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ANALYSIS OF SOFTWARE TOOLS FOR FUZZY MODELING OF BUSINESS PROCESSES OF PROJECT OFFICE OF OUTSOURCING COMPANY

At present, the global market for software working with fuzzy logic is actively developing. It features over 100 software packages that utilize this approach. Several leading IT companies stand out in this market. Their software tools are designed to apply fuzzy logic across a wide range of industries. Some of these software solutions include: CubiCalc from Hyper Logic, FuzzyTECH from Inform Software, FIDE from Ap-tronix, as well as add-on packages for MatLab: Fuzzy Logic Toolbox and FlexTool for MATLAB from Cynap Sys, and JFS from Jan Mortensen [1; 2; 5].

Most of these programs have a comprehensive user interface and extensive data exchange capabilities. They can be divided into the following categories:

– programs for creating code for microcontrollers based on fuzzy algorithms. Typically, the code is written in C or assembly languages;

– kits for developing expert systems based on fuzzy logic. Here, experts define fuzzy rules and membership functions. In all these programs, researchers are provided with the choice of membership function types, inference mechanisms, composition methods, and defuzzification. They also offer graphical representation of models and other dependencies [3];

– programs for modeling dependencies and classification systems based on adaptive fuzzy inference models.

FuzzyTECH and FIDE tools can be attributed to the first category. Programs from the last two categories particularly attract attention when modeling complex systems.

Almost all of the above-mentioned software solutions provide the ability to develop expert fuzzy systems. The cost of some of these programs can reach several thousand dollars for the basic package. Only a limited number of programs provide tools for adaptive modification of the structure and parameters of the fuzzy model.

During the analytical review of specialized programs focusing exclusively on adaptive fuzzy systems, none were identified. Of all the software packages considered, FuzzyTECH and the Fuzzy Logic Toolbox add-on for MatLab offer the most capabilities [4]. Let's try to explore the adaptive tuning possibilities of the fuzzy knowledge base in these packages.

In FuzzyTECH, some methods of structural adaptation of the fuzzy model are implemented, as well as methods for forming fuzzy "If-Then" rules. One approach is the creation of a complete base of fuzzy rules, each of which is assigned a specific significance coefficient, initially random. Then one of the four learning methods is chosen to correct these coefficients. Rules with a low significance coefficient are recommended to be removed, but the final decision remains with the researcher. This approach is similar to hybrid neuro-fuzzy systems.

Another method in FuzzyTECH uses a genetic algorithm to determine the optimal number of terms for each variable. However, this method has certain limitations, especially when the number of variables increases. The task of optimizing terms is less relevant than forming rules based on experimental data.

The "Fuzzy Logic Toolbox for MatLab" offers a broader range of capabilities compared to FuzzyTECH for approximating nonlinear interactions using adaptive fuzzy models [4]. One of its main advantages is the popularity of the MatLab mathematical environment in the post-Soviet space, as well as the availability of extensive sources of information and documentation on its application. The "Fuzzy Logic Toolbox" includes basic functions and algorithms for the Sugeno (TSK) inference mechanism. It supports both descriptive and approximative rules in the form of TSK. The model training process takes place in two steps. The first step involves rule generation and term boundary determination based on subtractive clustering methodology. In the second phase, the AN-FIS technique is used for iterative tuning of membership functions using the backpropagation of errors method.

This package does not have the capability for training Mamdani models and working with approximative rules in its form. With the additional Optimization Toolbox package, it's possible to adjust Mamdani membership functions, but one must set fuzzy rules manually. Genetic algorithms for tuning adaptive fuzzy models in this package are also absent. However, this capability is present in another extension for MatLab – the FlexTool package by CynapSys. It's one of the most renowned commercial packages allowing full customization of all elements of the fuzzy model. The researcher is offered a variety of functions, implication methods, superposition methods, defuzzification methods, and more.

Drawbacks of the FlexTool package are:

– high cost, to which the price of MatLab must be added, depending on the version;

– lack of Russian-language documentation for the FlexTool package;

– fuzzy model training methodologies in FlexTool are not described in the system manual.

The analysis of known software packages for fuzzy modeling indicates that most of them are geared towards creating fuzzy expert systems where the parameters of membership functions and rules are determined by a specialist. Only one package employs genetic methods for constructing a fuzzy model. Techniques for creating adaptive fuzzy models turn out to be more demanding and labor-intensive compared to other intelligent models. Major challenges are associated with the formation of the fuzzy rule base and changing the shape of membership functions. Currently, there isn't a single unified method for training fuzzy models, so an urgent issue is the development and exploration of new efficient approaches. Thus, it seems that at the moment, the most progressive research direction is the use of genetic algorithms for training fuzzy models.

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