Formation of the Structure of Multilayer Polyagent Functionals

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Abstract

The processes of intellectual monitoring in emergencies are studied. The intelligent monitoring system is an environment for creating and using intelligent agents to provide knowledge of decision-making processes. In emergencies, objects acquire new properties quickly, and the informativeness of the results of previous observations decreases. To increase the power of data mining tools, monitoring agents are combined into agent functionalities with a multi-tier structure. The paper presents the results of research on the processes of formation of multi-echelon polyagent functionals. The efficiency of construction of a multi-echelon polyagent functional in solving the problem of predicting the incidence of the population of Ukraine on Covid-19 in conditions of low informativeness of the results of observations has been experimentally confirmed.

Keywords

Intelligent monitoring, emergencies, polyagent functional, echelon, prognosis, Covid-19

1. Introduction

In the context of crisis monitoring, reducing the informativeness of the observations results is one of the problems that reduces the efficiency of the process of extracting knowledge from data sets. In emergencies, the monitored objects move to another state and acquire new properties. These properties are not fully reflected in the arrays of the results of previous observations. The period of time for new observations is much longer than the time during which it is necessary to provide the results of monitoring to the decision maker.

This problem is overcome by information technology of intelligent monitoring through the use of a multi-agent approach to the creation of monitoring information systems (MIS). A separate agent is built to perform monitoring tasks. When the informativeness of the input data arrays (IDA) is reduced, superagent formations are built - agents functionals. The concept of "functional" is interpreted here as "function of functions". Agent functionality (AF) is a structural element of the monitoring information system [1].

The technology of building polyagent functionalities (PAF) involves the creation of agents with structural tasks and combining them into a system based on a matching IDA. Matching IDAs for structural agents are formed on the basis of the same array of observation results [2].

This paper presents the results of research on the process of forming a many echelon structure of the polyagent functional of the monitoring information system. The technology of construction of PAF is presented on an example of improvement of process of performance of the monitoring task on forecasting of number of diseases of the population of Ukraine on Covid-19.

2. Multi-agent systems

There are several approaches to creating many-agent systems. The problem-oriented approach is based on the assertion that several agents can achieve a goal that is beyond the power

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of one agent [3]. This approach involves "developing mechanisms and methods that ensure agents interact at the human level (or better) and understand the processes of interaction of intelligent computing entities. Simplifying, the result should be an algorithm that will tell who how and with whom to interact (at any time) [3].

The object-oriented approach assumes that MAS is a combination of autonomous intelligent agents, each of which performs its task and each interacts with other agents of this MAS [4].

The problem-oriented approach to the creation of MAS is used by information technology of intelligent monitoring (ITIM) in the process of its implementation in the form of MIS to perform the task of predicting the incidence of the population of Ukraine on Covid-19.

In case it is not possible to build an agent to perform a new monitoring task due to insufficient informativeness of the array of results of previous observations, the agent functional is built. A system approach is used to build the agent functionality. Agent functionality is built as a system. The functional emergence is formed due to the effective combination of agents and a more complete reflection of the properties of the object in the model knowledge bases of the monitoring information system. This effect is manifested by improved signal characteristics at the MIS output and increased adequacy of interpretation of monitoring results. [1].

An attempt to build an agent with a monitoring task to predict the number of diseases in Ukraine with a horizon of 7 days with this forecast task was unsuccessful. The array of observation results obtained from an open source [5] was not informative enough. This array was formed by limited data on the incidence of Covid-19 abroad, and the simulated trait is presented in the form of an average incidence rate in Ukraine. It was not possible to obtain additional data on the incidence of the population in some regions, which contain different mechanisms of emergency formation. The error in predicting the incidence of the population of Ukraine at the 7th step of the forecast horizon was 16.90% with an average value of 7 steps - 11.01% [2].

MIS did not have built agents that would perform tasks based on different information sources in other subject areas, so the construction of multi-agent functionality was impossible. To fulfill the monitoring task, the IIA built the PAF.

The construction of a single-echelon PAF allowed to obtain the forecasting result with an error of 13.99% on the horizon of 7 days and to improve the average forecasting error to 6.15% [2]. The use of feedback in the construction of the PAF structure allowed to reduce the forecasting error on the horizon of 7 days to a value of 7.49%, while the average value of the forecasting error was 3.09% [2].

3. Problem description and tasks statement

To reliably assess the influence of factors, the signs of which are included in the array of observations, it is necessary to build a model with a minimum value of forecasting error. Therefore, studies of the process of constructing a PAF to enhance the emergence of an agent combination were performed. The task of building a PAF is to create a method that would provide knowledge about the patterns of pandemic development in Ukraine in the future from previously observed results. The forecasting problem formulated in [2] has a solved:

An array of X results of population morbidity monitoring during 2020 is given:

$$X = \{x_{ij}\},\ i=1,n;\ j=1,m\ , \qquad (1)$$

where n is the number of signs that reflect the incidence of the population, m is the number of observation points (recorded number of diseases in countries with a discreteness of 1 day).

The number of observation points is determined by the duration of the historical period of time during which the values of morbidity were recorded:

$$T = \{t, t_{-1}, t_{-2}, t_{-m}\}, \qquad (2)$$

where t is the observation time; m is the number of observation points.

The monitoring information system builds a set of agents with structural tasks:

$$\mathrm{Y} = \{Y_{x1}, Y_{x2}, Y_{x3}, \ldots, Y_{xn}\}, \qquad (3)$$

where n is the number of agents that perform structural tasks.

It is necessary to build a polyagent functional for predicting the incidence of Covid-19 population of Ukraine with a forecasting horizon of 7 steps, for which the deviation of the forecasting results from the actual values becomes minimal:

$$Z_{x1}= f(T, X, Y, t_{+7}), \qquad (4)$$

where Z_{x1} – signal at the output of the agent functional with the monitoring task of forecasting the number of diseases of the population of Ukraine; t_{+7} – forecast horizon (7 steps).

4. Hypotheses

Execution of new monitoring tasks on the basis of previous results of supervision is provided by construction of agent functionalities with multilevel hierarchical structure. The upper echelons of the functional are formed from agents that are not included in the structure of the lower echelons. Increasing the informativeness of the signals at the output of these agents is achieved by increasing the number of features in the agent IDA due to the signals from the output of lower echelon agents. The hierarchical structure of multi-echelon agent functionals is built by the method of ascending synthesis of elements [6]. The IDA for the structural tasks of the higher echelon agents is formed from the features obtained as a result of observations and from the output signals of the agents included in the structure of the lower echelons of the functional.

5. The results of experiments and their discussion

To perform the monitoring task of forecasting the number of diseases of the population of Ukraine on Covid-19 on the horizon of 7 days, an array of signs was formed, obtained as a result of observations of morbidity of the population of other countries during 2020 with a step of 1 day. The results of observations were obtained from an open source [5]. The list of features that formed the initial description of the monitored object is given in Table 1.

Table 1

Signs of the initial description of diseases on COVID-19 [2].

Indicators	Comments
Observation time; morbidity in Ukraine; morbidity in France; morbidity in Belarus; morbidity in Georgia; morbidity in Germany; morbidity in Israel; morbidity in Italy; morbidity in Moldova; morbidity in Slovakia; morbidity in Slovenia; morbidity in Russia; morbidity in Portugal; morbidity in Poland; morbidity in Romania; morbidity in Spain; morbidity in Turkey; morbidity in Egypt; morbidity in Greece; morbidity in the United States; morbidity in China; incidence in England	The results of daily observations obtained during 2020

After that, the method of forming the structure of a multi-echelon polyagent functional - ascending construction of layers was applied. Agents who did not complete their task on the lower layer of the PAF began to perform this task on the upper layer. All agents that performed the task formed the structure of the layer. The signals at the output of these agents were used as additional features in the input array of higher echelon.

Table 2 presents the characteristics of the output signals of agents that performed structural tasks in the construction of PAF layers. The characteristics of the agents that performed the structural task and entered the structure of the corresponding echelon in table 2 are highlighted in bold.

Thus, after the construction of the polyagent functional, the error in predicting the incidence of the population of Ukraine decreased by 72.96% compared to the results of forecasting this indicator by the agent who performed this task.

The input array for the upper echelon was formed from the signals at the output of the agents that entered the structure of the lower echelons.

If the error in predicting the signal at the output of the agent is less than the limit value of 12%, the structural task is considered completed, the agent acquires the state "Used" and is included in the structure of the corresponding echelon. Structural tasks that were not performed by the lower echelon PAF agents are assigned by the MIS to be performed by the upper echelon. According to Table 2, 9 structural tasks for morbidity forecasting in the respective countries were performed at the first echelon. The structure of the first echelon of PAF includes 9 agents. For execution on the second echelon MIS transferred 7 structural tasks. Of these, 3 tasks were completed.

And, accordingly, the structure of the second echelon was formed by 3 agents. The prediction errors in the signals at the output of all agents were less than the characteristics of the signals that had agents with the same tasks in the previous echelon. Therefore, unfulfilled tasks are transferred for execution to the highest echelon.

Of the 5 tasks of the third echelon, the agents did not complete any. Agents 4 and 19 at the output had prediction errors greater than those they had in the previous echelon.

Table 2

The average error of the forecast signals at the output of the agents

Agent	Agent tasks	The echelons of polyagent functional					
		1	2	3	4	5	6
1	Prediction of morbidity in Ukraine on the 7th day	**11,01%**					**2,60%**
2	Prediction of morbidity in France on the 7th day	**4,43%**					
3	Prediction of morbidity in Belarus on the 7th day	13,81%					
4	Prediction of morbidity in Georgia on the 7th day	114,80%	18,84%	20,02%			
5	Prediction of morbidity in Germany on the 7th day	**5,50%**					
6	Prediction of morbidity in Israel on the 7th day	69,94%	**7,59%**				
7	Prediction of morbidity in Italy on the 7th day	**3,56%**					
8	Prediction of morbidity in Moldova on the 7th day	**7,66%**					
9	Prediction of morbidity in Slovakia on the 7th day	101,38%	14,69%	13,78%			
10	Prediction of morbidity in Slovenia on the 7th day	197,22%	14,59%		**5,68%**		
11	Prediction of morbidity in Russia on the 7th day	14,18%					
12	Prediction of morbidity in Poland on the 7th day	**1,94%**					
13	Prediction of morbidity in Portugal on the 7th day	26,86%					
14	Prediction of morbidity in Romania on the 7th day	**2,94%**					
15	Prediction of morbidity in Spain on the 7th day	**8,80%**					
16	Prediction of morbidity in Turkey on the 7th day	**4,70%**					
17	Prediction of morbidity in Egypt on the 7th day	91,68%	26,75%	17,39%	16,10%		
18	Prediction of morbidity in Greece on the 7th day	48,90%	**5,59%**				
19	Prediction of morbidity in the United States on the 7th day	145,80%	14,39%	16,80%			
20	Prediction of morbidity in China on the 7th day	99,98%	**5,17%**				
21	Prediction of morbidity in England on the 7th day	2225,34%	42,59%	44,13%	43,95%	**8,82%**	
22	Prediction of morbidity in Canada on the 7th day	27,00%				**3,37%**	

In the fourth echelon, structural monitoring agents managed to complete the task of predicting morbidity in Slovenia. The construction of the fifth echelon of the PAF has made it possible to carry out morbidity forecasting tasks in England and Canada.

The output signal of the 6-tier polyagent functional performed the task of predicting the number of diseases in the population of Ukraine on the 7th day after the last observation. The forecasting error on the horizon of 7 steps became 4.57% with the average value of 7 steps - 2.6%.

6. Conclusions

The construction of multilevel polyagent functionalities allows overcoming the problem of performing monitoring tasks in the conditions of insufficient informativeness of the arrays observation results. Using the results of previous research on the construction of echelons the agent functional and feedback in their structure, a method for forming a multi-echelon structure of polyagent functional is proposed.

The experimental test of the method was carried out in the process of solving the task of forecasting in the conditions of insufficient informativeness of historical data.

The results of the solving problem are predicting the incidence of the population of Ukraine on Covid-19 in conditions of low informativeness. Due to the construction of a multi-tier polyagent functional, the prediction error is reduced by 72.96%.

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