Quantitative Reasoning of Goal Satisfaction in the *i** framework

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***Abstract*—In requirement analysis, goal models play an important role in assessing alternative design options of a software system. Many qualitative and quantitative goal reasoning approaches have been proposed for goal models such as Knowledge Acquisition in Automated Space (KAOS), Non-Functional Requirements (NFR), and Goal Oriented Requirement Language (GRL). However, for *i** goal model only qualitative reasoning has been proposed in Requirement Engineering literature. The aim of this paper is to present a quantitative goal reasoning for *i** goal model. The proposed approach was validated with case studies from existing literature and offers a guide in the decision process. To support the validation a simulation was developed in Visual C++.**

Keywords- Requirements engineering, i* goal model, quantitative analysis, fuzzy numbers

I. Introduction

In the early stages of Requirement Engineering (RE), goal models are considered a convenient way for modeling and reasoning about alternative design solutions of any software system [1-4]. These models through refinement hierarchy denote the alternative ways of achieving the stakeholder's goals. These different alternative designs have disparate impact on the system goals and different degrees of goal satisfaction. Alternative design solutions are assessed based on some evaluation criteria to choose the best among them. Many qualitative and quantitative reasoning approaches have been proposed in RE literature to support the goal analysis [4-7].

Qualitative reasoning is of limited use of reaching conclusions as the labels become ambiguous in the propagation algorithm. Also, it provides only a quick approach for coarse evaluation in the early stages of the RE process. Quantitative reasoning leads to limited conclusions due to the lack of accuracy and measurability of goal formulations. It is also crucial to assign definite numbers to stakeholder's requirements as requirement elicitation may involve distinct stakeholders having different preferences for the same requirements. The rationale behind it is that distinct stakeholders have different levels of knowledge, training and skills [8]. Moreover in reality, linguistic terms such as low cost, high profit are generally used by the stakeholders to communicate their requirement preferences. The linguistic representation of stakeholder's requirement preferences can be more easily expressed in Fuzzy Logic [9].

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The *i** frameworks are useful in qualitatively representing and analysing how stakeholders goals influence each other [7]. However, the existing RE literature seems to be lacking for some method of quantitative support for goal analysis. The objective of this paper is to present a fuzzy based quantitative analysis for evaluating different design alternatives and to identify the best one among them.

The remainder of the paper is structured as follows: Section 2 proposes the fuzzy based quantitative analysis for *i** goal models; Section 3 presents simulation and validation of our work; Section 4 discusses related works; Section 5 concludes the paper.

II. The Quantitative Fuzzy Based Reasoning of Goals

The proposed approach involves the selection of an option based on the impact of the alternative options on soft goals. The results are examined from the point of view of each actor. The goal impacts represented by make, help, hurt, and break are represented by triangular fuzzy numbers. These impacts along with the soft goal preferences are propagated to the high level soft goals in the goal model to find the level of satisfaction. The option that gives the highest level of satisfaction is selected. For understandability, the Youth Counselling case study as shown in Figure 1 has been used throughout the following section to describe the proposed approach. Due to space restrictions readers are directed to Yu [7, 10] for details on Youth Counselling case study and *i** goal models and Gani [11] for details on fuzzy numbers.

i) **Identify the correlation between goals and soft goals in terms of fuzzy weights:** The correlation between alternative options and leaf soft goals are assigned fuzzy weights and our representation is shown in TABLE 1. This contribution is referred to as $\bar{C}_{A*L,}$ where A is the alternative option and L is the leaf soft goal. It shows the extent to which an alternative option satisfies a leaf soft goal.

***Youth Counselling**:* For the actor *Kids and Youth*, correlation weights between the alternative option *Use Text Messaging* and the leaf soft goals *Comfortableness with service, Anonymity[service]* and *Immediacy[service]* are assigned (0.48, 0.64, 0.80), (0.48, 0.64, 0.8), and (0,0.16, 0.32) respectively (TABLE 2). The correlation links between the other option *Use Cyber Cafe/Portal/Chat Room* and the leaf

TABLE 1. FUZZY VALUES FOR GOAL AND LEAF SOFT GOAL CORRELATION

Name	Fuzzy contribution
Make	(0.64, 0.80, 1)
Help	(0.48, 0.64, 0.80)
Some+	(0.32, 0.48, 0.64)
Some-	(0.16, 0.32, 0.48)
Hurt	(0, 0.16, 0.32)
Break	(0, 0, 0.16)

soft goals are assigned weights (0.48, 0.64, 0.80), (0, 0.16, 0.32) and (0.64, 0.80, 1).

ii) **Assign weights to the leaf soft goals:** The leaf soft goals are assigned weights in percentage from 0 to 100 based on their relative importance. The weight is referred to as ω_L.

***Youth Counselling**:* The leaf soft goals (LSG) *Comfortableness with service*, *Anonymity (service)* and *Immediacy (service)* of the actor *Kids and Youth* are assigned weights based on their relative importance as 50%, 30%, and 70% respectively (TABLE 2).

iii) **Calculation of the leaf soft goal score:** For each alternative, the leaf soft goals are associated with a score showing its satisfaction level. The leaf soft goal score is represented by $\bar{S}_{L(A)}$ and is computed by the equation 1 below:

$$\bar{S}_{L(A)} = \bar{C}_{A*L} * \omega_L \qquad (1)$$

***Youth Counselling**:* For the actor *Kids and Youth*, the score for the leaf soft goal *Comfortableness with service* for *Text Messaging* is calculated as below

$\bar{S}_{Comfortablenesswithservice(Text\ Messaging)}$

$= (0.48, 0.64, 0.80) *0.5= (0.24, 0.32, 0.4)$

$\bar{S}_{Comfortablenesswithservice(CyberCafe/Portal/Chat\ Room)}$

$= (0.48, 0.64, 0.80)*0.5 = (0.24, 0.32, 0.4)$

TABLE 2 shows the scores of other leaf soft goals.

iv) **Propagation of leaf soft goal scores to find the scores of soft goal:** Once leaf soft goal scores are calculated for each alternative, the scores are propagated backwards to find the scores of the high level soft goals. Soft goals are recipients of multiple contribution links, which can be considered as children of each soft goal. The score is calculated in two steps. In first step, the score of its children are multiplied with their respective impact links. In second step, the combined effects of all the children are taken by using the fuzzy maximum operation. The soft goal score is referred to as $\bar{S}_{SG(A)}$ and is obtained by equation 2 :

$$\bar{S}_{SG(A)} = \Lambda_{i=1}^{n}\{\bar{C}_{SCi} * \bar{S}_{LCi|SCi}\} \qquad (2)$$

Where $\wedge$ represents fuzzy maximum operation**,** $\bar{C}_{SCi}$ is the correlation link between a soft goal and its i^{th} child, $\bar{S}_{LCi|SCi}$ is the score of its i^{th} child and '*n*' is the number of its children.

***Youth Counselling**:* For the actor *Kids and Youth*, the score of soft goal *GetEffectiveHelp* for the alternative option *UseTextMessaging* is

$\bar{S}_{GetEffectiveHelp(TextMessaging)}$ = **MAX {MAX** {(0.24, 0.32, 0.4)*(0.64, 0.80, 1), (0.144, 0.192, 0.24)* (0.64, 0.80, 1)}, (0, 0.112, 0.224)* (0.64, 0.80, 1)}

$\bar{S}_{GetEffectiveHelp\ (TextMessaging)} = (0.154, 0.256, 0.4)$

v) **Selection of an alternative with the highest score:** The scores are propagated backwards until we reach the soft goals that are top in the hierarchy. These soft goals are called top soft goals. These scores are compared to determine the best alternative implementation design option and there by assist the analyst in decision making. This is done from each actor point of view. To obtain quantifiable result, the scores are defuzzified by applying α-cut operation and using an optimal index λ. The λ indicates the degree of confidence and it can take values λ=0 for pessimistic index, λ=0.5 for moderate index and λ=1 for optimistic index.

***Youth Counselling**:* From TABLE 3 we can see that, for all actors the alternative option *UseCyberCafe/Portal/ChatRoom* has the highest score when compared to alternative option *UseTextMessaging.* The option U*seCyberCafe/Portal/Chat Room* provides the best satisfaction level and hence is selected for all the actors.

In case of scenario where all the actors have same type of alternatives and if the proposed approach gives different alternatives selected for each actor, then the composite score for each alternative is calculated. It is calculated by the summation of all top soft goals scores for each alternative. It is referred to as $\bar{S}_{AO}$ and is given by equation 3 below:

$$\bar{S}_{AO} = \sum_{i=1}^{n} \bar{S}_{SGi} \qquad (3)$$

where $\bar{S}_{SGi}$ is the i^{th} top soft goal score and '*n*' is the number of top soft goals. The sum is normalised if it is falls beyond the membership functions defined for goal contributions. The normalised value is defuzzified and the one with the highest is selected.

III. Simulation and Evaluation

Validation of quantitative models is a concern as they play vital role in critical decision making. The proposed framework was evaluated based on its ability to assist analyst in decision making. To facilitate this, a simulation was developed in Visual C++ and was tested with test cases taken from Meeting Scheduler System and Youth Counselling System (YCS) from existing literature [2, 7]. The proposed approach was found to be effective in deciding the alternative design options. Furthermore, it avoids ambiguity (when one or more goals lead to same label) that arise in the *i** qualitative approach. Algorithm 1 outlines the steps in alternative option selection. The soft goal score distribution graph for YCS is provided in Figure 2.

There are many qualitative [4, 5, 7] and quantitative approaches [6, 13] for goal analysis in the existing literature. In our approach, we use fuzzy numbers for alternative selection and goal estimations. By using fuzzy numbers, our approach can handle imprecise and vague requirements of stakeholders like high quality, low cost, good performance. On comparing with qualitative approach, our approach also avoids the requirements conflicts in decision making that arise in qualitative analysis. In quantitative analysis the alternative options are selected based on its impact to the leaf soft goals. It does not take into account its impact on other soft goals in goal graph. Our approach selects the alternative option based on the impact of the alternatives on soft goals by propagating the scores of the leaf soft goals to the top soft goals. Hence we can say that the alternative that is selected will have better satisfaction of the top soft goals.

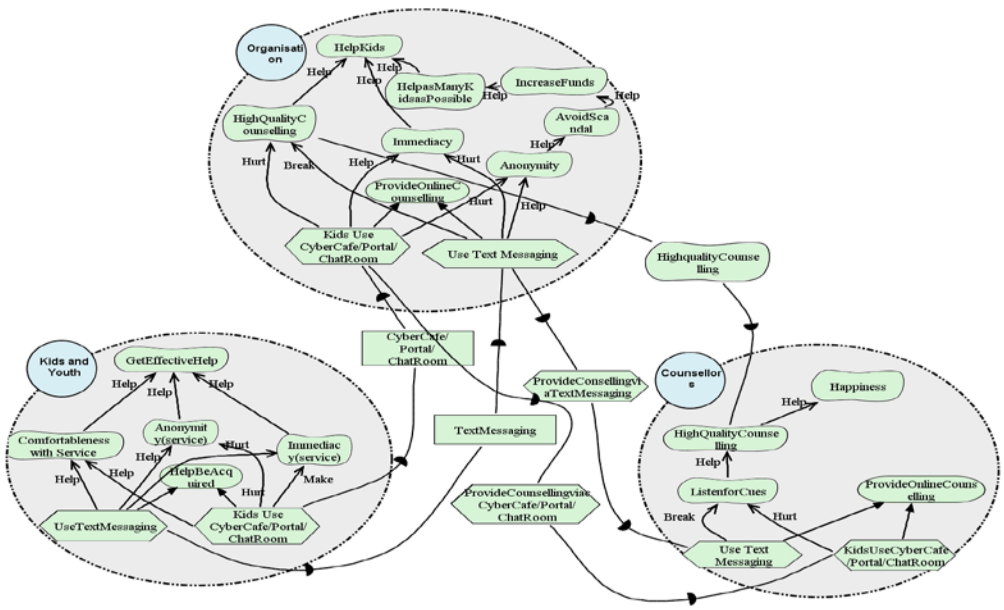

Figure 1. An SR Model: Youth Counselling Example (adapted from [7]).

TABLE 2. LEAF SOFT GOAL SCORES FOR ALL THREE ACTORS

LSG	Weight	Impact		Score	
		Use Text Messaging	***Use CyberCafe/Portal/ ChatRoom***	***Use Text Messaging***	***Use CyberCafe/Portal/ ChatRoom***
Comfortableness	0.5	(0.48,0.64,0.8)	(0.48,0.64,0.8)	(0.24, 0.32, 0.4)	(0.24, 0.32, 0.4)
Anonymity	0.3	(0.48,0.64,0.8)	(0,0.16,0.32)	(0.144, 0.192, 0.24)	(0, 0.048, 0.096)
Immediacy	0.7	(0,0.16,0.32)	(0.64 ,0.80,1)	(0, 0.112, 0.224)	(0.448, 0.56, 0.7)
ListenforCues	0.3	(0,0,0.16)	(0,0.16,0.32)	(0, 0, 0.048)	(0, 0.048, 0.096)
HighQualityCounselling	0.5	(0,0,0.16)	(0,0.16,0.32)	(0, 0, 0.08)	(0, 0.08, 0.16)
Immediacy	0.7	(0,0.16,0.32)	(0.48,0.64,0.8)	(0, 0.112, 0.224)	(0.336, 0.448, 0.56)
Anonymity	0.3	(0.48,0.64,0.8)	(0,0.16,0.32)	(0.144, 0.192, 0.24)	(0, 0.048, 0.096)

TABLE 3. TOP SOFTGOAL SCORES (*INDICATES GOAL SELECTION)

Actor	Top Soft Goals	Alternative option Score		Defuzzified scores	
		Use Text Messaging Text	***Use CyberCafe/Portal/Chat Room***	***Use Text Messaging Text***	***Use CyberCafe/Portal/ ChatRoom***
Kids and Youth	Get Effective Help	(0.154, 0.256, 0.4)	(0.287, 0.448, 0.7)*	0.53(53%)	0.94(94%)
Counsellors	Happiness	(0, 0, 0.03)	(0, 0.02, 0.064)*	0.0075(0%)	0.02(2%)
Organization	Help Kids	(0.004, 0.072, 0.18)	(0.16, 0.29, 0.45)*	0.05(5%)	0.15(15%)

IV. RELATED WORK

Lamsweerde [4] proposed a lightweight quantitative alternative evaluation system for KAOS framework. The proposal uses variables like gauge variable, ideal target value, maximum acceptable value associated with each soft goal. The values of these variables are obtained from the specification of the system. Lamsweerde et al. [12] proposed more accurate, but heavy weight approach based on probability's interpretation of numbers. Bayesian Networks concepts are used for making predictions about soft goals. This approach becomes difficult to use in case of a complex system.

Affleck et al. [13, 14] proposed a process-orientated, lightweight, quantitative extension to the NFR Framework. The objective of their proposal is to apply a quantitative approach for the decision process and impact of the decision over the system. Liaskos et al. [15] employed the Analytic Hierarchy

Algorithm 1: Goal/task Elicitation (Alternative Selection) and to find the satisfaction levels of intentional elements and actor

for each graph in the collection **do**
  Assign weights to each Leaf Soft Goal (LSG)
  for each task/goal associated in the graph do
    Find task/goal impact associated with each Soft Goal (SG)
    Calculate the LSG score
    for each SG in the graph **do**
      Calculate the SG score
    end for
  end for
  Defuzzify the top soft goal score
  Select the task/goal with the highest score
end for
case 1: the tasks/goals are same for each input graph
  if the task selected from each graph is different then
    For each task in the input graph
      Add the top soft goal scores of each graph
      Normalize the added score
    Defuzzify and select the highest one
  else
    Compare the alternative scores to select the highest
  end if
case 2: the tasks/goals are different for each actor in input graph
  Display the task/goal selected for each graph

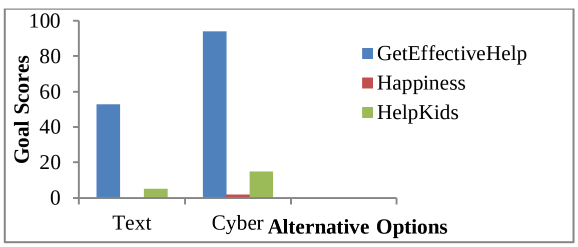

Figure 2. Soft Goals Score distributions

Process (AHP), a mathematical decision making method for goal elicitation in the semi-formal goal models. This suit for goal models that can be viewed as individual AHP problems based on eliciting contribution levels.

Horkoff and Yu [7] have proposed an interesting approach that evaluates goal achievement in enterprise models. However, the main issue with their approach is ambiguity of decision-making process when one or more goal receives the same labels. Furthermore, it requires frequent customer intervention.

Sidiq and Jain [16] proposed a fuzzy based AHP for requirements prioritization. The AHP pairwise comparison are used for assigning weights to goals/soft goals and finds the prioritized list of requirements using binary sort tree method. A. Teka et al. [17] applied fuzzy based reasoning to compare NFR and TROPOS to analyse the impact of goals and requirements changes in goal models. This approach suffers from specifying goal satisfaction levels in terms of concrete numbers.

V. CONCLUSION

This paper proposed a quantitative approach for analysing goals in *i** framework. Compared with the qualitative analysis of *i** framework, our approach strengthens the decision process by avoiding ambiguities and making decisions when the requirements are fuzzy. The proposed approach was validated by applying it to test cases such as Youth Counselling, Meeting Scheduler. In addition, a simulation was developed in Visual C++ to support the evaluation. As a future work, the approach will be extended by including inter-actor dependencies. Furthermore, we plan to apply goal optimisation to *i** goal models.

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