A new method for creating Mivar knowledge bases in tabular-matrix form for ground intelligent vehicle control systems

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Abstract. This research presents a methodology for creating mivar knowledge bases in tabular-matrix form for ground intelligent vehicle control systems. At its core, this methodology is kind of instruction for analysts facing the task of formalizing knowledge in a given subject area. The result of this formalization is a “knowledge map” created according to a special proposed template. In the future, this template allows forming a knowledge base for a given subject area in the formalism of bipartite oriented mivar networks. As an example, the subject area of ground-based intelligent vehicle control systems is used as a template. The proposed methodology of knowledge formalization makes it possible to simplify the process of creating models in Wi!Mi "Razumator-Consultant" 2.1 and also to level the probability of logical collisions when designing a knowledge model in the formalism of bipartite oriented mivar networks.

1. Introduction
Mivar technologies [1] make it possible to create a new generation of expert systems (ES) [2] for a wide variety of applications [3]. These applications include passenger transport management [4]; road accidents analysis [5] and their reconstruction; autonomous intelligent robots [6]; traffic monitoring; robot action planning [7] and even communicating with computer systems, and medical applications. Wi!Mi "Razumator-Consultant" 2.1 software package is used for mivar modeling and creating ES. Thus, if a mivar knowledge base of rules in causal formalism is created (causal dependencies) "If-Then", Wi!Mi "Razumator-Consultant" 2.1 successfully copes with the logical management of smart tools including transport. The actual problem is the creation of mivar knowledge bases. In this research, the following criteria have been considered: ability and knowledge formalization in mivar view, the knowledge formalization preparation process, as well as the process of knowledge formalization in mivar view. Moreover, a new methodology has been considered for creating Mivar knowledge bases in a tabular matrix form for ground intelligent vehicle control systems as an example.
A knowledge base is usually defined as a specific structure such as a database [8] which contains inference rules and facts – information about human experience and knowledge in a particular subject area [9]. When creating a knowledge base [10], it is necessary to describe the content semantic of the subject area [11]. However, there are many difficulties [12] in knowledge formalization by a person especially [13] when there is no formally recorded knowledge [14] of the subject area [15].

The process of knowledge formalization using mivar model can be divided into 4 main stages:
1. Knowledge analysis or the methodology.
2. Knowledge model design.
3. Knowledge model creation.
4. Knowledge model test.

It is important to understand that the possibility of formalizing knowledge using mivar model is determined by the following criteria:

• Hypothetical possibility to create algorithms to solve problems. If it is not possible to create a single algorithm, Wi!Mi "Razumator-Consultant" 2.1 will allow generating (creating) an algorithm for solving problems in real time.

• Completeness – knowledge should have an internal completeness, so that there are no "white spots".

• Consistency – knowledge must be definite and logical in its conclusions. One area of knowledge should not contradict with another.

• The presence of an expert.

The key advantage of mivar expert system is the ability to generate algorithms for solving the problem quickly [1] based on relationships, input parameters, and desired parameters embedded in the model.

At its core, the developed table-matrix knowledge formalization is a kind of instruction for the analysts facing the task of knowledge formalizing for the subject area. The result of this formalization is a clearly recorded preliminary "knowledge map" [16] created using a special template in Microsoft Excel format. This template, for example [17], represents the subject area of ground-based intelligent vehicle control systems [18]. The proposed methodology of knowledge formalization simplifies the process of creating models using Wi!Mi "Razumator-Consultant" 2.1 software package [1], and also leveling the probability of logical collisions when designing the knowledge model.

2. Preparing knowledge for the expert system (ES)
The first and the main question that needs to be answered when presenting knowledge is the question of determining the knowledge composition, i.e. determining "What to present?" in the expert system.

The second question is "How to represent?" knowledge. It should be noticed that these two problems are not independent.

The question "How to present?" can be divided into two independent tasks: how to organize (structure) knowledge [19] and how to present knowledge in a given formalism so that description of the subject area is in the "If-Then" format [20].

Usually it’s necessary to describe the following knowledge:

• Knowledge about the process of performing the task (i.e. control knowledge).

• Knowledge about methods of interaction with external environments (other departments, laboratories, etc.).

Before describing knowledge, the following must be done:
1. Define the role and business functions of the ES in Customer's work (use cases). In fact, the following questions must be answered: How is the process organized now or: How should it be organized in the future? In which Department of the Customer is the process organized?
2. Make sure that the described formal knowledge (knowledge base) is available and valid in the chosen direction. For example, it can be instructions, algorithms, experts, etc.

The quality of ES work directly depends on volume and completeness of the Customer's knowledge base. The case considered in the work is ground-based intelligent vehicle control systems.
To describe knowledge, it’s necessary to answer some questions such as:

- What are the tasks (from the total set of tasks) and what data does the expert work with?
- What are the preferred methods and solutions for the expert?
- What are the limitations of the subject area?
- What are the goals of the expert?
- What are the ES input parameters?
- What does the expert want to receive when exiting the ES?
- Are there formally described algorithms and processes for the automated business process of the ES?
- How is the task being solved now (how is it solved without ES)?

3. Universal table-matrix knowledge formalization

The table for knowledge formalizing is formed in a special template created using Microsoft Excel tool.

The template contains two sheets (Figure 1):

- Rules: in this sheet, all rules, relationships between rules and parameters are described, and input and output parameters with color indication are explicitly specified.
- Constraints in this sheet, all rules of restriction type and their relationships with parameters are described. Moreover; the parameters on which the restriction is applied with a color indication are explicitly specified.

![Figure 1. Structure of knowledge sheet template.](image)

As clear from Figure 2, the "Rules" sheet consists of the following components:

- Relationship – is a type of connection using abstract variables describing their interaction. The relationship is implemented using Wi!Mi "Razumator-Consultant" 2.1 model.
- Description – describes the essence of the relationship and its necessity in the model.
- A relationship body is a template implementing a rule that can have the following types: a formula, a conditional relationship, or a complex relationship described in JavaScript.
- Class – an abstract entity generalizing the concept which is used in the Wi!Mi "Razumator-Navigator" 2.1.
- Parameter – name of the parameter to be used in the Wi!Mi "Razumator-Navigator" 2.1. A parameter is essentially a characteristic of the subject area.
- Parameter description – describes the essence of the parameter if it is not obvious.
- Type – specifies type of the parameter: numeric, text, or Boolean.

It is also recommended to describe Input and Output parameters in detail, as shown in the example in Figure 2.

In order to track various collisions at the model design stage, the method of parameters "indication" should be used. To do this, Input and Output parameters should be filled in the input matrix respectively (Figure 3). For example, one of the common collisions is the absence of an Input or Output parameter in a rule.
Figure 2. structure of "Rules" sheet.

| A | B | C | D |
|---|---|---|---|
| Relation name | Vo – vehicle speed before braking |
| Description | Determination of vehicle speed before braking in m/s |
| Relation body | y=\text{Math.sqrt}(2 \times x1 \times x2 \times x3) |

Class | Parameter | Description | Type |
|------|-----------|-------------|------|
| Input: x1 = g (m/s^2); x2 = f(0.08 - 0.8); x3 = 54 (m). |
| Output: y = Vo (m/s) |

Figure 3. "indication" method of Input and Output parameters in the "Rules" sheet.

For cases where a single relation (rule template) can have multiple bound rules, a construction of n-bound rules to a single relation is used (Figure 4).

Figure 5 shows the "Restrictions" sheet. It contains identical components of the "Rules" sheet such as: Description, Class, Parameter, parameter Description, and Type. Restriction –term is used in WiMi "Razumator-Consultant" 2.1 [1]. Body of the "Constraint" relationship contains the restriction code written in JavaScript.

In the "Restrictions" sheet, the parameters "indication" plays the same important role as in the "Rules" sheet. Using restrictions "indicating" method, parameters which are subject to the corresponding restrictions can be easily tracked (Figure 6).
Figure 4. Construction of n-bound rules to a single relation.

Figure 5. Structure of "Restrictions" sheet.

Figure 6. "indication" method of Input and Output parameters in the "Restrictions" sheet.

It is worth noticing that if the analyst formalizing knowledge does not have experience in JavaScript, pseudo code (an algorithmic language) can be used as a description of the rules. For example:
Input (A train is approaching, The barrier is open)
Output y:
If (A train is approaching == 0 and The barrier is open == 1)
y = We are moving railroad crossing
Else if (A train is approaching, and The barrier is open)
y = We remain in place, the barrier does not work
Else if (A train is approaching, and The barrier is open)
y = We remain in place
Else if (A train is approaching, and The barrier is open)
y = We remain in place

For the situations where long rules are used (for example, more than 100 lines), it would be better to create this rule in a separate*. js file. The file name should correspond to the "Relationship name" and the full path to this file is placed in the corresponding "Body of relationship" cell.

For example: rules (Traffic Regulations) TRpdd.js.

At the same time, folders structures and their names in the "Rules" folder are left to the discretion of the analyst who is formalizing knowledge.

If there are rules in the model that have the same set of input and output parameters, only one representative of these rules will be used in the logical output. In other words, if the Wi!Mi "Razumator-Navigator" 2.1 [1] engine uses a rule that has a set of input parameters "I" and output parameters "O" when constructing a logical output, this output will not contain other rules with similar sets of input parameters "I" and output parameters "O". This restriction is made to avoid looping when building a mivar network and building a solution graph on it.

When designing a mivar model, there is a probability of error if the analyst formalizing knowledge deliberately minimizes size of the inference graph. If there is a possibility in the subject area, the model will make maximum use of the division of logic into its component parts ("elementary" rules). The output of intermediate rules [21] can potentially be used to solve a wide range of problems (even the model creator did not think about) [22]. A new method for creating mivar knowledge bases in a table-matrix form for ground intelligent vehicle control systems [23] has been developed [24].

4. Conclusion
Result of table-matrix knowledge formalization is a file which describes the table-matrix knowledge formalization and it is created using a special template in Microsoft Excel. This formalization allows simplifying models creation process in Wi!Mi "Razumator-Consultant" 2.1 [1]. Moreover; it allows minimizing the probability of logical collisions when designing the model.

Optionally, according to the analyst discretion or if there are long rules, the result can be a separate *.js file format.

Thus, in this research the criteria for the possibility of knowledge formalization using mivar representation have been identified. The process of preparing knowledge for formalization and the process of knowledge formalization itself using mivar representation have been described. A new method for creating mivar knowledge bases in a table-matrix form for ground intelligent vehicle control systems has been developed and presented.

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