Monitoring systems development using situational approach and fuzzy logic

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Abstract
The article describes trends of the designing modern monitoring systems: scenario and contingent approaches. The authors propose to use the frame model to represent operation the systems. The frame model supports the using of fuzzy logic.

Keywords: frame machine, trends of using frame model, fuzzy logic.

Introduction
In given paper we consider top trends in subject domain of monitoring systems development.

The trend of intellectualization is traced in works [1-7]. Intellectualization in the narrow sense means active use of intelligent sensors which not only obtain information on object of monitoring, but also are capable to process it, are capable to the analysis of external/internal environment, to adapt to changes, to use difficult procedures of self-testing, calibration, etc.

Intellectualization in the broadest sense means active use of the AI for drawing up domain models, for processing of the arriving information and the analysis of the saved-up statistics: transition from data to knowledge – identification of the hidden dependences, the forecast of the situation, etc.

Intellectualization is not the purpose, but means of achievement of the goal – construction of flexible monitoring systems. Intellectualization allows not only to consider specifics of data domain of creation of monitoring systems, but also to create tools to display the situation in the form of an interactive image and the elements of emotional coloring of the situation that facilitate the work of the AWP operator.

Integration trend. From definition of monitoring systems it follows that functions of monitoring can be assigned to one of parts (subsystems) of any ACS, or can represent the independent system. Today it is obvious that the monitoring system can be the object of both "horizontal", and "vertical" integration.

In papers [8-10] it is noted that functions of monitoring are performed by subsystems in automated systems. The trend of development of monitoring systems which are oriented to the integration with other monitoring systems and managements is observed. Thus, when developing the monitoring system it is reasonable to be guided by already existing standards (GOST-34, IEEE 29148-2011) of interaction between the ACS elements.

Good basis of process of integration is the unified theoretical basis of association of different systems: for example, the use of a situational approach to the construction of monitoring and control systems. One of the promising areas is the creation of technology for building monitoring systems for intelligent road transport systems, including highly automated software and hardware that can be customized to a specific subject area and purpose, reducing the cost of building such systems [11].

Theoretical analysis
Note that the monitoring systems solve a number of typical subtasks that are regularly repeated:
- check system performance, testing subsystems;
- identification of problems and emergency situations;
- parametric adjustment (calibration, etc.);
- monitoring of the work of subsystems (performance testing, etc.);
- system adjustment for changes in the external / internal environment of the monitoring system.

By “situation” we mean an object or process that is reproduced in the subject area of the monitoring system. The situation is described using a system of interrelated parameters. In the classical theory of frames, M. Minsky proposed using the network of frames [12] to describe a system of interrelated situations.

In [13], it was shown that the frame network, which describes the sequence of events in the scenarios of the interactive system, consists of three frame classes:
- frames-directive message;
- frames-dialog branching;
- frames-transformation of information on algorithms for the implementation of computational procedures.

Further development of this direction led to the description of the process of functioning of remote monitoring systems using a frame network, which included new classes. In paper [14], an extended frame unit was considered, the classification of which included a multimedia frame as the basis for building these monitoring environments.

As a result of the D.A. Belov’s research, new prospects were identified for the development of frames in creating additional classes (frames, tools for building them) in the form of the “Multimedia Frame” class (MF). The subclasses are: MF - electronic map, MF - presentation, MF - diagram with the emotional coloring of the situation, MF - video, MF - animation.

The conceptual representation of the subject area of the monitoring systems operation allowed automating the creation of software through the creation of toolkits for each type of the frame.

The toolkits are combined in the form of a database of program code templates (or tool objects of the technology of visual software building). Libraries are equipped with tools that facilitate their maintenance during the life cycle, facilitate the "transformation" of the template into a program model, etc.

Thus, tools are created allowing to get a "guaranteed result" - a workable software code for machine processing of the situation in the subject area of the monitoring system.

Technique

As part of the trend described above, it is proposed to create specialized tools that facilitate the construction of monitoring systems.

To solve this problem, it is proposed to use specialized software modules that allow to process information using fuzzy logic procedures [15] (Fig. 1, 2). This allows you to complete well-known classes of frames, including conceptual descriptions of system work - frames with fuzzy logic procedures.

We introduce and consider such a concept as a frame with fuzzy logic (FFL). FFL will be understood as a frame, the slots of which are completed by fields using fuzzy logic (fuzzing values), as well as slot-results, the values of which are obtained by processing fuzzy inference when processing the initial values of other slots. The frame structure is shown in Figure 2.
The type of slot values can be as numeric, as text values, and references to child frames (subframes). Frames with fuzzy logic can also be used as subframes. Storage of procedures with fuzzy logic in the frame is carried out in the form of lists of descriptors that are attached to the frame slots, and are executed when the values in the frame slots are updated.

To formalize this, we introduce the following frame designation $F_r = \langle idF, S, R \rangle$, where:

- $idF$ is the name or identifier of the frame;
- $S = \langle s_1, s_2, ..., s_n \rangle$ is the set of slots containing the facts defining the declarative semantics of the frame, where $n$ is the number of these slots;
- $R = \langle s_1, s_2, ..., s_m \rangle$ is the set of slots that provide links to other frames (semantic, logical, etc.), where $m$ is the number of these slots.

Frame slots can be formalized as follows:

- $s = \langle idS, T, D, V, L(V), \mu L(V) \rangle$, where:
  - $idS$ is the identifier or name field (required);
  - $T$ is the slot type field (required);
  - $D = \langle f_1, f_2, ..., f_k \rangle$ is a set of daemon procedures, including fuzzy logic, where $f$ is an attached procedure descriptor, $k$ is the number of frame procedures;
  - $V$ is a cell with a value, including subframe link;
  - $L(V)$ is the lexical value field of the linguistic variable’s term - the name of a fuzzy set according to the rule;
  - $\mu L(V)$ is the degree (measure) of belonging to the set of terms of a linguistic variable.

The basis for the implementation of fuzzy inference is the rule base, containing fuzzy “if-then” statements and membership functions for the corresponding terms of linguistic variables described earlier. The following conditions are required [16]:

Condition 1

There is at least one rule for each term of output linguistic variable (the sequential - the right part of the rule).

Condition 2

For any term of the input linguistic variable, there is at least one rule in which this term is used as a prerequisite (the antecedent - the left part of the rule).

The process of fuzzy inference is carried out in several stages (Figure 3):

1) development of fuzzy inference rules (pre-operative stage);
2) fuzzification (the stage of specifying the values of linguistic variables);
3) aggregation (the stage of determining the degree of belonging conditions for each of the rules of the fuzzy inference system);
4) activation (the stage of formation of membership functions of sequential production rules);
5) accumulation (the stage of finding the membership function of the output linguistic variable);
6) defuzzification (this is the process of transition from the membership function of the output linguistic variable to its precise numerical value).

In this paper, the Mamdani output algorithm is used. The defuzzification process implemented according to the center of gravity method [16].

| Slot 1 | Type 1 | Daemon 1 | value | Lex. Value | truth degree |
|-----------------|----------|-----------|-------|------------|--------------|
| Slot 2 | Type 2 | Daemon 2 | value | Lex. Value | truth degree |
| Slot N | Type N | Daemon N | value | Lex. Value | truth degree |

**Figure 2.** Structure of frame with fuzzy logic
Let us consider the example of using the frame with fuzzy logic (Figure 4). Using fuzzy production rules, the Mamdani algorithm calculates the alarm level value for subframes in the frame model tree, which determines the order of output of information from these subframes, as well as the choice of executing scenarios connected with these subframes by condition (for example, sending alerts). The fuzzy logic apparatus allows to generate an alarm level (as the final value of the calculations for the frame) depending on several factors (a set of monitoring parameters). In this case, a human-oriented interface is used - verbal rules-statements to form the conditions for the presentation of information about the monitoring object.

Following example ("CPU" subframe) describes the dependence of the processor alarm level indicator for a computer server on temperature, in combination with the server load and the cooling fan speed. The rule base may contain the following statements:

1) If the processor temperature is “medium” and the server load is “small” and the fan speed is “high”, then the alarm level indicator is “high”;
2) If the processor temperature is “high”, then the alarm level indicator is “high”;
3) If the processor temperature is “low”, then the alarm level indicator is “low”;
4) If the processor temperature is “medium” and the server load is “small” and the fan speed is “low”, then the alarm level indicator is “low”.

Figure 3. Fuzzy logic inference scheme
Let us consider the scheme of the system template (Figure 5). Here are the subsystems of the developed monitoring system template. This scheme differs from the analog subsystem. The structure of the tool complex includes the following elements:

1. Sources of information. Various methods of collecting information about the monitoring object are supported. This may be a computer network from other monitoring system and database. In our case (computer monitoring), agent programs are used.

2. Database. This subsystem is a means of accumulating “raw” data that do not describe the situation in the subject area.

3. Bank of situations stores reference situations in the monitoring domain, which are presented in the form of a frame model.

4. Information analysis system - software for processing information about a monitoring object.

5. The user interface.

The main typical tasks of the subsystem are:

• monitoring results data;
• situational analysis;
• formation of a bank of reference situations;
• highlighting of duplicate elements, conflicts and their resolution in the bank of situations.

6. Interpreter processes raw data and forms a situational description from a raw data - a frame. It compares the situational description with the elements of the situational bank, assesses the situation at the monitoring facility and interacts with the user (monitoring operator), warning the person (if necessary) about negative trends in the development of the situation at the monitoring facility.

7. The statistical data processing system allows obtaining “traditional” characteristics of time series from raw data.

8. The logging system for recording the operation of the monitoring system facilitates the expansion and debugging of the instrumental complex.

### Figure 4. An example of building a network of frames with fuzzy logic

| Subframe «CPU» | idS | D       | V     | L(V) | μL(V) |
|----------------|-----|---------|-------|------|-------|
| 005            | fuzzification | 46     | medium | 0,84 |
| 006            | fuzzification | 71     | high  | 0,67 |
| 016            | fuzzification | 58     | high  | 0,54 |
| 007            | Fuzzy inference | 0,28  | low   | 0,71 |

| Subframe «Memory» | idS     | D       | V     | L(V) | μL(V) |
|-------------------|---------|---------|-------|------|-------|
| 008               | fuzzification | 80     | high  | 0,76 |
| 015               | Fuzzy inference | 0,51  | medium | 0,92 |

| Subframe «Application» | idS   | D       | V     | L(V) | μL(V) |
|------------------------|-------|---------|-------|------|-------|
| 017                    | fuzzification | 44     | medium | 0,65 |
| 018                    | Fuzzy inference | 0,24  | low   | 0,73 |

### Frame «Computer»

| idS | T    | V      |
|-----|------|--------|
| 001 | Link | «CPU»  |
| 002 | Link | «Memory» |
| 003 | LINK | «Application» |
| 004 | Char | 5412_001 |

### Frame «Alert value»

- «CPU Temp, °C»
- «FAN speed, %»
- «CPU Load, %»
- «Alert value»

### Frame «Processes amount»

- «Alert value»
- «Used memory, %»
Figure 5. Generalized scheme of the monitoring system template

All subsystems of the monitoring system are functionally complete elements that are made in the form of skeletal shells that are tunable to a specific subject area (computing, transport, medicine, etc.). The skeletal monitoring system’s shell is made in accordance with the integration trend, and supports the connection of new subsystems. For example, if a multi-user monitoring system is built, the connection of the administration system and the subsystem of the logging of user actions is supported. The apparatus of fuzzy logic was used in the frame model as procedures - daemons, which allowed in this configuration to implement a mechanism for informing the operator on priority importance (alarm level).

Conclusion
The article describes the tools for implementing a situational approach to the construction of monitoring systems. The process of describing the domain of the functioning of monitoring systems using a modified frame model is presented. The positioning of the proposed approach relative to current trends in the development of monitoring systems has been completed. The paper describes elements of typical architectural solutions for monitoring systems built on the basis of a situational approach, which creates prerequisites for the implementation of an instrumental complex for automating the construction of systems of this class. These approaches can be applied to the implementation of intelligent transport monitoring systems with a high level of automation to increase the level of reliability and ensure operational safety.

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