Application of Fuzzy theory in project scheduling

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Abstract. Project scheduling is considered one of the most important stages of project planning, and aims to optimize the use of available resources to obtain satisfactory results within the limits of time, cost, and quality. Previously, dealing with the issue of project scheduling was considered by some parameters as fixed values (such as the duration of project activities). Subsequently, cloudy theory allowed the development of new methods with the ability to deal with engineering problems in a realistic way close to human processing, relying on the user’s knowledge and experience, and in cases of uncertain data. In this article, a research review of the use of motion blur theory to solve the project scheduling problem showed the potential ability to apply in multiple fields and its ability to integrate with other methods such as (genetic algorithm).

Keywords: Project scheduling, Fuzzy logic, CPM, PERT, RCS.

1. Introduction

The project is an environment that connects multiple parties, contains tasks with the aim of implementing ideas on the ground, using the available resources and taking into account the specific conditions of time, cost and quality.

To implement the project in the best possible and efficient manner, a project scheduling process must take place. Project scheduling means setting the start and end dates for all activities that make up the project, and determining the resources needed for each of these tasks [1].

The main goal of the project scheduling process is to ensure the completion of the project implementation taking into account the availability of resources and within the limits of cost, time and required specifications. The project scheduling problem has been studied by many researchers, where the activities’ periods were considered fixed and specific values.

In 1961, Kelley indicated that there is a relationship between the total cost of the project and the duration of activities that make up this project, thereby establishing the first mathematical model to solve the project scheduling problem. Then, in 1963, he devised a method to solve this problem in order to reach the lowest possible value for the project cost [2,3].

Since that time, many studies have been undertaken to solve the project scheduling problem, as the project activities have a fixed duration. Several solutions have been presented to this problem using different optimization methods [4-6].

However, in real life, the duration of project activities cannot be determined precisely because of the many factors that could affect them. Thus, uncertainty exists and is the best representation of real life. The idea of uncertainty has been attempted to solve the project scheduling problem by many researchers, as probability and chance constrained programming was used [7,8], three models were also built using stochastic activity duration times [9].
The complexity of the project scheduling problem is increased by the impact of the presence of several uncertainties, which in turn can be classified into three groups, related to activities, related to resources, and temporary uncertainties [10].

Intelligent systems are one of the most important tools that researchers use today, which has proven highly effective in solving many problems in multiple areas. Fuzzy logic, artificial neural networks and inverse programming are among the most important techniques used in the intelligent systems environment.

Loans are the main source of capital, thus the importance of scheduling the project is to achieve the greatest possible benefit, and provide the greatest amount of resources, by setting a timetable that guarantees the achievement of these goals.

2. Fuzzy logic

Since the introduction of fuzzy logic, it has been used to solve a large number of problems, and to process information in modeling, in the engineering field and in a large number of other fields [11]. Fuzzy logic aims to impart human knowledge expressed in the natural language, by representing it with variables that may take qualifiers or numerical values.

This flexibility allowed the application of fuzzy logic to such problems, as classification, in computers and control systems, amongst other things. The importance of fuzzy logic lies in providing an easy and effective way to represent the absence of accurate information or the inability to obtain it for any reason.

Fuzzy logic deals with variables realistically, and processes data in a way close to human processing, because it mainly depends on if-then rules, which form the basis for setting the mathematical model of the problem to be solved.

In fuzzy models, the data is represented as membership functions, enabling it to manipulate continuous values rather than dealing with individual values.

It is worth noting that fuzzy logic allows us to deal with different levels of uncertainty so that specific factors are defined for each of the problem variables to be solved.

2.1. Fuzzy sets

The concept of fuzzy set first appeared in 1965, and defined as a class of objects with assigned membership function grades [12].

Membership functions defined sets that can assign each set a membership grade with values from zero to one. In other words, a fuzzy set (class) A in X is characterized by a membership (characteristic function) \( f_A(x) \) which associates with each point in X a real number in the interval [0, 1].

A fuzzy set can be mathematically expressed as: if X is a collection of objects denoted generically by x, then a fuzzy set A in X is defined as a set of ordered pairs: \( A = \{(x, \mu_A(x)) | x \in X\} \) Where \( \mu_A(x) \) is called the membership function (or MF) for the fuzzy set A. The MF maps each element of X to a membership grade (or membership value) between 0 and 1 [11].

![Figure 1. Trapezoidal fuzzy set [11].](image-url)
2.2. *Fuzzy rules and Fuzzy reasoning*

The fuzzy rules and the fuzzy reasoning are closely related to each other, the idea of fuzzy reasoning depends on the presence of a structure that allows the process of processing consisting of three main parts: rule, information and reasoning.

For example:
- **Rule** - If there is a lack of resources, there will be a delay in carrying out the related activity.
- **Information** - there is a lack of resources of resources.
- **Inference** - there will be a delay in the implementation of the related activity.

The information is considered as input values to the fuzzy model, after ensuring that the condition is met, the result of this process will be inferred.

Fuzzy if-then rules and fuzzy reasoning are the foundation which the fuzzy thinking model is built on.

The main stages of fuzzy reasoning can be summarized to [11]: comparison – where the information collection and determine the degree of compatibility with the rules, combination - relate compatibility to membership functions in a single rule using AND or OR operators to form the defining conditions, Output creation - to combine different rules taking into consideration inputs (available information), to then come up with a consequent action (output).

2.3. *Fuzzy inference system (FIS)*

A fuzzy reasoning system can be defined as a system consisting of simple strategies aimed at update, input, and analyzing information using antecedent - consequent parameters.

Processes in the fuzzy inference system can be divided into three basic stages:
- In the first stage the data is entered by the user or by a controller, this data is converted to fuzzy values, i.e. from specific values to continuous values.
- In the second stage, the data entered in the first stage is processed after verifying that the conditions specified in the rules have been fulfilled after that actions are taken that correspond to problem's conditions and their proper weighting [13].
- In the third stage, the processing results are converted to crisp values again, thus obtaining the final result of the problem.

![Figure 2. Fuzzy Inference System.](image1)

![Figure 3. Deffuzification Schemes [13].](image2)

Mainly three fuzzy inference systems are considered to use the most [13]: Mamdani FIS, Sugeno FIS and Tsukamoto FIS.
2.4. Fuzzy Modeling
From the above we see that the fuzzy reasoning system is designed based on prior knowledge or procedures known to us before, so this system is fully capable of understanding these procedures and knowing the appropriate conditions for their implementation.

These systems are characterized by their ability to simulate human knowledge and experience, and work effectively with expert systems, which allows to reach more accurate results and benefit from them later in other conditions.

Converting reality into a mathematical model and dealing with numbers greatly easier to understand, and a lot easier to work with.

To build any blurry model, the related variables must be determined, and then choose a fuzzy inference system according to the available information, and then set rules (if-then) to set the procedure corresponding to each input.

2.5. Fuzzy priority rules
Fuzzy priority rules have been studied by several researchers, and it has been found that priority heuristics using crisp or fuzzy time parameters can be used effectively in the case of a single project or multi-project scheduling [14, 15]. The most used rules are listed in Table 1.

| Abbreviation | Description                          |
|--------------|--------------------------------------|
| EST          | Early start time                     |
| EFT          | Early finish time                    |
| LST          | Late start time                      |
| LFT          | Late finish time                     |
| MINSK        | Minimum slack                        |
| MAXSINK      | Maximum slack                        |
| SPT          | Shortest processing time             |
| LPT          | Longest processing time              |
| LIS          | Least immediate successors           |
| MIS          | Most immediate successors            |
| MTS          | Most total successors                |
| GRD          | Greatest resource demand             |
| SASP         | Shortest activity from shortest project |
| LALP         | Longest activity from longest project|
| GRPW         | Greatest rank positional weight       |
| LRPW         | Least rank positional weight          |

3. Project scheduling under uncertainty
The project consists of activities, to determine the period of time necessary to end this activity, then we have two cases: Either this activity was previously performed repeatedly, and therefore we have historical data, in which case these values can be considered sufficient, and to express uncertainty, it can be according to the distribution Probability through known statistical methods, but in the absence of historical experience or its scarcity, they would expressed as fuzzy variables through the expert's opinion and knowledge.

Fuzzy theory was applied into project scheduling problem for the first time in 1979 [16]. Then there were studies that examined different types of project scheduling problems, as the duration of activities was considered as fuzzy values [17, 18].

As mentioned earlier, the theory of fuzzy sets allowed to deal not only with fixed values but also with fuzzy or undefined values, so that it has become a promising method for modeling uncertainty in manufacturing-related problems and project scheduling problems [19].
The new concept of decision-making under the influence of uncertainty, made the application of this theory in many areas of industrial systems [20].

To deal with the effect of uncertainty during project scheduling, both probability theory and fuzzy set theory were used, and the Stochastic Resource Constrained Project Scheduling Problem was most researched [21].

3.1 Fuzzy in CPM and PERT
To deal with the logical sequence of implementing activities in the project scheduling, Program Evaluation and Review Technique (PERT) and Critical Path Method (CPM) are considered [22,23].

As these two methods are considered one of the most important methods of planning and scheduling projects that are widely used in various fields regardless of the size of the project, and because it adopts an analytical method, it has great importance for decision makers.

The project scheduling calculation process is divided in both ways in two phases: forward propagation and backward propagation. The earliest starting and finishing dates values are calculated throughout the forward propagation, and the latest starting and finishing dates values are calculated throughout the backward propagation.

The bulk of the research that studied solving the project scheduling problem using fuzzy theory focused on using a method that combined fuzzy theory with CPM or PERT, although, in CPM, the duration of activity is assumed to be constant when the deterministic method [24].

It should be noted that the application of fuzzy theory during the calculation of backward propagation is no longer applicable because uncertainty would be taken into account twice.

The problem complexity and propose some algorithms to calculate the tasks’ latest dates and floats while uncertainties are represented by intervals [25].

3.2. Resource constrained scheduling
Among the constraints that play an important role during project scheduling are resources, their different types and availability. The need to allocate resources led researchers to study Resource Constrained Scheduling Problem (RCSP) in the early 1950s. Its importance as it was the need to implement a large number of multiple projects with specific resources.

There are several ways to get the best use of the available resources, the two most important methods are resource constrained scheduling (RCS) and resource leveling (RL) [26].

One of the proven classic techniques played an important role in solving the RSCP are Serial method, the Parallel method, the Branch and Bound algorithm, and the Utility Index calculation.

There are several attempts to apply fuzzy theory to solve this issue, such as the serial and the parallel scheduling schemes and the resource levelling technique, generalized to handle fuzzy parameters, and more with other artificial intelligence methods like genetic algorithm.

4. Conclusion
Fuzzy theory provided the ability to deal with problems realistically, and more closely to human treatment, and showed a great ability to introduce the concept of uncertainty into solving various engineering problems, including the project scheduling problem.

Several methods were developed to use fuzzy theory to solve problems with the use of other methods such as (genetic algorithm), and demonstrated the possibility to integrate these methods with each other in order to reach models closer to the actual reality.

Fuzzy theory ensures that engineering problems are solved taking into account human experience and knowledge, i.e. converting human knowledge into mathematical models that allow better use of it over time and more experience.

The methods of artificial intelligence have changed traditional concepts in solving engineering problems, and the horizon is still open to offer more in this regard.
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