MULTI-AGENT AUTOMATION SYSTEM FOR MONITORING, FORECASTING AND MANAGING EMERGENCY SITUATIONS

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Abstract. The paper outlines the general concept of multi-agent approach to develop the automation system for monitoring, forecasting and managing emergency situations and its models and algorithms included.

Introduction. Emergency situations response and prevention efficiency primarily depends on the availability of required information on controlled objects and processes and its quick transition into instructions, plans, projects and actions. Such terms as information systems, automation management system, data base management system, etc. are appeared to be determined when considering relations between management and information.

The main objectives of monitoring and forecasting are observation, control and prediction of hazardous processes and nature phenomena, technosphere and external disturbing factors (armed conflicts, terrorist attacks, etc.) acting as a source of emergencies. They are also committed to track development dynamics of emergency situations and define their scale within the framework of measures taken in prevention and elimination of hazards.

Known solutions. The information is the key resource that directly enhances efficient activities [1, 2]. The management theory reasonably describes information as a unity of data on all the changes occurring in the system and its environment that decreases our knowledge uncertainties pertaining to specific object. It enables to organize data exchange between people, human and machine, machine and machine. Information is used as a resource to execute work functions as well as a mean of business communications arranged in the process of various data transmission.

It is obvious that such system is impossible to be developed on the single platform because of its fragmentation, constant multi-task increase and inter-agency incoherence. Such system is required to be considered as a complex geographically-distributed hierarchical structure processing information, material, power and other possible resource flows to make decisions in terms of collection and semantic analysis of information received from multiple heterogenic channels. Nowadays possessors of its certain components are successfully applying functional software with no intentions to reject implemented solutions. As practice of establishing the operating control system within even EMERCOM of Russia shows, such projects may be prolonged for a certain period of time without any results expected.

The issue was frequently described in works of A.A. Vavilov, V.I. Varshavskiy, V.A. Vittikh, V.M. Glushkov, T.A. Gavrilova, V.I. Gorodetskiy, L.A. Kalinichenko, A.V. Kostrov, O.I. Larichev, A.A. Letichevskiy, V.V. Lipaev, V.E. Marley, J. Martin, M. Minskiy, G.S. Osipov, E.B. Pesikov, G.S. Pospelov, D.A. Pospelov, E.B. Popov, K.A. Pupkov, B.L. Sovetov, V.L. Stefatok, E.A. Trakhtengerts, B.F. Fomin, V.F. Khoroshevskiy, I.G. Chernorutskiy, R. Shenk, E.L. Yushenko, S.A. Yakovlev, A.I. Yashin.

The research work is based on multi-agent approach application enabling to unite current parts of information environment into unified system of data exchange step by step in order to develop distributed and integrated decision support for Russian System of Prevention and Response to ES.

The crucial objective of multi-agent management system is to distribute the agents. The task is performed by optimized program agents distribution in different sites of computer networks. In this case, optimality is characterized by shrinking time for data execution needed for the decision support system. This objective is appeared to be complicated due to a great number of limiting factors available while distributing agents. Based on the concept of developing distributed computer networks for decision making in extreme situations, it is noted that technical resources are owned by various organizations and institutions thus blocking further system establishing on the unified techno and program platform.

Proposed solutions. Nevertheless, by studying different information systems included into distributed computer networks for decision making in extreme situations, the whole range of typical solutions somehow applied to develop each of them can be distinguished. In spite of diversity in approaches and their development, the network infrastructure in most cases counts on solutions suggested by CISCO Company that is considered to be acknowledged leader in telecommunication facility production (it is estimated that the facilities of this company provide of about 80 % of web-traffic). It is explained by high standards for data transmission security and certification required for cryptographic solutions –program and hardware-software systems developed by «Infotecs» Company. The program part of its network equipment is based on Cisco IOS or adapted version of Linux operating system (products of «Infotecs» Company). Nowadays, both determined operating systems support OS capability above Linux core and provide high availability and integration of services.

To achieve acceptable level of standardization and unification of NetWare Management Agents, it is suggested to place them exactly on the base of communication equipment of these vendors.

The additional advantage of such placement is low work load of telecommunication server computing resources that is confirmed by statistical analysis of 170 units of Siberian segment of distributed computer network for decision making in extreme situations. The analysis results showed that daily average processor utilization comprised not more than 12,3% out of the highest possible level.

The range of management agents observed enables to track raw data collection from the source units, monitor workload of distributed computer network resources, coordinate computing tasks assignment between them, manage data stores and enhance efficiency of data communication channel usage. This range of agents is managed to be influenced by signals of out-of-order requests on data and values production from the decision support system.

It should be noted that the goal we are going to achieve is similar to Zeno’s paradox due to constant development of distributed computer network elements. However, the system solution approach allows downsizing the distance to «tortoise» rather quickly. Along with management agents distribution, the template solutions for any state-of-the-art information systems development are recommended to be considered. The majority of state-of-the-art information systems is aimed at collecting and processing mass data. There is also no exception pertaining to the distributed computer network for decision making in extreme situations. The model data base management systems (DBMS) are applied to process and store the information. After statistical data processing, it is possible to make conclusion that the following DBMS tend to prevail in distributed computer network for decision making in extreme situations – MS SQL, Oracle RDBMS with MySQL dominating in a smaller extent to solve various local tasks. Implementation of data exchange agents in the DBMS enables to computerize communication flow in the distributed computer network for more than 70%. Furthermore, retrieving information from the databases will allow minimizing development of raw data collecting agents at the initial stages.

The main requirements applicable to agents-integrators are as follows: knowledge of basic SQL requests (get access to database, add information to the database, change information in database, remove information from the database, etc.), language skills for data message exchange in multi-agent environment, database request understanding, database encoding skills, reporting to managing agents.

In most cases, the analysis of technical and organizational systems is managed to describe such components as mission, vision, strategy and processes. Multi-agent approach application is reported to determine the systems as dynamic ones based on the values.

The dynamic model of discrete process is characterized by means of the following mathematical tool: Petri net, multiqueue system and system dynamics model. Later on, the intelligent agents supplement the models. Consequently, the integration of simulation modelling, expert systems, case and multi-agent modelling is considered to be resolved.

The model of the intelligent agent shall be represented as follows:

Agent=<Name, Purpose, Priority, KB, M_in, M_out, B_scen, Control_O, Chief_A, Sub_A>,

where Name – the name of the agent, Purpose – goals of the agent, Priority – priorities of the agent, KB – database of the agent, M_in – number of incoming messages, M_out – number of outgoing messages, B_scen – performance plan, Control_O – multitude of controlled objects, Chief_A – multitude of dominated agents, Sub_A – multitude of subordinated agents.

The agent is capable to accomplish the following actions:

- Analyze the current situation though external parameters evaluation;
- Detect the situation;
- Manage the knowledge base;
- In case of detecting certain situation, the agent is managed to seek the action script in the knowledge base or set it up independently;
- Make decisions;
- Define and adjust its goals and goals of subordinated agents;
- Control goals achievement;
- Exchange messages.

In order to build the system core, the tool of production systems is applied. The structure of production system is described as follows:

PS=<CSs, KBs, Ms>,

where CSs={RES(t)}∪{MECH(t)} ∪{U(t)} ∪{G(t)} – current status of resources, facilities, executive instructions, goals (рабочей памяти); KBs – the rule set of agent’s activity and transformations (knowledge base); Ms – inference engine consisting of task scheduler and inference machine of the agents’ knowledge data base.

The method comprises the following steps:

Step 1. Determination of current time SystemTime=min(Tj), j∈rule.

Step 2. Processing of agent’s actions.

Step 3. Algorithms queue scheduling.

Step 4. Execution of rules and goals modification.

To detect the current state of the system and generate control commands, the system refers to consulting program.

The hierarchical structure of the multi-agent system is specified by means of system flow charts with large scale integration level and the object – based structured approach for developing models of the technical and organizational systems suggested by T.A. Gavrilova [3]. The approach based on frame-concepts and conceptual flow charts proposed by A.N. Shvetsov is used as a tool for knowledge formalization [4]. The task description of resources allocation is declared by the author in the research work [5].

As defined previously, the model of intelligent agent in general terms is represented by Agent=<Name, Purpose, Priority, KB, M_in, M_out, B_scen, Control_O, Chief_A, Sub_A>. Furthermore, its model of behavior scenario shall be outlined - B_scen:

B_scen = (MIS, MG, MSR, MA),

Where MIS –model of information space, MG – model of goal - setting, MSR – solution search model, MA – model of active actions. The intelligent agent is managed to make decisions on realization of certain scenario at a time.

From the standpoint of actions execution, the models are considered to be divided into three classes: predetermined finite set of primitive actions, plans multitude, selectable messages and actions in the logical language.

The intelligent agent is suggested to obtain a great number of statical goals $SP=\{sp_j, j=1,...,n\}$. There is a certain range of $Rules_j$, $j=1,...,n$, that are followed and lead to sp_j. Each agent adheres to certain plan with messages and actions already established within.

The solution search model is designated by the function $SS: SP \rightarrow VO$, where *VO* – the set of rules of intelligent agent. The model of active actions is defined by the visualization $AM: AS \rightarrow VO$, which selects the rules required to be executed at the moment. Active goals alteration (*AS* multitude) is expected to result in termination or activation of certain rules.

SA(0) shall be estimated as the entry-level configuration of intelligent agent's properties with *lvo* the list of its rules, *SMA(0)* – entry-level configuration of *MA*, *ls* – the list of agent's strategies, *lsg* – the list of statical goals, *ltg* – the list goals prescribed by dominating agent, *lbg* – list of goals transmitted to subordinating agents, *ldag* – the list of dynamic goals, *lag* – the list of active goals. Calculation axiomatic statement for K_{B_scen} at the time t_0 shall be as follows $AA=(SA(0),lvo,SMA(0),ls(0),lsg(0),\emptyset,\emptyset,\emptyset,\emptyset)$.

To simplify transcription of information space V and its status SV, we shall identify:

$lia=\{Name_j,\{A_{Agentj}^k, k=1,\dots,m\},j=1,\dots,l\}$,

$lio=\{Name_j,\{A_{Agentj}^k, k=1,\dots,m\},j=1,\dots,l\}$,

The independent operation of the agents requires assignment of decision algorithms. The algorithms are exemplified below.

Decision-making on data collection for calculation (Algorithm 1).

1. Define the list of necessary data
2. Estimate the time for all the data collection
3. Arrange data by the receipt time
4. Arrange data by receipt requirements for accurate calculation. Determine minimal (threshold) values for calculation.
5. Delimit the objective on two stages in accordance with Step 4 – approximate calculation and full calculation.

6. Set priority 1 for the data assigned to preliminary calculation and priority 2 for the other one.

7. Proceed with data collection (in parallel with all the sources) in terms of priorities.

8. Send the calculated model to decision-maker upon completion of preliminary calculation.

9. Evaluate time needed to accomplish final calculation. In case it is less than the time left to make decision, continue to collect data.

10. Elaborate final calculation and send it to decision-maker.

Decision on route selection (Algorithm 2).

In this particular case, the route is characterized as not only data transmission but also as data transformation (computing). The instrument of multi-version control suggested in works [6-8] is applicable in this algorithm.

After requesting data transmission to decision-maker:

1. Examine the network and make a list of possible routes.
2. Forecast time and reliability (transfer expectations) of the routes. Subordinated agents perform these calculations.
3. Determine the necessity to launch concurrent processes by utilizing the instrument of multi-version control.
4. Set up data transfer through the routes identified.

Algorithm of data transmission (transmission only) (Algorithm 3).

1. Receive the close-in point of data production from superior agent (the server nearby enabling to transit current data to the data of higher rank).
2. Define the volume of data transmitted to the closest point of data production.
3. Make a list of possible routes.
4. Select the best route by the function value $F(x)=TP*R(t+1)$, where *TP*- certainly value of adequate amount of data transmission to the end point in accordance with *t*, $R(t+1)$ – certainly value of transmission channel efficiency at the moment $t+1$ (operational availability).
5. Set up data transmission.

The example of algorithm for distributed geoinformation system (based on Algorithm 1).

1. Define the goal of modeling from the request of decision-maker.
2. Compose a list of data for modeling.
3. Make a list of data resources.
4. Examine data supply sources in terms of readiness for the actual data transmission.
5. Organize schedule for data delivery.
6. If probability estimate of total time needed for data acquisition (T_1), data delivery (T_2), transformation (computing) (T_3) is more than the time assigned for making decision (T_r), it is considered to divide the task on 2 steps: sample calculation and final calculation.
7. Take up the time available for sample calculation (T_{r1}) from inequality $T_{r1} <= T_r$.
8. Outline time for primary data receipt as $T_1` <= T_r.- T_2-T_3$.
9. Set out the list of data possible to be delivered during the certain time period in accordance with $T_1`$.
10. Launch data collection.

11. Inquire managing agents about current and prognostic state of the Network.
12. Settle possible routes.
13. Identify data pools based on the object pools of the model.
14. Launch data transmission for calculation upon closing (collecting all the necessary information for calculation) data pools.

Conclusions. The research activities have resulted in developing methodology for inter-agency intelligent decision support in the Russian System of Prevention and Response to ES which allows upgrading the intelligent level of ES monitoring and forecasting system acting as a functional informative-analytical subsystem of the RSPR. Consequently, the time needed for control solution shall be downsized greatly in conditions of changing information environment. The complex of methods elaborated enables to computerize the development process of corporate, intelligent decision support systems, consider specific features of subject field and type of management tasks solved, minimize expenses on exploitation and enhance efficiency of information resources applied.

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