Fuzzy Controller for IT Project Cost Estimation*

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Abstract

Based on the fuzzy system for IT project cost estimation, a fuzzy controller has been developed that enables the formation of project cost corridors. This approach is quite realistic for modern IT development, as project cost is a dynamic process due to changing requirements. The Function Point Analysis method is used as the basis for estimating the cost of an IT project. In this case, the project cost is determined by its complexity, which is defined by function points and influence factors. The degree of influence of these parameters is determined by weighting coefficients based on expert evaluations.

The controller consists of four components: a fuzzification unit, a knowledge base, a decision-making unit, and a defuzzification unit. The fuzzy controller has been modeled in the Simulink environment of the MATLAB simulation package. The proposed fuzzy controller makes it possible to formalize expert knowledge into a project budget management model depending on changes in requirements.

Keywords

IT project, project cost estimation, Function Point Analysis,, fuzzy system, fuzzy controller, Simulink, Mamdani algorithm

1. Introduction

The main problem in the implementation of IT projects is the control and forecasting of their cost, as they are characterized by a high level of uncertainty, dynamic requirements, complexity in estimating labor resources, and the influence of internal and external factors. Traditional project cost management methods based on precise mathematical calculations are not suitable under conditions of uncertainty that arise during the planning and development stages of IT projects. This is because the parameters that determine project cost – such as the level of software complexity, the experience of the development team, the degree of changes in customer requirements, and the risks of delays – are qualitative or expert-based in nature.

Under such conditions, the application of fuzzy logic methods is appropriate, as they allow the formalization of expert knowledge, the description of factors using linguistic variables, and the construction of decision support systems under uncertainty. Fuzzy controller, in turn, enables the analysis of the project execution state and, based on this, the adjustment of parameters for managing its cost.

A widely used method for estimating the cost of IT projects is the Function Point Analysis (FPA) Method, which is based on the functional parameters of the project [1–7]. In this case, project complexity is determined by the implemented functions as well as by external and internal influencing factors, which are inherently imprecise, thereby reducing the accuracy of cost estimation. At the same time, the description of influencing factors requires the involvement of experts, which in turn introduces subjectivity into the obtained results.

Thus, reducing the level of subjectivity in factor-based evaluation and improving the accuracy of IT project cost estimation under dynamic requirements necessitate the development of tool that

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enables project budget management while accounting for changes in complexity factors. This is especially important at the early stages of project development.

2. Research analysis

As software tend to grow in size and complexity, this in turn requires significant labor and computational resources to estimate project size, which is one of the determining indicators of project cost. FPA, as an analysis of the structural elements of system, makes it possible to obtain project cost estimate with substantially lower labor expenditure [1–3].

It should be noted that the accuracy of software size estimation is one of the key problems in the field of IT project development, and a complete understanding of software complexity is essential for assessing its quality and functionality [1]. The transition from the analysis of simpler elements, such as a function point, to the evaluation of the system as a whole, that is, a completed IT project, significantly saves time and resources.

At the early stages of the life cycle, especially for new projects, estimating software cost on the basis of code lines is a difficult task. Under such conditions, it is advisable to determine function points, which characterize software size through its functions or changes in them [4].

The combination of the FPA method with fuzzy logic makes it possible to develop models for IT projects complexity estimation under conditions of data uncertainty. In particular, in [8–10], the authors proposed Fuzzy FPA method that allows the complexity of implementing non-standard projects to be formalized on the basis of fuzzy description of the function point calculation procedure.

In [9, 10], the fuzzy FPA method was applied to obtain project cost estimate based on two input factors, namely software complexity and data processing complexity. However, it should be emphasized that the developed model is incomplete, since it does not take into account all significant factors influencing the overall project cost estimate.

In [11], the Fuzzy FPA method was improved by introducing an additional factor, namely the level of intervention in the system according to the state of the development environment. However, this extension does not fully solve the problem of project cost estimation with respect to the factors affecting complexity, and the obtained estimates are often rather rough.

Models of information system functioning quality using influence factors based on the fuzzy logic mechanism are presented in [12, 13]. It should be noted that the assessment of IT project complexity underlies the project development management system [14], while environmental factors affect the timeliness of project completion [15]. However, in order to obtain adequate project management models, these characteristics require preliminary processing.

Fuzzy controller for IT project management, which makes it possible to analyze the influence of external and internal environmental factors on the duration of individual tasks, as well as on financial and human resources, was described by the authors in [16]. Such controller consists of subsystems that allow the involved resources to be modeled separately; however, it does not provide a clear understanding of how exactly project cost is formed.

In [17], an improved method for IT project cost estimation was developed based on the introduction of integrated parameter for project complexity assessment using fuzzy logic. Since project development is a dynamic process in which requirements are refined at each stage, it is advisable to develop fuzzy controller in order to adjust the budget and reflect the relationship between changes in project attributes and the final project cost.

3. Function Point Analysis

Within the FPA method, each functional component of the system, namely input and output data, database queries, internal files, and integration interfaces, is classified according to its level of complexity [1]. Each function is assigned certain number of function points, which reflects its relative importance to the user and the amount of resources required for its implementation. To

ensure higher estimation accuracy, the base FP value is adjusted using the General System Characteristics (GSC) (see Table 1). The total number of function points makes it possible to quantitatively assess the project size and serves as a basis for forecasting labor effort, development time, and implementation

Considering the above, the formula for calculating the adjusted function points based on the influence factors is as follows:

$$AFP = UFP \times (0.65 + 0.01 \times TDI), \quad (1)$$

where UFP – the weighted sum of all function point weights, 0.65 – s the base coefficient, 0.01 – is the increment to the TDI coefficient due to complexity, TDI – is the influence coefficient that determines the basic functional size of the project.

Table 1
General System Characteristics

No.	System Characteristics	Опис
1	Data Communications	Data communications between system components
2	Distributed Data Processing	System implementation on distributed platforms
3	Performance	System performance requirements
4	Heavily Used Configuration	Configuration workload
5	Transaction Rate	Transaction frequency and its impact on complexity
6	On-Line Data Entry	Online data entry
7	End-User Efficiency	Complexity of user interfaces
8	On-Line Update	Need for online system updating
9	Complex Processing	Complexity of data processing and algorithms
10	Reusability	Possibility of reusing system elements
11	Installation Ease	Complexity of installation and configuration
12	Operational Ease	System operation and maintenance
13	Multiple Sites	Operation on different platforms
14	Facilitate Change	System adaptability to changes

Thus, AFP takes into account the implementation software complexity, which is determined by the above-mentioned factors.

In [17], based on the developed fuzzy system, an integrated index for assessing the software complexity was introduced, and thus formula (1) takes the following form:

$$AFP = UFP \times (0.65 + 0.7 \times CI), \quad (2)$$

where CI – integrated system complexity index.

4. Fuzzy Controller for Project Cost Estimation

Fuzzy controller for IT project cost management is based on fuzzy logic methods, which makes it possible to take into account data uncertainty and expert judgments in the decision-making process. To describe the relationship between the factors that determine project complexity and project cost, fuzzy controllers, unlike classical mathematical models, employ linguistic variables and set of "if–then" rules, that is, a knowledge base [18].

Since project development is a dynamic process, the use of fuzzy controllers makes it possible to respond flexibly to changes in the conditions of IT project implementation, improve the accuracy of cost estimation, and support decision-making under uncertainty.

Fuzzy controller was modeled using the MATLAB software package, in particular the Simulink library, which is an interactive environment with set of ready-made tools for modeling dynamic data of nonlinear systems. Figure 1 presents the generalized scheme of the fuzzy controller for IT project cost estimation. The controller is implemented by the Fuzzy Logic Controller block, which operates on the basis of the fuzzy system developed in [17].

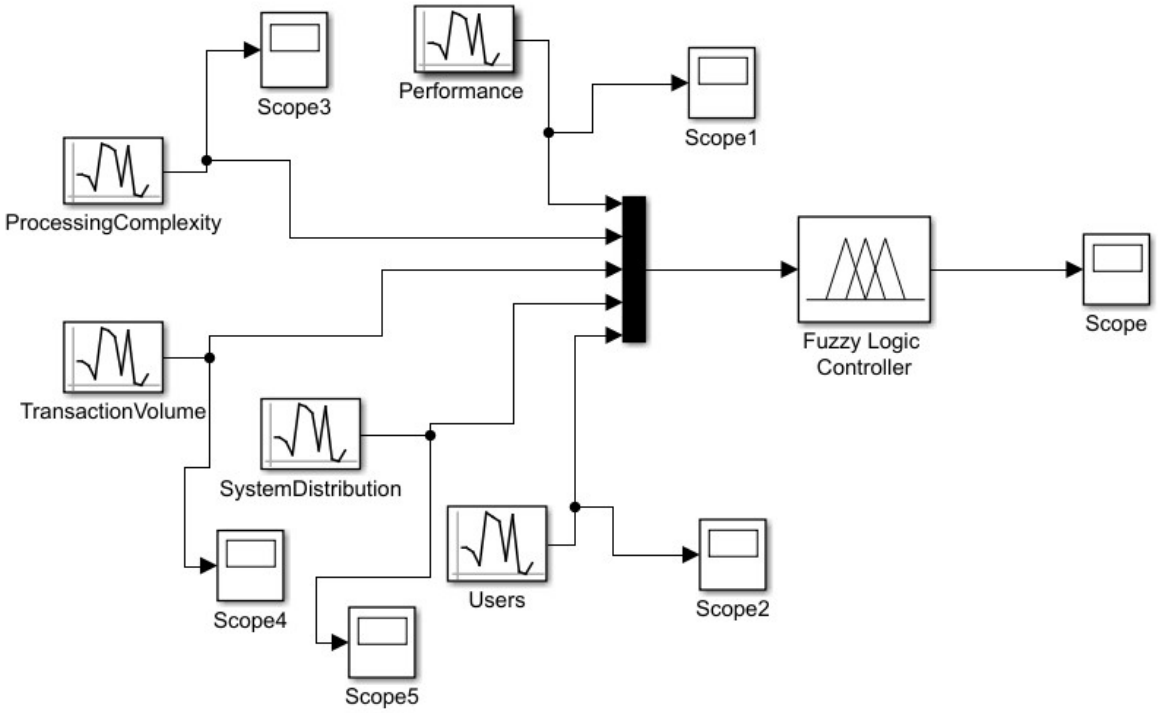


Figure 1: General scheme of the fuzzy controller

The input variables, namely performance, data processing complexity, transaction volume, system distribution, and user interface complexity, are generated using the Random Number generator. The connected scopes provide visualization of the results of the fuzzy controller operation.

Figure 2 shows the procedure for processing input values according to fuzzy rules. Each rule has corresponding weight in the knowledge base, which is specified by the Weight constant.

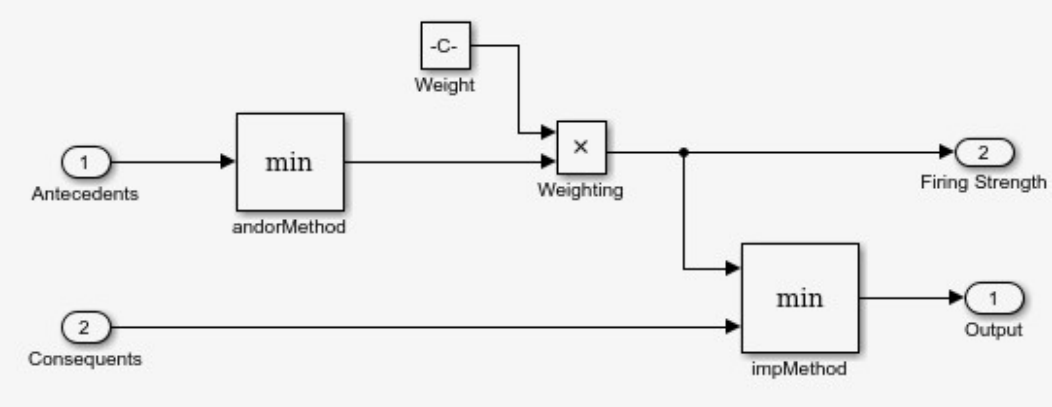


Figure 2: Scheme of input value processing based on fuzzy rules

All rules are equally important in the computation of the result; therefore, their weights are set to 1. Consequently, the contribution of each rule to the fuzzy inference depends solely on its degree of activation, that is, how well the conditions are satisfied, rather than on any additional coefficients. As a result of this procedure, the output fuzzy value, Output, is formed and then used for aggregation and defuzzification.

The fuzzy conclusion based on the Mamdani fuzzy inference algorithm is provided by the defuzzification procedure. Its implementation is carried out through the composition of the knowledge base rules using the "min–max" function. The crisp value of the output variable, namely the IT project cost estimate, is obtained using the centroid method for processing the aggregated result. The scheme of the fuzzy controller defuzzification procedure is shown in Figure 3.

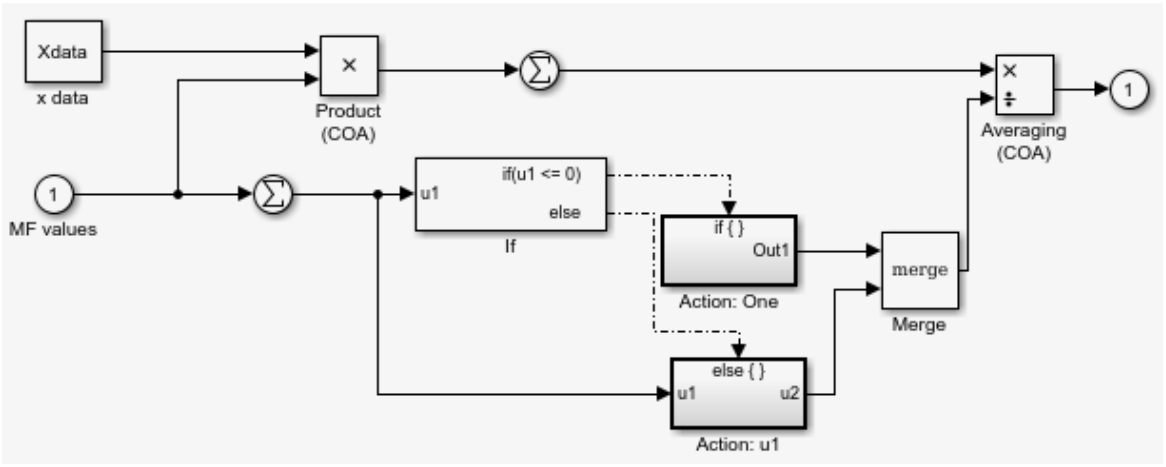


Figure 3: Defuzzification scheme of the fuzzy controller

Considering the above, the defuzzification procedure ensures the conversion of fuzzy output data into a crisp value for the IT project cost estimate. Thus, the developed fuzzy controller formalizes expert knowledge in the form of a mathematical model that can be used for decision-making in IT project management.

5. Controller Performance Analysis

For the analysis of the fuzzy controller operation for IT project cost estimation, Scope blocks were used. The controller's output, based on the input data – namely, the significant factors affecting project complexity, which determine its costis, presented in Figure 4.

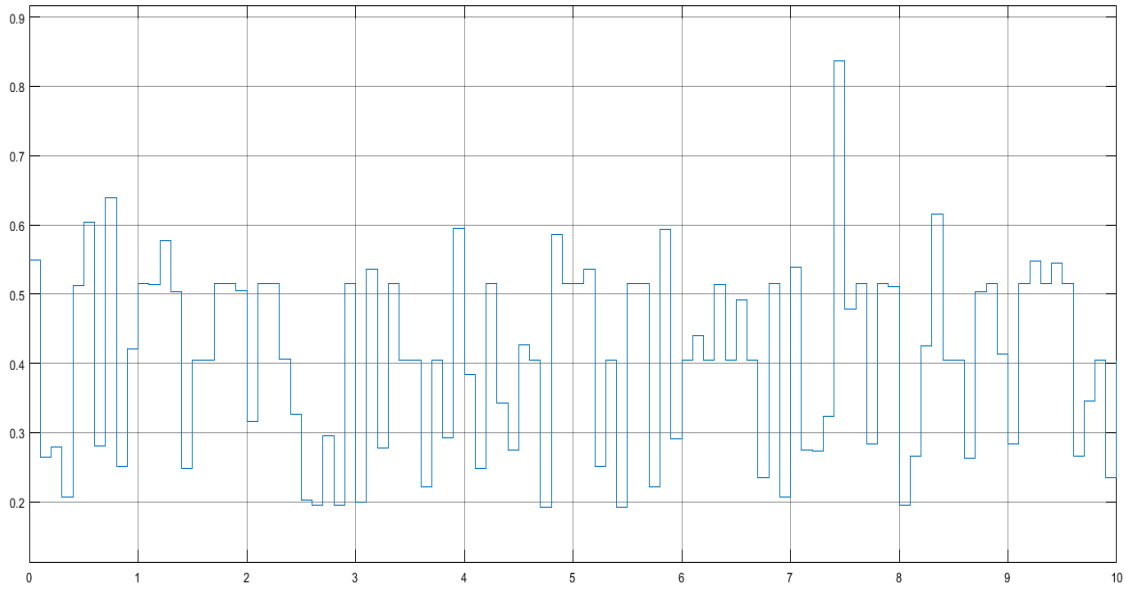


Figure 4: Fuzzy Controller Output

The curve exhibits irregular fluctuations, which are typical for fuzzy logic systems. This is because the value of the output variable is formed based on an «if–than» rule base and membership functions. At each moment in time, the system calculates the degrees of membership of the input parameters to corresponding fuzzy sets, after which certain rules from the knowledge base are activated.

The absence of sharp jumps or monotonic changes indicates smooth control, which is one of the main advantages of fuzzy controllers. By using fuzzy sets and the logical inference mechanism, the system provides an adaptive response to changes in input parameters while maintaining the stability of the output signal.

Thus, the results of the fuzzy controller simulation confirm the adequacy of the developed model for IT project cost estimation. This indicates the potential of applying fuzzy systems for similar control tasks.

6. Conclusions and Future Work

A fuzzy controller for estimating the complexity of IT projects has been developed, based on the FPA and fuzzy system with complexity estimation accuracy over 90% [17]. The experimental results confirmed the effectiveness of using such tool for IT project cost estimation under variable conditions and dynamic requirements. Since the controller output is formed based on randomly varying input parameter values, which represent significant factors influencing project complexity. This allows reducing subjectivity in decision-making and managing the project budget depending on changing factors. The proposed approach can be applied to various types of IT projects, as it does not depend on specific implementation technology and is based on the functional characteristics of project and expert knowledge.

Although five of the most significant complexity factors were identified during the system development, the resulting knowledge base is quite extensive. To optimize it, clustering methods [19] can be applied in future research. Since data at the early stages of project development are often abstract and limited, the development of neuro-fuzzy models for cost estimation, based on artificial neural networks and fuzzy logic, will make it possible to obtain process models using unstructured and limited datasets.

Declaration on Generative AI

During the preparation of this work, the authors used ChatGPT in translate the text and rephrase commonly used terminology. After using these tool, the authors reviewed and edited the content. Artificial intelligence tools were not used in the formulation of scientific results, analysis of research findings and formulation of conclusions.

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