consist in the following.

1. For efficient application of recognition, it is necessary to provide processing of less but more informative data in the current situation and level of interference and distortion.

2. For ensuring a priory defined reliability of recognition at simultaneous decrease a time-complexity of the heterogeneous data analysis, the new situational-

event model of hybrid patterns recognition was developed. That model considers the level of stationary and non-stationary informativity characteristics of complex systems patterns was developed. In this case, decision-making happens on the basis of processing smaller quantity, however the most informative data (at the current level of hindrances and distortions as manifestations of a situation).

The efficiency of the offered model was confirmed experimentally for three various information systems: analysis of spatial distribution of temperature of coke pie, ultrasonic measurement of linear distances and verifications of text data on uniqueness. For all three applications, a positive result was obtained that confirmed the correctness of the problem solution.

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