



The Intelligent Systems to Support the Automated Systems During Life Cycle

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Abstract—The paper discusses the main directions of the development of the automated system intellectualization in IT field. A classification of systems with two levels of hierarchy is proposed in the article. The first level contains systems which are based on artificial intelligence. They solve tasks in various subject areas. The development of the systems leads to the appearance of complex software and hardware systems. The increasing complexity of the systems is the reason for the development of specialized systems. The intelligence systems are used for automating the development of the automated system and supporting then during their life cycle. These systems are placed at the highest level of the hierarchy of the classification system. At the highest level, the systems are based on artificial intelligence and support the operation of automated systems in various subject areas. A dynamic model for describing the operation of the second-level systems is given as an example.

Keywords—*automated systems, frame model, semantic networks, intellectual support, agent system.*

I. INTRODUCTION

Intellectualization is a global trend in the world of information technology. The main classes of systems which are represent this trend are following:

- the smart grid;
- the smart house and smart city;
- the intelligent transportation systems (unmanned ground vehicles, intelligent subsystems in the transportation systems end etc.);
- the expert and diagnostic systems in various subject areas (medicine, technical systems, environment protection systems and etc.);
- the intellectual support systems of business processes in various subject areas (trading on the exchange, management, controlling and etc.);
- the decision support systems in various subject areas (situational control centers, control rooms and etc.);

The classification is used to describe the intellectualization directions in various subject areas. The

classes are consolidated in the lowest hierarchy model level of the intelligence tools.

As a rule, a set of tools for solving problems in the specific subject area are consolidated in an automated system. The system is an object of a high level of complexity. The system needs to support during the life cycle.

In the paper the systems of intellectual support of functioning of automated systems of the low level are consolidated at the higher level. The intellectual support systems at this level support the operation of automated systems, independently of the subject area of their application. Thus, the second-level intelligent support systems are more universal than the low level systems.

It should be noted, that today a universal methodology for building intelligent support systems for automated systems is not formulated. The dynamic model of the operation of these systems and an example of its implementation are described in the paper.

II. ANALYSIS

The system have two common attributes [1]. They are following: supporting the software and hardware complex of automated systems of a higher level of complexity and the use of the artificial intelligence tools.

Let us define the system of intellectual support of the automated system as a complex for using the intellectual support of the automated system operation [2]. The support is used during the life cycle. Usually, the intelligent support is used to evaluate the situation in the external/internal environment of an automated system and to plan actions. The intelligent support is useful for technical subsystems of automated systems and for their users.

The attributes of the modern system of intelligent support of an automated system are as follows:

- the artificial intelligence tools are used for the design of the mathematical and algorithmic support;
- the competitive advantages for software and hardware of the automated system are provided.

Let us consider the specific characteristics of intelligent support systems in more detail. The operation of the intellectual support systems is based on the following apparatus: production systems [3], frame systems [4], semantic networks [5], fuzzy logic [6-7], neural networks [8], hybrid forms of knowledge representation [9-12].

Let us focus on the information models of intellectual systems. They are the following:

1. The production systems [3]. They are oriented at modification and expansion. This is proved by the unique property of the production rules: a high level of independence of each element in the production system, and as a consequence, the additivity and locality of each change in the system.

Let us focus on the low-level of the classification system of the decision support systems. At the level, the production systems are used to design the decision support systems, the situational centers, the control center, expert system etc.

At the high-level of the classification system of the production systems are used to support its operation scenarios. The interpreter allows the automatic system to transform the scenario, to overcome emergency situations and to adapt to changes in the external/internal environment of the hardware and software systems.

2. Frame networks. The frame networks [5] make possible to harmoniously use the ideas of the situational approach and artificial intellect for designing the decision support system. They are the following: intelligent monitoring systems in various subject areas [13-14]; intelligent support systems for groups of system administrators in companies [14]; situational management centers; control centers; business intelligence systems and etc.

The frame approach is used to describe processes using the machine-independent model – a network of frames. The frame model is used as a conceptual model. This property allows developers to design tools for the "low costs transformation" from frame conceptual model to information and software systems [15-17].

3. The semantic network [4] is a static form of knowledge representation. Models for the knowledge representation are used for designing the systems of standards in interoperable systems. They are also used in the standard systems to support the business processes in industry etc.
4. The neural networks [8] are actively used to solve tasks in various subject areas. They are the following: monitoring systems, intelligent data processing, image recognition, text analysis tasks, etc. The problem of choosing the architecture of a neural network is the casual factor for the success of the entire project.
5. The fuzzy logic apparatus [6-7] is used to solve tasks in specific subject areas and to develop the intelligent support systems of the automated systems during their life cycle [16-17].
6. Hybrid knowledge is used to compensate for the disadvantages of the classic knowledge bases information models [10-12]. For example, the hybrid knowledge allows combining the advantages of

production systems and frame networks [18], the advantages of frames and the multimedia frames [15], combining the fuzzy logic with the situational approach advantages [10].

The paper presents the dynamic model for describing the process of an automated system with an intelligent support subsystem and its implementation using a multi-agent system, the apparatus of production rules and the frame model.

III. METHOD

The model is used for the representation of the operation scenarios in an automated system. The operation scenario consists of events. Let us consider an event to be theoretical primitive. These theoretical primitives are indivisible. The theoretical primitives are consolidated into set S . An element of the scenario-generating set of events S is interpreted as a graphic object. This object is the graph node. The cause-and-effect relationships of the scenario event in the graphic object are represented by graph edges coming from the nodes.

The edges of the graphic object correspond to identifiers $\{r_1, r_2, \dots\}$. Each edge has a terminal which is represented in the figure with an arrow. The set of terminals of a graphic object is used to determine the outcome of the event. The outcome of the event determines the cause-and-effect relationship which is used to control the scenario.

The elements of the scenario-generating set of events are graphically represented in fig. 1. The generation of scenarios is carried out by filling the terminals of the edges. The events are entered into the terminals. Thus, the structure of events with cause-and-effect relationships scenario is formed.

Scenarios which are constructed from elements of S are shown in fig. 2 and fig. 3.

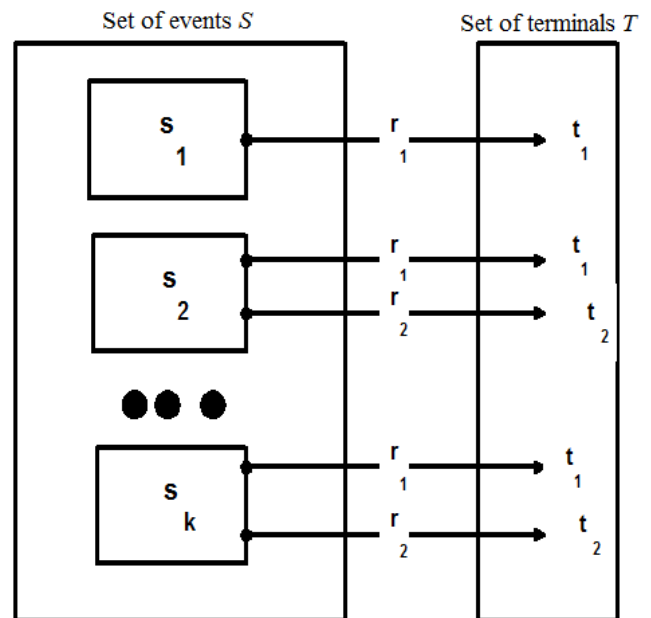


Fig. 1. The elements of the scenario generating set S .

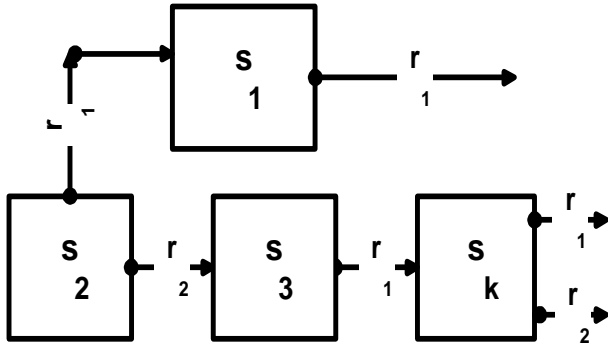


Fig. 2. The scenario which is constructed from the elements of the set S .

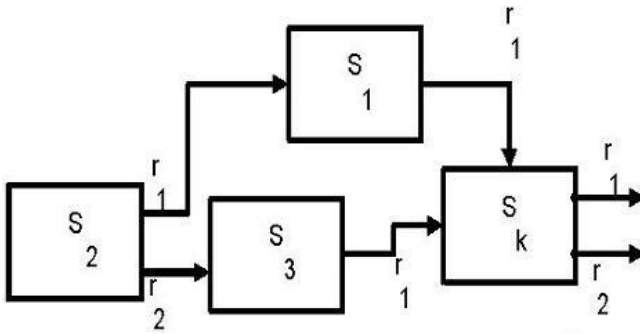


Fig. 3. The scenario which is constructed from the elements of the set S .

When an automated system is operating, the structural relationships between the scenario events may change. Thus, the scenario adapts to the changing situation in the external or internal environment of the hardware-software systems. The changes in the structure of events change the information flows in the system. The changes can lead to the generation of incorrect input data for the script event.

Therefore, it is necessary to analyze the structure of the scenario events. The purpose of the analysis is to identify incorrect information logistics chains and to repair them.

Several technologies can be used to generate a scenario using the elements of the set S . They are following:

- designing a scenario by a programmer when a system is programmed;
- performing an interactive procedure (the procedure must be performed by the system administrator or a user);
- developing the scenario by an intelligent support system automatically.

The intellectual support system solves the following set of tasks:

- the analysis of changes in the external/internal environment of the automated systems;
- the adaptation of the system operation scenario to those changes;
- the identification of incorrect logistics chains in scenarios;

- the generating of a scenario to correct the incorrect logistic chains.

The operation of the automated system is described by the following equations:

$$\begin{cases} s_{k+1}^I = f(s_k^\Psi, r_{jk}^\Psi) & , \text{ if the agents didn't operate} \\ s_{k+1}^I = \xi_k(\cdot) & , \text{ if at least one agent operated} \end{cases} \quad (1)$$

$$r_{jk}^\Psi = \varphi(s_k^\Psi, D_{system}^k) \quad (2)$$

$$D_{system}^{k+1} = C(s_{jk}^\Psi, D_{system}^k) \quad (3)$$

$$O_k = \lambda(s_k^\Psi) \quad (4)$$

where f is the functional used to describe the process of switching events in the scenario; s_k^Ψ is the scenario event which is being performed by the automated system at the discrete time k ; s_{k+1}^I is the scenario event which will be performed by the automated system at the discrete time $k+1$; r_{jk}^Ψ is the identifier of the cause-and-effect relation of the event s_k^Ψ from set S which is used for controlling the scenario; φ is used to describe the algorithm of generation of the outcome flag value r_{jk}^Ψ of the event s_k^Ψ ; C is functional of the situation description; λ is used to describe the set of procedures O_k of the event s_k^Ψ ; $\xi_k(\cdot)$ is the function for describing the mechanism of switching from one scenario to another (in our model it is a situation of switching from the working scenario to the corrective scenario).

Equation (1) is used to describe the transfer of the control process from a scenario event to another one by using the cause-and-effect relationship. The flag r_{jk}^Ψ of the event outcome (1) is used for displaying the result of the situation analysis in the external/internal environment of the automated system.

Equation (3) is used to describe the succession of situations descriptions D_{system}^k at time $k = 0, 1, 2, \dots$

The element s_k^Ψ from set S is used to describe the operation set O_k in (4).

The element $\xi_k(\cdot)$ takes two values: $\xi_k(\cdot) = 0$ if switching from one scenario to another does not operate; $\xi_k(\cdot) = s^{ai}$, where s^{ai} – the event of the corrective scenario.

If $\xi_k(\cdot) = 0$ then (1) looks the following way: $s_{k+1}^I = f(s_k^\Psi, r_{jk}^\Psi)$. If $\xi_k(\cdot) = s^{ai}$ then (1) looks the following way: $s_{k+1}^I = \xi_k(\cdot)$, where a_i is an agent procedure for solving problems of the typical scenario in the subject area (1).

Let us consolidate the elements a_i into a set $A = (a_1, a_2, \dots)$. The set of agents $A = (a_1, a_2, \dots)$ is used to support a typical scenario in an automated system during its life cycle.

The function $a_i(s_k^\Psi, D_k)$ has two values. They are following: $a_i(s_k^\Psi, D_k) = 0$, if the agent is passive; $a_i(s_k^\Psi, D_k) = s^{ai}$, if the agent is active.

If the agent is active, it informs the system about the need to switch from the current script to the script of correcting problems $\xi_k(\cdot)$ (which is not equal to zero).

Thus, equation (1) can be interpreted as follows: $s_{k+1}^I = f(s_k^\Psi, r_{jk}^\Psi)$, if all agents is passive; $s_{k+1}^I = \xi_k(a_1, a_2, \dots)$, if one or more agents is active.

If none of the agent-element of the set A worked, then the automated system interprets the top-level scenario for solving the typical task in the subject area.

If the agent is active, the automated system does a lower-level script, which in our model is indicated by the symbol s^{ai} .

The agents are used to support the hierarchical model of the automated system operation scenarios. The low-level script has to correct the problem in the automated system. Then the automated system returns to the top-level scenario to solve the typical task in the subject area. If the lower-level script has a problem, the agent transfers control to a lower-level corrective scenario for correction of the problem (goes down to a new lower level of the hierarchy) and so on.

Model (1)-(4) belongs to the class of dynamic models [19]. The model satisfies the system of Bellman axioms [20].

IV. IMPLEMENTATION

The mathematical model (1)-(4) was used for the design of an automated system. The intelligent support for the automated system contains two subsystems for detecting and overcoming the emergency situations. In this paper an emergency situation is the fact of the incorrect data generation for a scenario event. The emergency resolution algorithms automatically generate scenarios for correcting of the incorrect input data. The architecture of the automated system is shown in fig. 4.

When the automatic system operates the scenario of solving a typical task in a subject area, the software operates (step by step) the events of the typical scenario. Fig. 2 shows the scenario.

The functional f (1) is executed in the production system in the example. Set (5) of the rules describes the casual relationships in the scenario (fig. 2).

$$\begin{aligned}
 &\text{If } s_2 \text{ and } r_1 \text{ then } s_1; \text{ If } s_2 \text{ and } r_2 \text{ then } s_2; \\
 &\text{If } s_2 \text{ and } r_1 \text{ then } s_k; \text{ If } s_k \text{ and } r_1 \text{ then } \dots; \\
 &\text{If } s_k \text{ and } r_2 \text{ then } \dots; \text{ If } s_1 \text{ and } r_1 \text{ then } \dots;
 \end{aligned} \tag{5}$$

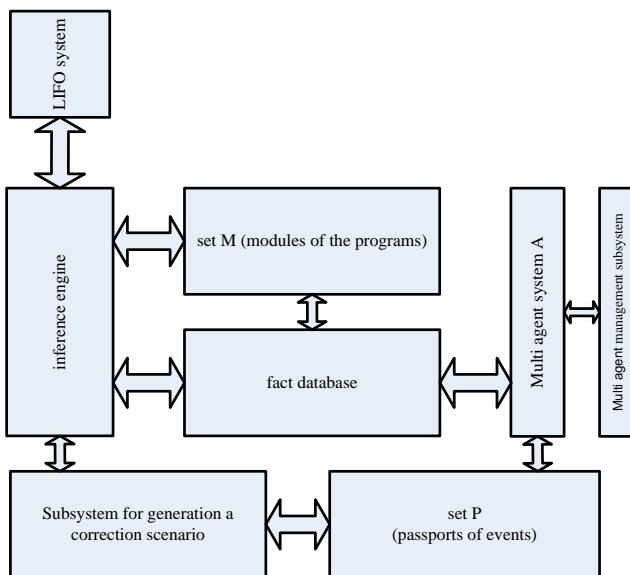


Fig. 4. The architecture of the automated system.

The scenario for solving typical tasks in the subject area is the highest level of the scenario hierarchy.

The presents of a problem in the scenario is indicated in the agent system (multi-agent system). The multi-agent management subsystem A (fig. 4) resolves conflicts between the agents (if two or more agents indicate incorrect data at the same time).

The intelligent support system automatically generates [16] a correction scenario for overcoming the emergency situation using a special subsystem (fig. 4). It is a low level scenarios.

Then the automated system stops the interpretation of the high-level scenario and initializes the corrective scenario. In the dynamic model, the process is described by the operator $\xi_k(\cdot)$ (1).

The set M (modules of the programs) is used for the interpretation the events S (fig. 1). The high level scenarios and the correction scenarios consist of the events S . Every element m_i is used for programming the procedures O_k of event s_i (4). Also it is used to analyze the situation in the automated system and to generate the value of the flag of the event outcome r_{jk}^w (2).

The LIFO system is designed to store a working and corrective scenario. The inference engine is used for operating the sequence of events (1). The set P of frames is kept for situational description. In the paper the frames are called "passports of event" (fig. 4). The identifier of the input and output data for every scenario event are in the passport. The descriptors of the procedures for verifying the correctness of input and output data are kept in the passport too.

The data for supporting the operation of the automated system are accumulated in the fact database (special database). Thus, dynamics of the situational description of D_{system}^k (2)-(3) is displayed in the fact database.

The automated system (fig. 4) supports the scenarios for solving typical tasks in the subject area during the life cycle. The goal of intellectual support is "data in time and in the right place of the automated system" [16].

V. CONCLUSION

The intelligent systems are developed for supporting of the automated systems during their life cycle. The operating of the intelligent systems is based on the dynamic model (1)-(4). The intelligent systems (1)-(4) increase the operating stability of the software and hardware.

Intellectualization as a trend in the information technologies has a huge potential in the subject field of supporting automated systems during the life cycle. It is efficient to use the artificial intelligence apparatus to develop tools for supporting the software and hardware complexes. The complexes are developed as the following subsystems:

- a part of the architecture in the software and hardware complexes;
- autonomous intelligent complexes. If there are troubles, the autonomous system connects to automated systems to overcome the difficulties or emergency situations.

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