A Fuzzy Approach to Requirements Prioritization

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Abstract. One of the most important issues in a software development project is the requirements prioritization. This task is used to indicate an order for the implementation of the requirements. This problem has uncertain aspects, therefore Fuzzy Logic concepts can be used to properly represent and tackle the task. The objective of this work is to present a formal framework to aid the decision making in prioritizing requirements in a software development process, including ambiguous and vague data.

Keywords: Requirements Prioritization, SBSE Applications, Fuzzy Logic.

1 Introduction

Search Based Software Engineering (SBSE) is a field that proposes to modeling and solve complex software engineering problems by using search techniques, such as metaheuristics. Among the problems already tackled, the requirements prioritization problem has received special attention recently.

In [1], approaches to deal with the requirement prioritization problem are presented, where genetic algorithm is employed. Such optimization approach does not consider the fuzzy and vagueness human goals, such as linguistics evaluations of stakeholders.

Examples of goals that may be measured in a fuzzy linguist approach are stakeholders' satisfaction, deliver on time, deliver on budget, deliver all planned scope, meet quality requirements, team satisfaction, and deliver all high-priority functionalities in the first release.

An approach to prioritize requirements using fuzzy decision making was proposed in [2]. The proposed algorithm assists stakeholders in analyzing conflicting requirements in terms of goals and constraints of reaching to a crisp optimal decision value against which an appropriate priority can be assigned to the conflicting requirement. The influence of requirements prioritization on goals was not considered.

Therefore, the objective of this work is to present a formal framework guided by fuzzy goals to be used in the requirements prioritization task.

Section 2 presents the proposed formal framework. Section 3 shows some initial results with the requirement prioritization problem. Section 4 outlines conclusions and future works.

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2 Formal Framework

In this framework, capital letters denote sets, fuzzy sets and fuzzy relations, $U = 0.0 + 0.1 + ...+ 1.0$ is the discourse universe for the definition of fuzzy sets and $L = [0,1]$ is the interval for defining the participation values, $F(U)$ denotes the family of fuzzy sets defined in U. Section 2.1 formalizes the information regarding the Software Fuzzy Goals. Section 2.2 formalizes an evaluation function for this approach.

2.1 Definitions

This first part of the framework allows the representation of fuzzy software goals, fuzzy desired situations and fuzzy requirements for the stakeholder. Each attribute of a goal is represented by a linguistic variable (X) [3] [4]. The values of these variables are sentences in the language formed by terms that are aspiration level values, e. g., *T("Aspiration") = ... + low + medium + ... + high + ...*. The meaning of these levels corresponds to fuzzy subsets of U, e. g., *low = [1.0, 1.0, 0.9, 0.7, 0.5, 0.2, 0.0, 0.0, 0.0, 0.0, 0.0]* and *high = [0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.3, 0.5, 1.0, 1.0, 1.0])*. Where the "+" sign represents the union of the elements of set.

A pair (variable, aspiration level) defines a fuzzy software goal. In general, more than one fuzzy software goal is used in the specifications of a desired fuzzy situation. Each goal contributes to a different degree to the meaning of the situation. The next three definitions formalize software goal, desired situation and requirement.

Definition 1. A software goal Gm is fuzzy if the aspiration level Am, assigned to attribute Xm of a desired situation, is described in terms of a fuzzy subset of U:

$$G_m = \left(X_{m,}, A_m = \sum_{i=1}^{L} A_m\,(u_i)/u_i \right), \tag{1}$$

where X_m is the name of the m-th linguistic variable that represents the m-th attribute of a desired situation; L is the limit of elements in U; A_m is a particular linguistic value of X_m belonging to *T("Aspiration")* and represents the aspiration level assigned to X_m; and $A_m(u_i)$ is the participation degree of $u_i \in U$ in the fuzzy set that defines $A_m \in F(U)$.

Definition 2. A situation is denominated fuzzy if its concept is a fuzzy set described in terms of fuzzy goals Gm and the degrees of participation μm (m = 1, ..., M), subjectively indicating how much these goals are important in a fuzzy desired situation DS,

$$DS = \sum_{m=1}^{M} \mu_m/G_m \tag{2}$$

Definition 3. A requirement Rer is denominated fuzzy if its concept is a fuzzy set described in terms of pairs (Xm, Rmr) and degrees of participation μm (m = 1, ..., M),

$$Re_r = \sum_{m=1}^{M} \mu_m / (X_m , R_{mr}) \tag{3}$$

where X_m is the name of the m-th linguistic variable employed for the representation of the m-th attribute in a desired fuzzy situation; and $R_{mr} \in F(U)$ are particular linguistic values of X_m belonging to *T("Aspiration")* and represents the achieved level assigned to the attribute X_m due the implementation of the requirement r.

2.2 Evaluation Function

The evaluation function for fuzzy requirements considers similarity measurements between the fuzzy sets that express the achieved and the aspired levels in each one of the attributes, and their respective values of importance within the context of the fuzzy requirements and fuzzy desired situations [5]:

$$f_{eval(Re_r,DS)} = \sum_{m=1}^{M} \mu_m \alpha(R_{mr}, A_m) \Big/ \sum_{m=1}^{M} \mu_m \tag{4}$$

Where α is a similarity measurement between fuzzy sets and assumes, in this article, the form:

$$\alpha(R_{mr}, A_m) = 1 - \left(\sum_{i=1}^{L} |R_{mr}(u_i) - A_m u_i| \,/ L^{1/2} \right) \tag{5}$$

where $u_i \in U$ and L is the limit of elements in U.

The second term of the difference in (5) is the Euclidean distance between fuzzy sets [6]. It is worth noting that: α: $F(U)xF(U) \rightarrow [0, 1]$. Therefore, as the similarity values between the levels in Re_r and DS increase, *f_eval* increases. In this case, for each m = 1, ..., M, if $R_{mr} = A_m$ then *f_eval* is 1 maximum and equal to 1. As the similarity values decrease, *f_eval* decreases, reaching a minimum equal to 0. These properties allow the stakeholder to obtain measurements as promising as the fuzzy requirements are in the design of a satisfactory prioritization.

3 Evaluation

This section presents some tests performed with the prioritization mechanism, programmed from the formal framework proposed in the last section. It was divided into two subsections. Section 3.1 presents information on the evaluation instance. Section 3.2 presents a specific prioritization problem, the solution produced by the proposed prioritization mechanism, and a brief analysis of these initial results.

3.1 Evaluation Instance

The evaluation instance used for testing the framework for requirements prioritization in a fuzzy linguistic approach is composed of seven goals and nine requirements.

These goals are frequently used in [7] to help stakeholders to reflect the dimensions of the success of a software development project. The objective is to verify the capability of the proposed framework over the prioritization task and its level of responsiveness in requirements evaluation changes.

Table 1 describes some aspired levels and their representation in terms of fuzzy sets. Table 2, according to Definition 1, describes the scenario with seven attributes (X_m) that define seven fuzzy software goals (G_m). According to Definition 2, it presents a description of the fuzzy aspired level and the importance degree (μ_m) of the goals that define the fuzzy desired situation (*DS*). According to Definition 3, it also presents the achieved fuzzy levels (R_{mr}) of the fuzzy requirements (Re_{mr}) in the attributes that define the desired situation. Fuzzy aspired levels in the seven fuzzy software goals that define the desired situation were represented by [m, h, l, h, l, h, m].

Consider, as an example, the development of an ATM system. The attribute X_1 may represent "Deliver all high-priority functionalities in the first release" and has an aspired level medium (m) in the software goal G_1, that defines the fuzzy desired situation. The requirements Re_4 and Re_7 are, for example, “Withdrawal Transaction" and "Show Welcome Message" respectively. In this example, the first transaction contributes in high degree (h) to the level of attribute X_1, while the second influences at low level (l) to X_1, as can be seen in table 2.

Table 1. Description of each priority in linguistic terms and their representation in terms of fuzzy sets

Linguistic Term	Fuzzy Set Representation
low (l)	[1.0, 1.0, 0.9, 0.7, 0.5, 0.2, 0.0, 0.0, 0.0, 0.0, 0.0]
medium (m)	[0.0, 0.0, 0.0, 0.8, 0.9, 1.0, 0.7, 0.0, 0.0, 0.0, 0.0]
high (h)	[0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.3, 0.5, 1.0, 1.0, 1.0]

Table 2. Description of each fuzzy requirement, contribution level to achievement of goals and desired state of each goal

Attributes (X_m)	X_1	X_2	X_3	X_4	X_5	X_6	X_7
Importance (μ_m)	0.6	1.0	0.4	0.2	0.4	0.8	0.6
Desired Situation (*DS*)	m	h	l	h	l	h	m
Re_1	m	h	l	h	l	h	m
Re_2	h	m	h	m	h	l	l
Re_3	h	h	m	h	l	m	h
Re_4	h	l	m	h	l	l	h
Re_5	m	l	l	m	h	h	m
Re_6	h	l	m	h	l	m	h
Re_7	l	m	m	h	l	h	h
Re_8	m	m	m	h	l	h	h
Re_9	h	m	m	h	l	h	h

3.2 Prioritization Results

Table 3 describes the results of the execution of three tests. At each column, there is a requirement description and a real number representing the level of similarity of that requirement to goals. For each test, one variable was changed to alter the generated prioritized list obtained with the application of the evaluation function in Expressions (4) and (5). Test 1 was the control test where requirement Re_1 was left purposely equal to the desired state. In Test 2, the desired fuzzy situation *DS* was changed to [m, **l**, l, h, l, h, m], where just the aspired level in X_2 was changed from high to low. In Test 3 the importance of G_4 was changed from 0.2 to 0.8. In the fourth test the values of representation of linguistic variables "low", "medium" and "high" were all changed to 0.1.

Table 3. Prioritized lists generated form each test. First value is the requirement number and second is the level of importance to goals

Test 1	Test 2	Test 3	Test 4
Re_1,1.00	Re_5,0.88	Re_1,1.00	Re_1,1.00
Re_5,0.68	Re_1,0.80	Re_8,0.69	Re_2,1.00
Re_8,0.64	Re_8,0.67	Re_5,0.63	Re_3,1.00
Re_3,0.57	Re_7,0.58	Re_3,0.62	Re_4,1.00
Re_7,0.55	Re_6,0.57	Re_7,0.61	Re_5,1.00
Re_9,0.53	Re_9,0.56	Re_9,0.59	Re_6,1.00
Re_6,0.37	Re_4,0.56	Re_6,0.45	Re_7,1.00
Re_4,0.36	Re_3,0.37	Re_4,0.44	Re_8,1.00
Re_2,0.26	Re_2,0.29	Re_2,0.26	Re_9,1.00

As expected, in Test 1 Re_1 achieved 100% of similarity with goals since it has exactly the same definition of the desired fuzzy situation [m, h, l, h, l, h, m], this is also seen in Test 3. There was a reordering in Tests 2 an 3 influenced by the changes in the aspiration and importance levels. For Test 2, for example, there is no requirement whit 100% of similarity, since all of them are different from the desired situation. For Test 3, as expected, Re_1 was still at the top of the list, and the reduction on importance of G_4 motived the new requirements' order. For Test 4, we find that by using the same value to represent the linguistic variables, there is no improvement proved unexpectedly strong, given that all requirements are evaluated the same way.

4 Conclusion and Future Works

Requirements prioritization is a hard task to be performed. Previous works tackled the problem without bearing in mind the uncertainty present in a software development process. This paper proposed a formal framework guided by fuzzy goals to be applied to solve the requirements prioritization problem.

Besides presenting the formal framework, a sample application to evaluate the effectiveness of the proposed approach was described. The results demonstrated the ability of the approach in relation to the flexibility that may occurs in the task. For the tests, the variation of a configuration leads to a new solution by the proposed framework.

Future studies include interdependency between goals, also included the prioritization taking into account the evaluation of the stakeholders involved and changing the value of the contribution of goals for the use of fuzzy terms instead of real numbers, and application of the framework to a real world project.

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