A Program for Modeling the Perception of Success Factors of an IT-Project Using Fuzzy Cognitive Maps

Peganov Nikita
Faculty of Computer Science
National Research University Higher School of Economics
Moscow, Russia
nspeganov@edu.hse.ru

Abstract — This research work presents a novel program for modeling the perception of success factors in Information Technology projects using Fuzzy Cognitive Maps (FCMs). The study aims to provide a comprehensive understanding of the complex relationships and interdependencies among various factors that contribute to the success of IT projects. The proposed program employs FCMs, a cognitive modeling technique that captures the inherent fuzziness and uncertainty in human reasoning and decision-making processes. The program's effectiveness is evaluated through a series of case studies involving real-world IT projects. The results demonstrate the program's potential in accurately modeling and analysis of the success of IT projects, thereby aiding project managers in strategic planning and decision-making.

Keywords — Cognitive maps, Fuzzy cognitive maps, IT-project, Success Factors, Risk Management, Success Perception, Project Management, Fuzzy Logic, Decision Making, Fuzzy Set Theory.

I. INTRODUCTION

The general purpose of the developed program is to visualize, analyze and understand the success factors of IT projects. This is achieved by using fuzzy cognitive maps, which allows you to include any variables (factors) in the model, even those that are difficult or impossible to measure in quantitative terms. The main purpose of this software is to identify and visualize the relationships between various factors from the point of view of stakeholders.

The program implements fuzzy computing models, with which analysts can evaluate and analyze the data obtained based on the proposed fuzzy computing models. Fuzzy Cognitive Maps (FCM) make it possible to model the same system in different ways, depending on the goals and professional skills of people or groups of people, fixing the time-varying values of the simulated situation.

The program generates FCM that can be used to visualize complex systems and display their development over time. At the same time, in some cases, SWOT analysis is used - this allows us to more fully characterize the factors under study.

Over time, not only the factors themselves can change, but also the connections between them. The program allows you to take this into account by rebuilding and modifying maps. This makes it possible to iteratively adjust the model and search for new dependencies and vulnerabilities.

The target audience of this program is mainly specialists working in the IT sector, namely analysts, project managers and IT directors. This is due to the fact that the program allows you to model the perception of success factors of IT projects and can be useful for researching and managing various aspects of such projects.

At the same time, this program can be used for educational purposes and has the potential to be useful for students and teachers of IT specialties, especially for those who study or teach courses related to IT project management, data analysis, artificial intelligence or cognitive science.

Finally, potential users of this program may also be authors of scientific research in the field of IT and cognitive science. It can be useful in studying the perception of factors influencing the success of IT projects, and in researching decision-making mechanisms within such projects.

At the same time, it should be noted that this program can be operated mainly by people who have the necessary skills and knowledge to work with fuzzy cognitive maps. It implies the use of the program by one analyst and many stakeholders to create the result of a collective discussion.

Recently, in light of the growing dependence of business on technology, the successful implementation of IT projects has become especially important for organizations of various fields of activity and scale. However, measuring and predicting success in the case of IT projects is still a difficult task, as they depend on many factors characterized by ambiguity and mutual connection with other aspects of consideration.

In this regard, the program for modeling the perception of success factors of IT projects using fuzzy cognitive maps is gaining significant relevance. The success factors of a project are often vaguely defined and interpreted, which makes the use of fuzzy cognitive maps an appropriate choice for their analysis and modeling.

The methodology of cognitive modeling was proposed by the American political scientist and economist Robert Axelrod [1]. Cognitive modeling was designed to make decisions in poorly defined situations. Fuzzy cognitive maps, first proposed by Bart Kosko [2], are a mixed type of graphical representation of knowledge that includes elements of cognitive maps and fuzzy logic.

In recent years, they have again attracted the attention of researchers, just as neural networks, after their "oblivion" in the 90s of the 20th century, are now experiencing their peak popularity again. For example, fuzzy cognitive maps are used in research papers written in 2018, 2019 and 2022 [3, 4, 5]. Like neural networks, fuzzy cognitive maps can be used to model complex relationships and obtain results based on vague and fuzzy information.

In numerous research papers, the authors consider fuzzy cognitive maps as a convenient and visual modeling tool. Factors and relationships between factors are located in FCM in a structure similar to the structure of the human brain (in a very simplified form), so the resulting model is easily perceived and convenient for discussion. Fuzzy cognitive maps are also versatile, which allows them to be used in many different areas [6].

Despite the neural network-like structure of fuzzy cognitive maps, the use of complex neural network algorithms is not expected within the framework of this final qualification work. This is mainly due to the specifics of the chosen methodology — fuzzy cognitive maps. This approach involves creating a model using a network structure that reveals the direct and inverse relationships between various success factors of an IT project.

II. LITERATURE REVIEW

Modeling the success factors of an IT project is one of the areas in which fuzzy cognitive maps are successfully applied. For example, in the work "Modeling IT projects success with Fuzzy Cognitive Maps" [7], the authors use FCM to model the success factors of a mobile payment system, a project related to the rapidly developing world of mobile telecommunications. The methodology described in this paper uses four matrices to represent the results that the methodology provides at each of its stages. These are the Initial Success Matrix (IMS), the Fuzzified Success Matrix (FZMS), the Relationship Strength Success Matrix (SRMS) and the Final Success Matrix (FMS). The authors of the article conclude that Critical Success Factors (CSF) are the necessary conditions that a project must meet in order to be perceived as successful. Improved processes for identifying and evaluating suitable CSFs for IT projects are required due to increased complexity and uncertainty.

In the work "Using cognitive maps for modeling project success" [8], published in the same year, cognitive maps are used. For clarity, it examines a real construction project implemented in Turkey. The paper also describes the advantages and disadvantages of cognitive maps. Among the advantages of cognitive maps, the authors note their ability to present complex ideas and information in a simple and understandable form. Cognitive maps also help to improve the understanding and organization of knowledge, as well as contribute to more effective decision-making. However, cognitive maps also have disadvantages. They can be difficult to create and interpret, especially if they involve a large amount of information or complex relationships. In addition, they can be subjective because they are based on the knowledge and perception of an individual or a group of people.

The article "Assessing it projects success with extended fuzzy cognitive maps & neutrosophic cognitive maps in comparison to fuzzy cognitive maps" [9] presents a study in which the authors compare the use of extended fuzzy cognitive maps and neutrosophic cognitive maps in assessing the success of a mobile payment system project. To do this, they created various cognitive maps with several groups of stakeholders. As a result, the authors concluded that neutrosophic cognitive maps showed better results than fuzzy cognitive maps and improved cognitive maps.

An analysis of the literature shows that the use of cognitive maps is an effective tool for modeling and evaluating the success factors of IT projects. These methods allow you to present complex ideas and information in a simple and understandable form, improve the understanding and organization of knowledge, and contribute to more effective decision-making.

However, as noted in the analyzed papers, these methods have their drawbacks, including the complexity of creating and interpreting maps, especially with a large amount of information and complex relationships, as well as subjectivity, since they are based on the knowledge and perception of an individual or a group of people.

It is also worth noting that the importance of identifying and evaluating critical success factors (CSF) for IT projects is emphasized in all the papers reviewed. This confirms the relevance of our research and the chosen topic of the final qualifying work.

Thus, the development and use of a program for modeling the perception of success factors of IT projects using fuzzy cognitive maps is a useful and relevant approach to solving the complex problem of IT management and planning.

III. METHODS

The program for modeling the perception of the success factors of an IT project is based on the use of fuzzy cognitive maps.

Types of fuzzy sets:

1. Fuzzy sets (of the first type) are a key element in the field of fuzzy logic, which was first proposed by Lotfi Zadeh in 1965 [10]. Unlike classical binary logic, where an element either belongs to a set or not, fuzzy sets allow elements to belong to a set to a certain extent. This is achieved by introducing the membership function, which assigns to each element a number from 0 to 1, reflecting the degree of its membership in the set. This approach allows for more accurate modeling of the uncertainty and fuzziness of the real world, which makes fuzzy sets useful in many fields, including artificial intelligence, decision-making systems, image processing, and many others.

   A fuzzy set A is understood as a set of ordered pairs composed of elements x of the universal set X and the corresponding degrees of membership $\mu_A(x)$:

   $$A = \{(x, \mu_A(x)) | x \in X\}$$

   where $\mu_A(x)$ is the membership function indicating to what extent the element x belongs to the fuzzy set A. The function $\mu_A(x)$ takes values in some linearly ordered set M, which is called the accessory set.

2. Fuzzy sets of the second type are an extension of the classical theory of fuzzy sets proposed by Lotfi Zadeh in 1975. They were introduced to simulate situations where the degree of belonging of an element to a set is itself fuzzy. Unlike ordinary fuzzy sets, where each element is assigned a degree of belonging in the range from 0 to 1, in fuzzy sets of the second type, a fuzzy set of the first type is assigned to each element. Thus, fuzzy sets of the second type allow for a large degree of uncertainty and fuzziness, which makes them useful in many applications, including decision-making systems, fuzzy information processing and modeling of complex systems. Thus, formally fuzzy sets of the second type can be expressed as:

   $$\tilde{A} = \int_{x \in X} \int_{u \in J_x} \mu_{\tilde{A}}(x, u)/(x, u)$$

   where the sign of double integration means the union of valid x and u for a continuous universal set (for discrete universal sets, double summation symbols are used instead).

3. Fuzzy Sets of Type 3 is an improved version of Type 2 sets, designed with advanced capabilities for uncertainty management. In type 3 sets, the secondary membership function is also a type 2 membership function. This means that the upper and lower limits of membership are not fixed, unlike type 2 sets. This characteristic allows fuzzy type 3 sets to cope with a higher degree of uncertainty [11]. A fuzzy set of type 3 can be defined as follows:

   For each element $x \in X$, the membership function $\mu_A(x)$ a fuzzy set A of type 3 is defined as:

   $$\mu_A(x) : X \to [0, 1] \times [0, 1]$$

   where the first element of the pair represents the lower limit of membership, and the second element represents the upper limit of membership. Secondary membership function $\mu_A^{'}(x)$ is defined as:

   $$\mu_A^{'}(x) : [0, 1] \to [0, 1]$$

   where $\mu_A^{'}(x)$ represents the degree of confidence that x belongs to the set A.

1. An intuitionistic fuzzy set is a generalization of a fuzzy set that includes the degree of non-belonging of a function in addition to the membership function. It was introduced by Atanasov as a way to deal more comprehensively with uncertainty and inaccuracies. An intuitionistic fuzzy set can be defined as:

   Let X be a nonempty set. The intuitionistic fuzzy set (IFS) A in X is defined as $A = \{(x, \mu_A(x), \nu_A(x)) | x \in X\}$, where $\mu_A(x) : X \to [0, 1]$ and $\nu_A(x) : X \to [0, 1]$ are functions representing the degree of belonging and non-participation of each element x in X to the set A, respectively, satisfying the condition $0 \leq \mu_A(x) + \nu_A(x) \leq 1$ for each $x \in X$.

   In this definition, $\mu_A(x)$ is an affiliation function, and $\nu_A(x)$ is a non-affiliation function. Condition $0 \leq \mu_A(x) + \nu_A(x) \leq 1$ guarantees that the sum of the degrees of membership and non-membership for any element does not exceed 1, which is a fundamental property of intuitionistic fuzzy sets.

In this final qualifying work, sets of type 1 and type 2, as well as intuitionistic fuzzy sets, will be considered. Fuzzy sets of type 3 are not intuitive enough, and also complicate data entry on the part of the program user.

Types of accessory functions: Membership functions are used in fuzzy set theory to determine the degree to which an element belongs to a particular set. Here are a few basic types of membership functions:

1. Triangular membership function: This is the simplest membership function, which has the shape of a triangle. It is defined by three points: the beginning, the top and the end.
2. Gaussian membership function: This function has the shape of a bell and is defined by two parameters: center and width. The Gaussian membership function is often used in cases where the data has a normal distribution.
3. Trapezoidal membership function: This function has the shape of a trapezoid and is defined by four points: the beginning, the beginning of the plateau, the end of the plateau and the end.
4. Sigmoidal membership function: This function has the shape of an S-shaped curve and is defined by two parameters: center and width. The sigmoidal membership function is often used in cases where the data has a binary distribution.
5. Z-shaped and S-shaped membership functions: They are used to represent increasing and decreasing trends.
6. Parabolic membership function: This function has the shape of a parabola and is defined by two parameters: center and width.
7. Beta membership function: This function is defined by four parameters and can take various forms, including bell shape, S-curve and others.
8. Gamma membership function: This function is defined by two parameters and can take various forms, including bell shape, S-shaped curve and others.

Each of these membership functions has its advantages and disadvantages, and the choice of a specific function depends on the specifics of the task and the data. In this paper, the triangular membership function, the Gaussian membership function and the trapezoidal membership function will be considered as the most popular.

Defuzzification algorithms:

1. The Center of gravity method (COG - Center Of Gravity), which calculates the center of gravity of the membership function.
2. is the Bisector Of Area (BOA) method, where the bisector of area under the membership function is calculated.
3. The Mean Of Maximum (MOM) method, where the average value of the maximum values of the membership function is calculated.
4. is the Maximum Of maximums (Maximum Of Maximum - MOM) method, where the maximum of the maximum values of the membership function is selected.

IV. EXPECTED RESULTS

V. CONCLUSION

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