Agent-Oriented simulation modeling of systems

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***Abstract*—A situational model of identification of a state of a complex technological system under conditions of uncertainty is proposed based on a structural and parametric description of the system and agent technologies. The methodology of developing a self-learning intelligent agent capable of identifying the current situation with incomplete and fuzzy information and making adequate decisions on its normalization in real time in the management of a processing plant's technological system is described.**

Keywords— situational analysis, multi-agent modeling, technological system.

1. Introduction

An intelligent agent [1] is a simulation model of an active element capable of performing certain assigned functions of a living or cybernetic organism, depending on the behavior of other agents and environmental influences.

Self-learning purposeful agents are able to accumulate knowledge based on current data and the ontology of events in the process of interaction with other agents and the environment, adapt to the situation, choose a strategy for achieving the chosen goal and assess the degree of its achievement.

The general algorithm of behavior of an intelligent agent (see “Fig. 1”) includes the following steps: identifying the situation, assessing its own state, and correcting the goal, followed by a reflexive reaction or meaningful (intellectual) decision-making towards the goal.

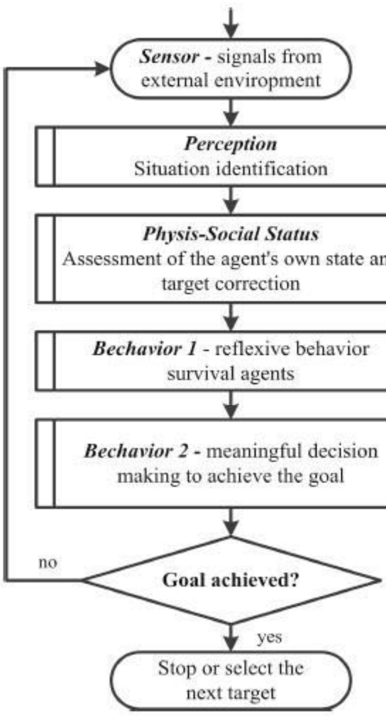

Fig. 1. General algorithm for the behavior of an intelligent agent

The criterion of agent's intelligence is the degree of completeness and depth of a priori knowledge, learning strategies, and decision-making algorithms in conditions of uncertainty, risk, and conflict.

Each operation has its own algorithmic and software module that provides:

- Perception of information and accumulation of knowledge about the external environment and the environment of interaction or conflict (sensory module).
- A mechanism of interaction and processing of data from counterparties.
- Analysis of own and counterparty status with selection or correction of objective functions (intelligent module).
- Making autonomous decisions and choosing strategies.

The behavior of the agent can be represented by some recursive form which describes the finding and choosing at the next step of a function the transition from the initial state to a new state towards an improved objective function.

In some cases, such a problem can be solved by mathematical programming methods with correction of the objective function and individual constraints at the next step of changing the agent's state depending on the situation and the distance to the goal in conditions of uncertainty and fuzzy information.

The parametric description of an agent includes a set of goals and a knowledge base in a particular area, a vector of characteristics of its state, a bank of models and behavior strategies, and a description of external relations with agents and the environment.

2. The Methodology of Agent-Based Modeling

The methodology of agent-based modeling of a self-learning agent is reduced to the following stages.

- Parametric description of the external environment of agent's activity with formalization of a set of factors influencing the functional state and objective function of the agent in situational decision-making conditions.
- Parametric description of functional blocks of a technological system in the form of a set of vectors of input and output factors, state parameters, and an objective function.
- Description of an autonomous intelligent agent with multiple state variables, input and sensor variables that communicate with other agents and the environment.
- Development of a mathematical model of agent training and an algorithm for its behavior with training procedures and identification of current situations and

decision-making in the form of a discrete-event description and decision-making strategies in conditions of sufficient, incomplete and fuzzy information.

- Software implementation of the agent model in an agent-oriented model description language, in the form of a basic component [2, 6] of a multi-agent model of a technological system.

The basic component includes the sections describing the agent's state variables DECLARATION OF ELEMENTS and the dynamics of changes in its state (behavior) DYNAMIC BEHAVIOR with an analytical or discrete-event description. The syntactic form of the basic component is as follows (see “Fig. 2”).

```
BASIC COMPONENT  < name >
    [mobile_subclass_declaration        - mobile components]
    [subunit_declaration                - base units]
    [local_definitions           - arrays, functions, distribution laws]

    DECLARATION OF ELEMENTS
        [list_of_constants – constants]
        [list_of_state_variables          – state variables]
        [list_of_dependent_variables  – calculated variables]
        [list_of_sensor_variables       – sensory variables]
        [list_of_random_variables      – random variables]
        [list_of_transition_indicators  – transition indicators]
        [list_of_sensor_indicators      – touch indicators]
        [list_of_locations                  – storage arrays]
        [list_of_sensor_locations        – sensor drives]

    DYNAMIC BEHAVIOUR
        | algebraic_equation             – algebraic equations
        | differential_equations          – differential equations
        |region_defining_statement  – areas of certain states
              | event_defining_statement       – events
      END
END OF   < name >
```

Fig. 2. The syntactic form of the basic component

- Practical implementation of agent-based technologies in a universal simulation system that provides an experimentation environment, an agent-oriented model description language, and software tools for organizing experiments [2, 6].

- An easy-to-learn non-commercial tool for implementing agent-based technologies and multi-agent simulation modeling is the Simplex3 universal simulation system with its own object-oriented language Simplex3-MDL (Modell Deskription Language) [1, 6] for describing system-dynamic, discrete-event, and multi-agent models. The Simplex3 system, developed at the Universities of Nuremberg-Erlangen, Passau and Magdeburg (Germany), is intended for teaching the art of modeling and for non-commercial use in research and development.

- The main advantage of the Simplex3–MDL language is the simplicity of description of agents and multi-agent models of large systems of any physical, social, or biological nature in a form close to natural parametric descriptions of the state of agents, their sensory connections with other agents, and the dynamics of state changes using well-known mathematical tools, and discrete-event descriptions.

In our country, the most widespread modeling system is the universal modeling system Anylogic [3], developed by the Russian company XJ Technologies and based on modern information technologies with graphical model construction and programming in the object-oriented language Java.

3. Conclusion

Agent technologies with neural network algorithms for the behavior of self-learning intelligent agents with recognition of current situations in conditions of fuzzy information, uncertainty and risk open up a new direction for the intellectualization of expert computer decision support systems in complex technological process management systems, as well as in virtual research of the influence of various technological factors on abnormal system states.

For software implementation of a self-learning intelligent agent, the *Simplex3* universal simulation system can be used with the specialized object-oriented language *Simplex3-MDL (Modell Deskription Language)* for describing system-dynamic, discrete-event, and multi-agent models [1]. The procedure for training an agent in the dynamics of its behavior is based on a multi-layer neural network with pairs of interconnected input and output vectors and recurrent tuning of synaptic connections based on similarity (for example, Hamming distance). The training sample vectors are formed using a structural-parametric situational model and an algorithm for causal identification of a technological system in conditions of certainty [4, 5].

The proposed direction of intellectualization of the situational modeling of systems lays the foundation for the construction of intelligent expert systems (IES) for making optimal decisions and operational management of food quality and safety at various stages of production at processing enterprises of the agro-industrial complex [4, 5].

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