Quantitative Non Functional Requirements evaluation using softgoal weight

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Abstract

The goal oriented requirements analysis approaches have been introduced to compare non-functional requirements (NFR), such as safety and security. Several approaches to manage goal attributes have also been proposed to evaluate NFR goals quantitatively. In this paper, the quantitative weighted softgoal is proposed based on the Softgoal Interdependency Graphs (SIG) that helps engineers evaluate non-functional requirements. The evaluation results of the weighted SIG applications are shown to develop non-functional requirements and choose alternative design decisions. Additionally, the industrial case study of the weighted softgoal is shown to select the appropriate architecture decision in an automotive software development domain.

Keywords: Non-Functional Requirements, NFR framework, Softgoal Interdependency Graphs, softgoal weight, Attributed Goal Graph

1 Introduction

There are three types of the goal decomposition tree application in the software engineering research. The Softgoal Interdependency Graph (SIG) is used to represent non-functional requirements refinement structure [3]. Fault Tree Analysis (FTA) [11] uses the fault tree that decompose the root fault into subsequent causes in the form of tree structure. The Goal Structuring Notation (GSN) [7, 8] is used to explain the system assurance propositions by decomposing the top goal into sub goals that are supported by evidences. Although these methods used qualitative goals, quantitative goals are not considered. For example, SIG are used to define qualities and validate that system architectures achieve the quality requirements. NFR framework is traditionally focusing on qualitative evaluation of softgoals, and different kinds of softgoals are evaluated separately. As NFR framework cannot evaluate security and safety softgoals in the integrated way, it is difficult to resolve the conflicts between safety and security softgoals explicitly. This paper discusses the effectiveness of a softgoal weight extension based on SIG diagrams of the NFR framework. The weight values are assigned to softgoal decompositions and contributions link as well as achievement of softgoals. The new main top goal is also added to resolve conflicts among different softgoals that are decomposed from the main top softgoal. The weights assigned to each link define clearly priority between decomposed softgoals. The rest of the paper is constructed as follows.

Section 2 describes the related work of quantitative attributed goal analysis approaches based on softgoals. Section 3 formalizes an approach to introduce quantitative weights to SIG diagrams. Section 4 describes an industrial case study of the proposed approach for evaluating alternative platform architectures based on the weight of softgoals. In section 5, we discuss the effectiveness and limitations of the proposed approach. Section 6 concludes the paper and shows future work.

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2 Related work

There are several quantitative attribute extensions on the goal oriented requirements analysis methods. Table 1 summarizes the quantitative attribute based goal oriented approaches. The table compares attribute based goal oriented approaches by the goal graphs, attributes, purposes, and methods.

Table 1: Attribute based Goal Oriented Approaches

Approach	Goal graph	Attribute	Purpose	Method
QA-NFR	NFR SIG	satisfice, contribution, criticality metric	Architecture evaluation	satisfice propagation
SGW	NFR SIG	Decomposition, contribution, achievement weight	Architecture evaluation, conflict resolution	Weight propagation, Tabular calculation
AGORA	Goal graph	Preference, contribution	Conflict recognition	attribute expressions for calculating the values
FBCM	Goal tree	Correlation coefficient KPI	Goal dependency management	statistical analysis of correlation coefficient for KPI values
IGEPM	Goal tree	Contribution, validation, achievement KPI	Dynamic goal graph improvement for business change	Goal selection based on KPI based business attributes
GQM	GQM tree	KPI	Quantitative goal satisfaction condition	Metric based Question evaluation

QA-NFR (Quantitative Assessment using NFR approach) [14] and SGW (Soft goal using weight) [15] based on the NFR SIG (Soft goal Interdependency Graph) to evaluate softgoals quantitatively. QA-NFR is used to evaluate architecture by defining levels of safety and security requirements. The SIG (Softgoal Interdependency Graph) is applied to define security and safety softgoals. The soft goals are non-functional requirements softgoals, operationalization softgoals, and claim softgoals. The required quality properties of target systems are clarified by non-functional requirements softgoals. Softgoals are, then, decomposed into sub softgoals to develop SIG. The operationalization softgoals are assigned to the bottom levels of softgoals to provide the target system functions.

In SIG the design decisions for the target system are represented by operationalization softgoals. The operationalization softgoals are validated for satisfying parent soft goals.

For analysing functional requirements, alternative requirements are selected to satisfy non-functional softgoals. If the conflict between non-functional softgoals is occurred, the conflict should be resolved by using the criteria whether non-functional requirements are satisfied.

QA-NFR was proposed by Subramanian et.al to analyse safety and security property of the software architecture quantitatively [14]. Safety and security properties are represented by non-functional softgoals. The satisfice, contribution, and criticality metric are defined on the SIG to propagate attributes from the operationalization softgoals that are allocated on the bottom level of the SIG. The satisfice metric represents the achievement level of the softgoals. The contribution metric is used to represent the contribution value of the child softgoal to the parent softgoal. The criticality metric is used to define the criticality of the softgoals. The propagation rules are used to calculate the level of safety and security of the target architecture.

As QA-NFR approach did not consider quantitative relationship between child softgoals for the softgoal decomposition, Yamamoto [15] proposed the SGW (Softgoal Weight) approach. The decomposition attribute defines the priority among sub softgoals. This approach can be used to balance among reciprocal softgoals such as safety and security. Although SGW shows a simple tabular form to calculate the weight propagation, the tabular calculation method was not clearly defined.

AGORA (Attributed Goal-Oriented Requirements Analysis) defines preference and contribution attribute for goals to recognize requirements conflicts among stakeholders [6]. The attribute expressions are provided for calculating the values. Although the contribution attribute is similar to the above NFR based approaches, AGORA did not consider to evaluate software architectures.

FBCM (Fact Based Collaboration Modelling) approach [9] was proposed to revise the target goal tree by statistically analyzing the correlation coefficient among goals based on KPI values. FBCM can provide the statistic evidences for the goal decompositions.

IGEPM (Incremental Goal Evolution Process Methodology) was proposed to continuously improve goal graphs based on the business environment changes[12]. IGEPM collects KPI values observed from the real activities of business processes. Attributes of IGEPM are defined as follows:

Cnt (y, x) is the contribution value of the sub goal y to the parent goal x.

Vld (x) is the means of the least contribution value for the path x from the root goal.

Acv (x, c) is 1 if the KPI value c of the goal x is achieved, otherwise 0.

IGEPM provides means to select appropriate task goals based on the quantitative business performance.

GQM is the method to identify metric for evaluating the achievement of goals [2]. GQM consists of Goals, Questions, and Metric. GQM did not concern about softgoals decomposition. Therefore, the dependency attribute among goals was not treated in GQM.

In case of FTA and GSN, the attributes of goals are not explicitly defined, although goals are considered to be hold. The truth value can be assigned to goals of FTA and GSN. For GSN, the top goal approval is supported by the valid sub goals and the confident evidences. The probability can be assigned the level of approval for the goals of FTA and GSN.

OCTAVE and ATAM are proposed to evaluate the quality of architecture. OCTAVE (The operationally critical threat, asset, and vulnerability evaluation) provides the check list to evaluate vulnerability [13]. OCTAVE did not concern about the conflict resolution between safety and security requirements.

ATAM (Architecture Trade off Analysis Method) [10] provides a scenario based method to describe critical factors that significantly impact on architectures by using utility trees. Although ATAM provides the quality trade off analysis method to analyze safety and security requirements, attributes are not treated in the utility trees.

3 Softgoal weight

3.1 Basic concept

The concept of softgoal weight is formally defined as follows. The SIG G is defined as $< g_0$, S, O, D, P_w, C_w, $A_w >$. S is a set of softgoals of G. The root goal g_0 is a special element of S. O is a set of operationalization softgoals. D defines dependency relationship between elements of S and O.

P_w defines priority weight for the decompositions of softgoals. If a softgoal decomposed into sub softgoals, then the decomposition weight label $P_w =< W_1,..,W_k >$ is appended to the parent softgoal name. Where k is the number of sub softgoals, and W_i are defined to satisfy $\sum_{i=1,\,k} W_i = 1$.

C_w defines the contribution weight between the parent and child softgoals. There are positive and negative contributions in SIGs. The weights of positive and negative contributions are +N and -N, respectively. N is either 1 or 2. 1 and 2 also mean weak and strong contribution, respectively. The positive and negative contributions can be represented by styles of relation lines. The solid and dotted lines show positive and negative contributions, respectively.

A_w defines achievement weights of softgoals. The achievement weight of the operationalization softgoals is given initially. The achievement weight of upper levels of softgoals $A_w(g)$ are calculated by the achievement weight of operationalization softgoals as follows.

$A_w(g) = \sum_{h\ in\ Child(g)} P_w(h) * C_w(h) * A_w(h)$

, where Child(g) represents the set of sub softgoals of g.

3.2 Example

To explain the proposed approach, the SIG to compare ID media solutions is shown in Fig.1. RFID (Radio Frequency Identification) and Bar code are represented as the bottom operationalization softgoals in the SIG. The top NFR softgoal is decomposed into information flexibility, input operability, and cost softgoals. The information flexibility softgoal is decomposed into diversity, capacity, ID reusability, and modifiability softgoals. The input operability softgoal is decomposed into simultaneous reading, readability, and pollution tolerance softgoals.

The total impact value of the quality requirements for the RFID is calculated as follows.

(1/6+1/3+1/3+1/6)/4 + (1/3+1/3+1/3)/2 + (-1)/4 = 1/4 + (1)/2 - 1/4 = 1/2

The total impact value of the main non-functional requirements for the bar code is calculated as follows.

(-1/6-1/3-1/3-1/6)/4 + (-1/3-1/3-1/3)/2 + (1)/4 = -1/4 + (-1)/2 + 1/4 = -1/2

The result shows that the RFID is better than the bar code for the ID Media requirements.

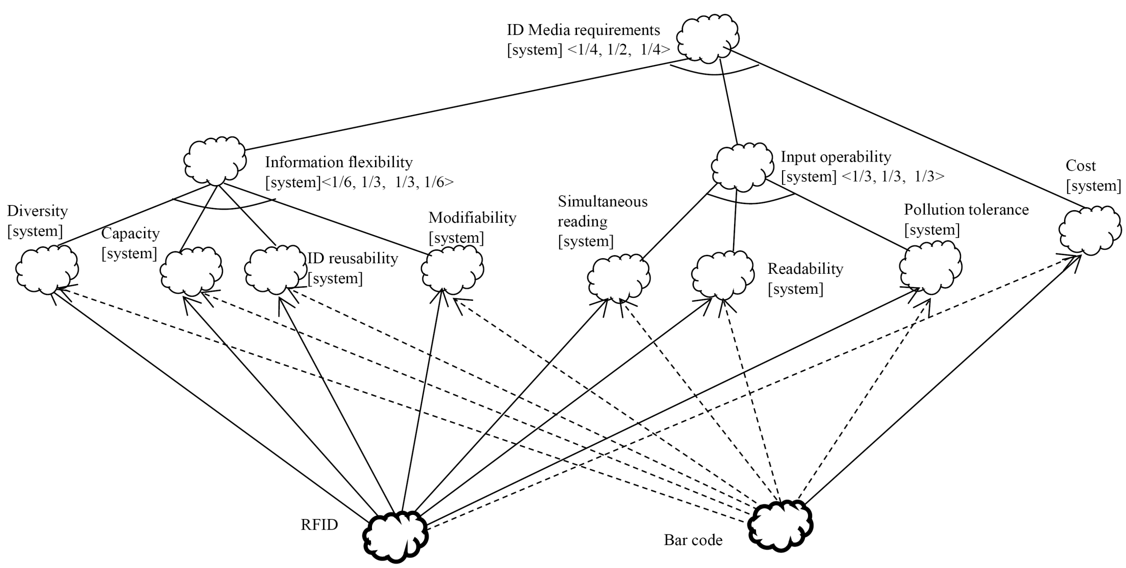

Figure 1: Evaluating the impact of solution alternatives on the ID media requirements

It is worth to remark that the contribution weight is not assigned to the bottom level non-functional requirement softgoals in Fig.1. Because the RFID and the bar code softgoals are different alternative operationalization softgoals, the bottom level non-functional requirements softgoals have no weight value list.

3.3 Tabular calculation of the achievement weight

The impact evaluation can also be calculated by a tabular form. The position of the goal g in the table is represented as $(x_g,\ y_g)$, where x and y are the positions of row and column of the table, correspondingly. Let B(g, i) be the number of the corresponding bottom goals of the i-th sub goal of g. Let the position of the i-th sub goal of g be $(x_{(g,i)},\ y_{(g,i)})$. The positions $x_{(g,i)},\ y_{(g,i)}$ can be calculated as the following equations.

$x_{(g,\,i)} = 1 + (x_g - 1) + \sum_{k=1,\,i-1} B(g,k) * 2$

$y_{(g,\,i)} = y_g + 2$

The first row describes the heading label. The achievement weight for the goal g is represented in the position $(x_g + 1, y_g)$. The priority weight of g is shown in the column $y_g + 1$. The achievement weight for the operationalization softgoals are defined in the last column of the table. For example, let the depth of the SIG be N, the last column of the table for the SIG is 2N+1. The achievement weight Wa(g) for the NFR softgoal g is calculated by the following equation.

$Wa(g) = V(x_g + 1, y_g) = \sum_{k=1,\,i} V(x_{(g,k)} + 1, y_g + 2) * V(x_{(g,k)}, y_g + 1)$

Where V(x, y) is the value for the corresponding table element (x, y). $V(x_{(g,k)} + 1, y_g + 2)$ means the achievement weight for the k-th sub softgoal of g. $V(x_{(g,k)}, y_g + 1)$ means the priority weight for the k-th decomposition of g.

Table 2 shows the tabular evaluation of the RFID solution for the SIG diagram in Fig.1. On the top left first column corresponds to the main softgoal. The value in the next row of the same top left column is the total evaluation value for the selected alternative solution. The second column shows the decomposition priority weight of the top goal. The 6-th column values of the RFID shows the contribution values for NFR softgoals.

Table 2: Tabular evaluation of RFID solution

SIG decomposition structure					RFID
ID Media requirements 0.50000	1/4	Information flexibility 1	1/6	Diversity 1	1
			1/3	Capacity 1	1
			1/3	ID reusability 1	1
			1/6	Modifiability 1	1
	1/2	Input operability 1	1/3	Simultaneous reading 1	1
			1/3	Readability 1	1
			1/3	Polution tolerance 1	1
	1/4	Cost -1			-1

4 ECU architecture solution evaluation example

The AUTOSAR (Automotive Open System Architecture) [1] aims to standardize the System Architecture of ECU (Electronic Control Units). AUTOAR has the standardized specifications of AUTOSAR platform. The two alternatives for developing automotive applications are Full AUTOSAR and Full Own system architectures shown in Fig.2. Software engineers can purchase the commercial software compliant with AUTOSAR specifications from the other company. The own platform is not compliant with AUTOSAR. The legacy ECU software is used in the own platform. The functionality of AUTOSAR platform includes those of the own platform.

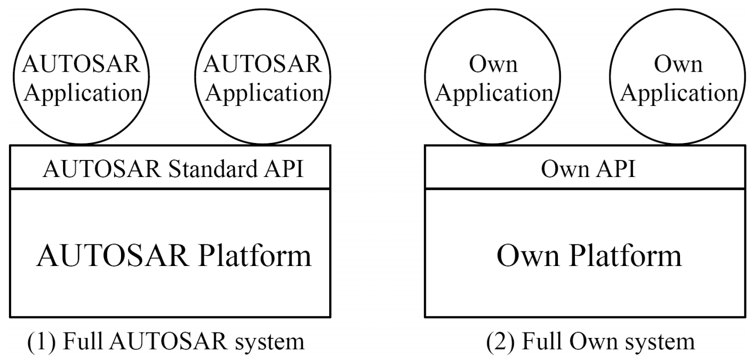

Figure 2: Solution alternatives for new software architecture

The application example of the weighted SIG in automotive software development is shown below. Software engineers always need to choose the better software architecture to be compatible for various requirements. However, it is difficult to choose it, if they did not have a method to choose the optimal alternative based on the quantified evidence. Fig.3 shows the comparison of alternative software architectures for the new ECU software based on legacy ECU software. The top NFR softgoal is decomposed into performance, reusability, cost, and modifiability softgoals. The new ECU software architecture needs to be compatible for requirements from various clients, and to provide the environment to focus on the application layer's development. Therefore, reusability and modifiability are important in evaluating impact of solution alternatives. In accordance with the above-mentioned, the coefficient vector of the NFR softgoal is $< 1/6,\ 1/3,\ 1/6,\ 1/3 >$. The total impact value of the main non-functional requirements for Full AUTOSAR system is calculated as follows.

$$(-1/2-1/2)/6+(1/2+1/2)/3+(-1/2-1/2)/6+(1/3+(1/2+1/2)/3$$
$$+(-1/2+(1/2+1/2)/2)/3)/3=-1/6+1/3-1/6+(1/3+1/3+0)/3=2/9$$

On the other hand, the total impact value of the main non-functional requirements for Full Own system is calculated as follows.

$$(1/2+1/2)/6+(-1/2-1/2)/3+(1/2+0)/6+(1/3+(-1/2+1/2)/3$$
$$+(1/2+(-1/2+1/2)/2)/3)/3=1/6-1/3+1/12+(1/3+0+1/6)/3=1/12$$

For requirements required for new ECU software architecture, the results shows that Full AUTOSAR system is a better than Full Own system.

The Table 3 shows the tabular evaluation of Full AUTOSAR architecture. The Full Own system evaluation of the tabular form is omitted because of the space limitation.

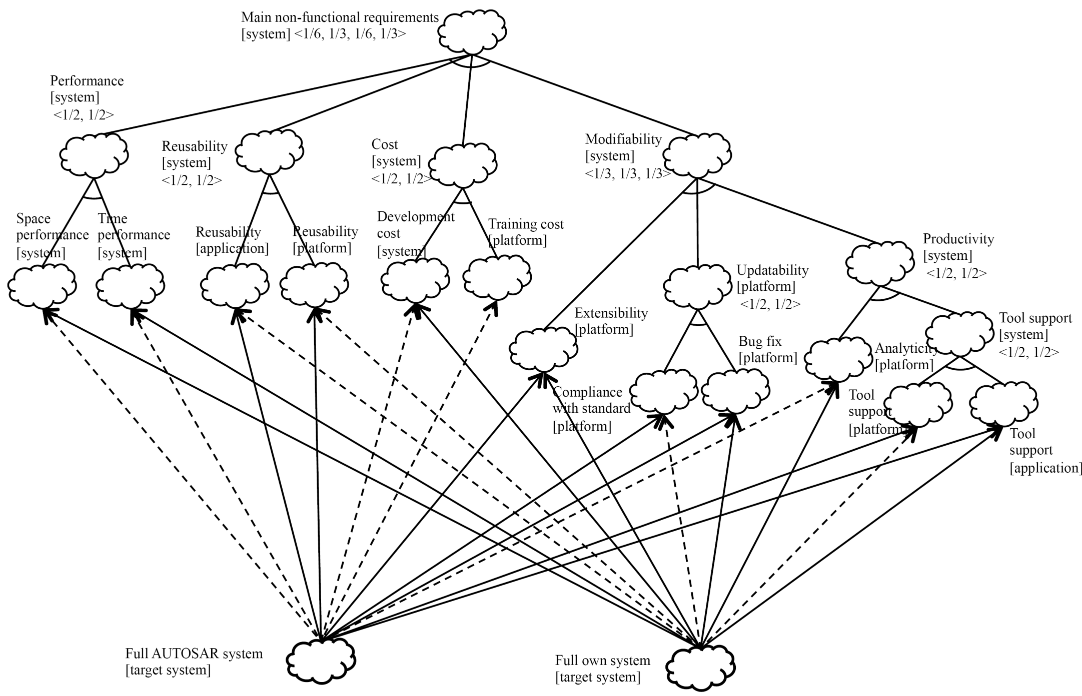

Figure 3: Evaluating the impact of solution alternatives for ECU software architecture

5 Discussion

5.1 Effectiveness

The industrial architecture selection example case was examined to validate the effectiveness of the proposed approach. As the above case study showed, the weighted SIG approach was useful to analyze the satisfying relationship between non-functional and operationalization softgoals in the automotive application domain. Although the evaluation was only executed for an example, the same results can be expected for other application domains.

The example of the conflict resolution between security and safety requirements was resolved quantitatively in [15] by using decomposition weight of SIGs. The mechanism is generic and widely applicable to quantitative evaluation of the validity of various architectures. The proposed approach can be applicable for evaluating not only software architectures, but also business and technology architectures [4, 5].

5.2 Difference with the previous paper

This paper formalized the weighted SIG approach that was originally proposed in our previous paper [15]. The previous paper only described the approach intuitively. It also showed the tabular calculation method of the achievement weight of softgoals based on the weight of operationalization softgoal. The applicability of the approach for the automotive software development case was also provided in this paper.

Table 3: Tabular evaluation of Full AUTOSAR system solution

SIG decomposition structure									Full AUTOSAR system
Main non-functional requirement 0.222222	1/6	Performance [system] -1.00000	1/2	Space Performance [system] -1.00000					-1
			1/2	Time Performance [system] -1.00000					-1
	1/3	Reusability [system] 1.00000	1/2	Reusability [application] 1.00000					1
			1/2	Reusability [platform] 1.00000					1
	1/6	Cost [system] -1.00000	1/2	Development cost [system] -1.00000					-1
			1/2	Training cost [platform] -1.00000					-1
	1/3	Modifiability [system] 0.66667	1/3	Extensibility [platform] 1.00000					1
			1/3	Updatability [platform] 1.00000	1/2	Compliant with standard [platform] 1.00000			1
					1/2	Bug fix [platform] 1.00000			1
			1/3	Productivity [system] 0.00000	1/2	Analyticity [platform] -1.00000			-1
					1/2	Tool support [system] 1.00000	1/2	Tool support [application] 1.00000	1
							1/2	Tool support [platform] 1.00000	1

5.3 Limitation

Although this paper examines the effectiveness of the weighted SIG approach, it only examines qualitatively the effectiveness of the proposed method for an automotive industry case study. It is necessary to show the effectiveness of the method by evaluating more number of applications.

The capability of different quantitative approaches on the goal attribute was compared in section 2. The new weighted softgoal approach can be constructed to integrate different attributed goal analysis methods described in section 2. Future work is needed for integrating these approaches.

6 Conclusion

This paper introduced the softgoal weight for evaluating NFRs. Evaluation examples of the approach were also shown for quantitatively validating quality of solutions represented by operationalizing softgoals. The automotive case study evaluation showed the industrial effectiveness of the approach, and possibility of application to automotive software development.

Future work includes more experimental evaluation of the proposed approach, comparative analysis of different quantitative extensions to the NFR framework. GSN is also a candidate to extend goals with quantitative attributes. It is also necessary to consider the integration for the family of different weighted goal tree approaches.

Acknowledgments

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