REQUIREMENTS ANALYSIS PROCESS USING ROLE-BASED GOAL MODELING

NOR ASHILA ABDUL RAHMAN

UNIVERSITI TEKNOLOGI MALAYSIA

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NOR ASHILA BINTI ABDUL RAHMAN

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ABSTRACT

Requirements analysis is the process of analyzing the requirements of various stakeholders that represent the specification of system behavior. This must be stated precisely in order to proceed to the design phase. It is noted that the current process of requirements analysis is not sufficient for identifying and representing the existence of multiple stakeholders, which could lead to various conflicts and overlapping requirements. Furthermore, the involvement of various stakeholders normally leads to inconsistencies and misinterpretation of requirements. Therefore, this study is conducted to enhance goal modeling representation, namely role-based goal modeling. Role-based goal modeling highlights each stakeholder's role identification in discovering the intentions and requirements of various stakeholders including the integration of data elements in order to determine the dependency of data when dealing with multiple stakeholders. An Integrated Plantation System was selected as a case study for this research with participation from different stakeholders. Besides that, the Integrated Learning Management System and NIMSAD approaches were used to evaluate the proposed method. From the result, it is found that role-based goal modeling showed improvement in deriving high feasibility (five goals) and high adequacy (one goal) requirements for implementation. The integration of data elements indicates high complexity when multiple stakeholders interact with the same data element. In sum, role-based goal modeling can facilitate the process of analyzing and prioritizing requirements from multiple stakeholders in the early stages of the development process.

ABSTRAK

Analisis keperluan adalah proses menganalisis keperluan pelbagai pihak berkepentingan yang menunjukkan spesifikasi sebuah sistem. Hal ini perlu dinyatakan dengan tepat supaya fasa reka bentuk boleh dimulakan. Proses analisis keperluan yang sedia ada didapati tidak cukup untuk mengenal pasti dan mewakili kewujudan pelbagai pihak berkepentingan dan seterusnya boleh menimbulkan pelbagai konflik dan pertindihan keperluan. Tambahan pula, penglibatan pelbagai pihak berkepentingan lazimnya akan menyebabkan percanggahan dan salah tafsir keperluan. Oleh itu, kajian ini dijalankan untuk menambah baik perwakilan pemodelan matlamat iaitu pemodelan matlamat berasaskan peranan. Pemodelan matlamat berasaskan peranan menekankan pengenalpastian peranan pihak berkepentingan dalam mengesan kehendak dan keperluan pelbagai pihak berkepentingan termasuk integrasi elemen data untuk menentukan kebergantungan data apabila melibatkan pelbagai pihak berkepentingan. Sistem Sawit Bersepadu dipilih sebagai kajian kes untuk penyelidikan ini dengan penglibatan daripada pihak berkepentingan yang berbeza. Selain itu, pendekatan Sistem Pengurusan Pembelajaran Bersepadu dan NIMSAD digunakan untuk penilaian model yang dicadangkan. Daripada keputusan kajian, didapati bahawa pemodelan matlamat berasaskan peranan menunjukkan kemajuan dalam memperoleh keperluan dengan kebolehlaksanaan (5 matlamat) dan kecukupan (1 matlamat) yang tinggi untuk tujuan pelaksanaan. Integrasi elemen data menunjukkan kerumitan pada tahap tinggi apabila pelbagai pihak berkepentingan berinteraksi dengan elemen data yang sama. Kesimpulannya, pemodelan matlamat berasaskan peranan boleh memudahkan proses menganalisis dan mengutamakan keperluan pelbagai pihak berkepentingan dalam peringkat awal proses pembangunan.

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LIST OF SYMBOLS

H	-	High
L	-	Low
M	-	Medium
N	-	None

LIST OF ABBREVIATIONS

ACHIEVE	-	Achievability
ADEQUATE	-	Adequacy
AGORA	-	Attributed Goal Oriented Requirements Analysis
AHP	-	Analytic Hierarchy Process
ASSUME	-	Assumptions
CGM	-	Constrained Goal Model
COMPLEX	-	Complexity
CONF	-	Conflict
CR	-	Change Request
CReML	-	Comprehensive Requirements Modeling Language
DATA	-	Data Element
ENGAGE	-	Engagement
FEASIBLE	-	Feasibility
GORE	-	Goal-Oriented in Requirements Engineering
GQM	-	Goal-Question-Metric
HQ	-	Headquaters
iLMS	-	Integrated Learning Management System
KAOS	-	Knowledge Acquisition in Automated Specification
MANDATE	-	Stakeholder's Mandate
NIMSAD	-	Normative Information Model-based Systems Analysis and Design Evaluation
SPEM	-	Software Process Engineering Meta-model

CHAPTER 1

INTRODUCTION

1.1 Overview

As a primary focus of a large and complex system development, one of the greatest difficulties is in understanding what a "requirement" really is. Before proceeding to the design stage, requirements can be categorized in many different ways that must be stated clearly, consistently and unambiguously (Irit *et al.,* 2013). Requirements can be summarized into an illustrative representation that should be useful for and understood by project manager and requirement engineer. In requirement engineering (RE), requirement can be classified under different perspectives; high level description, abstract statement and formal specification. Since the RE process is known as a continuing process that involves discovering, documenting and maintaining (Shams *et al.*, 2010; Lemai and Graeme, 2009) a set of requirements, requirements analysis therefore is one of the most important processes that requires high-reliability procedures. Requirements analysis can be difficult because the requirement engineer needs to come out with a set of requirements (Kenneth *et al.,* 2011; Yuanyuan *et al.*, 2011) that could represent a specification of the system (Michel dos *et al.*, 2011). There are two fundamental issues to be addressed in requirements analysis: (i) involvement of multi-stakeholders and (ii) integration between data elements.

Developing a large and complex system will require identification of the different levels of stakeholders' within an organization as well as their roles and objectives (Yuanyuan *et al.,* 2011) that need to be analyzed by the requirement engineer. Considering that stakeholders have valid interests that may be affected directly or indirectly by the system (Niels and Hans, 2013), it is important to analyze multi-stakeholders' requirements. Lack of understanding of the business requirements and engaging key stakeholders could contribute to a project's failure. Lack of stakeholders' role identification such as needs and expectations could contribute to the failure rate of up to 60% in large and complex projects as described by Jeffrey *et al.* (2013). Christopher (2013) stated that multi-stakeholders' role involvement has been seen as a risky factor of project success. With the increment in the list of stakeholders, the requirements can be unmanageable which will lead to increased risk of failure. For that reason, analyzing requirements that come from multi-stakeholders is important in order to improve the selection requirements with high feasibility and adequacy accordingly before proceeding to the system design phase.

In addition, when dealing with a large and complex system development, requirements might conflict and overlap which could lead to project failure. Nikhilesh and Amitabh (2008) stated that when a project fails, there are three possible problems that need to be figured out: (i) requirements are incorrect or incomplete, (ii) requirements are interpreted wrongly and (iii) variation of stakeholders' goals and priorities. Stakeholders are required to carry out different activities according to their roles and goals. A stakeholder's role is considered as an essential element that is associated with the software artifacts. Xu *et al.* (2010) claimed that dependencies between stakeholder and other artifacts are poorly executed in the industry nowadays. Throughout the system development life cycle, stakeholders are certainly associated with the requirements source and other created artifacts. As a result, analyzing requirement requires an extensive process in mapping out the requirements and other software artifacts.

Requirements are the cornerstone of any development. It is essential for the requirement engineer to trace the dependency between requirements and other artifacts. Considering the requirements can be described in various forms: (i) goals, (ii) scenarios, (iii) user profile and (iv) use cases, it is therefore important for the requirement engineer to analyze the number of dependencies that might occur in system development. Because of the growing size, complexity and customization of software systems, the dependencies between requirements and other artifacts should be traced effectively. According to Arda *et al.* (2014), whenever changes are made to the requirement, the requirement engineer needs to find out the affected parts on other software artifacts, such as requirement, design elements and source code.

1.2 Problem Background

The process of requirements analysis is carried out not only to define customers' needs, objectives and functions, but also to synthesize solutions in order to optimize of performance requirements. The process of analyzing requirement still becomes the root cause of failures in development of software project (Shams *et al.*, 2010). There are two challenges that have been discovered accordingly in requirements analysis: (i) multi-stakeholders' requirements and (ii) integration with data element.

1.2.1 Challenge in Multi-stakeholder Requirement

Multi-stakeholder requirement is one major theoretical issue that has become a main concern in requirement analysis for many years. In developing a large and complex system, the involvement of different level of stakeholders from several

departments that share the same information and communicate with each other is required. All stakeholders' needs must be determined clearly from the very first phase of the development process. It is difficult for the requirement engineer to deal with all collections of need (Tom *et al.*, 2013; Michel *et al.*, 2011) that come from different stakeholders with their own desires about the system being developed. Each stakeholder plays an important role which reflects the success of the system development. Under such circumstances, Christopher (2013), holds the view that the increment of stakeholder list will lead to unmanageable requirements since each requirement engages with different level of risk. Besides, the lack of identification of stakeholder's role is seriously taken in a large and complex system development.

Throughout the requirements analysis process, goal modeling represents the relationships between roles in terms of specific goals that one role depends on the other role to provide. Goal has been applied by Kenneth *et al.* (2011) who propose a goal sketching technique that emphasizes the presence of assumptions and distinguishes them from the various system elements to be constructed. However, the goal sketching that is used does not describe the requirements from multiple stakeholders. Vikas and Guillaume (2013) stated that assumptions are usually implicit during requirement modeling. However this often leads to goals and requirements that may cause potential traceability errors and reduce the quality control of the system development. Other approaches used an obstacle analysis (Antoine and Axel van, 2014) that is crucial as it should be more adequate and complete requirements. Unfortunately, requirement analysis process is still the root cause of software-project delays, overruns and failure in systems development.

1.2.2 Challenge in Integration with Data Element

Other challenges in requirement analysis that often affect the development of large and complex systems are requirement conflict and overlap. Stakeholders are required to accomplish a lot of different activities during the development. The variation of stakeholders' goals and priorities is one of the factors that will lead to requirement conflict and overlap. Often, during development, there will be stakeholders who misinterpret the requirements and claim that the system is not being developed accordingly. Besides, there are also stakeholders who do not express all their needs and desires for the system that is to be developed. As a consequence, the requirement engineer could not fully understand the requirements because the design of a to-be system is reliant on requirements from stakeholders (Xu *et al.*, 2010).

Since each stakeholder's requirement is attached with different level of risk, it is important for requirement engineer to analyze and prioritize requirements from the stakeholders. Previous studies such as Kenneth *et al.* (2011) indicate that dependency could be expressed in goal graph using the operationalizing elements of the system-to-be that might not be dependable to the goals. Dependency on the other hand used to define relations between actors in goal modeling formation. Thi-Thuy-Hang and Alain (2012) mentioned that a quality of requirements describes a constraint whose satisfaction or fulfillment ranges on a scale of possibilities and that can constraint a goal. Besides, Chitra *et al.* (2015) in their study implemented inter-actor dependencies using the fuzzy concepts to capture requirements where an actor depends on other actors for its goal accomplishment. However, although the above method has been widely used, the process of analyzing the level of confidence attached to a set of requirements is often poorly executed in the industry nowadays.

1.3 Problem Statement

This study was conducted in the area of requirements analysis process and driven by the problems arising from the process of analyzing requirements specifically in developing large and complex systems. Problems such as lack of representation of multi-stakeholders consequently affect the process of analyzing and prioritizing requirements from multiple stakeholders before proceeding to the design phase. Besides, the integration between requirement and other data elements need to be identified discretely in order to minimize complexity of the requirements. In this study, the problem of analyzing multi-stakeholders' requirements is addressed, during design time, in an attempt to facilitate the modeling expressiveness. To realize the research goal, there are three research questions (RQ) that need to be answered.

a) RQ 1: What should be done to show the involvement of multi-stakeholders in goal modeling when analyzing requirements?

The first factor that is considered is to manage a set of requirements that come from multi-stakeholders. The importance of analyzing requirements is to improve the selection of feasibility and adequacy of requirement at the earliest stage that should be realized in a to-be system. Requirement analysis is one of the crucial steps that need high-reliability process. Requirement analysis process can be difficult because the requirement engineer needs to come out with a set of requirements that could express all the various stakeholders' needs. Therefore, the representation by including stakeholder-oriented identification is important for classifying requirements based on stakeholders' roles and functions.

b) RQ 2: How to integrate and evaluate data element in goal modeling?

The second factor that has to be considered is the ease in determining the complexity of dependency of data when dealing with multi-stakeholders to perform a lot of different activities. Data dependency happens when the data can be an input or output from one goal to another goal. Consequently, the data has been changed or intervened from one goal to another goal.

c) RQ 3: How to validate the improvement of multi-stakeholder representation and the integration of data element?

The validation of the analyzing process is measured based on the applicability of the improvement to the real-world requirement analysis. The improvement process is practical to show the appearance of multi-stakeholders attached in a set of requirements to show the complexity of data element integration. Therefore, the process is particularly useful during requirements analysis and the early stages of systems development.

1.4 Objectives of the Study

The goal of this research is to enhance the requirement analysis process by improving the goal modeling representation that consists of two main components; role-based goal model by highlighting the stakeholder role identification together with integration with data element as a second component. In order to realize the goal, several objectives need to be achieved:

a) To enhance the representation of goal modeling by including the stakeholder role identification in order to demonstrate multi-stakeholder intentions and requirements.

b) To propose and evaluate the integration of data element in role-based goal modeling in order to determine the complexity of data dependency of requirements.

c) To validate the role-based goal modeling using NIMSAD evaluation.

1.5 Scope of the Study

In order to achieve the objectives stated in this study, the scopes of this study are bounded under these limitations:

a) This study focuses on improving the requirement analysis process with representation of stakeholder role identification plus integration with data element.

b) Goal representation is applied in order to illustrate the requirements from multi-stakeholders.

c) The integration with data element is used to show the complexity of data dependency of data when dealing with multi-stakeholders.

d) Plantation Integrated System (PIS) that focuses on labor management is used in this study in order to demonstrate the proposed model.

e) The integrated learning management system (iLMS) is used to assess the applicability of the improvement process.

f) The numbers of change request (CR) from iLMS testing phases are taken into consideration for the evaluation in this study.

g) The evaluations considered in this study are: (a) feasibility and adequacy of multi-stakeholder requirement and (b) the complexity of the dependency in data element.

1.6 Significance of the Study

The results from this study will assist the requirement engineer to derive a set of requirements that represent a specification of system behavior. Since requirement analysis is an essential activity in requirement engineering, this study aims to reduce time consumption in requirement analysis and minimize project failure at an early stage (Kenneth *et al.*, 2011). This study observes the importance of analyzing

requirements from two different perspectives: (i) development estimation and (ii) managing requirement.

In development estimation, the lack of requirement analysis could increase the project failure rate (Jeffrey *et al.*, 2013) in large and complex system development. Besides, whenever user makes changes in requirement, the requirement engineer will have to systematically monitor and document each change. Moreover, if analysis of requirements is not strictly taken into consideration in system developments, it can cause project delays, overruns and will lead to high cost and budget development (Jeffrey *et al.*, 2013; Shams *et al.*, 2010; Kenneth *et al.*, 2011).

From the perspective of requirement management, insufficient analysis of requirement will affect the consistency of the requirements that have been gathered from stakeholders (Christopher, 2013). If the requirements are not analyzed accordingly, the feasibility of requirement cannot be achieved and it is difficult for the requirement engineer to prioritize the requirements based on the aspect of adequacy and feasibility before proceeding to the design stage (Kenneth *et al.*, 2011). Therefore, this study intends to improve the requirement analysis process by highlighting the multi-stakeholder requirements and minimizing requirement conflicts and overlaps in system developments.

1.7 Organization of the Thesis

This thesis is organized into seven chapters. Chapter 1 defines the challenges, current methods, problem, objectives, scopes and significance of the study. Chapter 2 reviews the main subjects of interest, which are the goal modeling domain, the formation of goal modeling and the assessment of goal modeling. The last section of this chapter will present the trend and tendencies related to this study. In Chapter 3, a

brief review of the proposed role-based goal model development framework is presented, followed by detailed descriptions of a pilot and implementation case study and instrumentation used and result analysis.

Chapter 4 gives a brief overview on the enhancement of goal realization technique that highlights the stakeholder role identification in discovering the intentions and requirements of multi-stakeholders. This includes the assessment of four risks factor in order to analyze the feasibility and adequacy of the requirement. Next, Chapter 5 extends the role-based goal model by considering the integration element in goal modeling. Integration of data element is intended to show the complexity of dependency of data when dealing with multi-stakeholders to perform a lot of different activities. Chapter 6 gives the overview of the whole achievement of the research objectives. The role-based goal modeling is evaluated and compared with the basic goal graph. Subsequently, the role-based goal modeling is then implemented and analysed using a case study of exam registration module in the integrated learning environment case study in order to assess the quality of the proposed model. Finally, Chapter 7 the achievement results to date are presented. The contributions and future works of the study are also described.

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