User Characteristics Validation for User Scenario Based on Use-Case Models in Requirements Analysis

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***Abstract*—Nonfunctional requirements, such as user characteristics and system architecture, are factors that make it difficult to acquire proper requirements when constructing a system for business improvement by Information and Communication Technology (ICT) for small-scale companies that are behind other medium and large-scale companies. This paper discusses an incremental requirement acquisition and analysis method of a system based on a use-case model in Unified Modeling Language (UML) with the experience of requirements analysis for a small-scale manufacturing company as a joint lesson at our university.**

Keywords—Nonfunctional requirements; Use-case analysis; UML; validation.

I. INTRODUCTION

It is well known that requirement analysis is a key to success in developing high-quality systems in an efficient manner. Requirements specification must determine not only functional requirements but also nonfunctional requirements. Nonfunctional requirements include the system goal, external interfaces with the user, hardware, software, and communications. Moreover, user characteristics that are general characteristics of the intended users of the product, including educational level, experience, and technical expertise affect not only the system usage but also the service quality.

As the system architecture and users become diverse, the initial model of a system often depends on these features with regard to nonfunctional requirements. These features restrict the specification and need elaboration by considering these features step by step at the early stage of system development, as discussed in the Twin Peaks Model [1]. User characteristics and the system architecture are the factors that make it difficult to acquire proper requirements when constructing a system for business improvement by Information and Communication Technology (ICT) for small-scale companies that are behind other medium and large-scale companies.

On the other hand, functional requirements can be modeled as essential use cases [2] by a semiformal and widely used language such as the Unified Modeling Language (UML) [3] in model-driven development. System usage scenarios can be defined by a combination of these use cases. However, the abovementioned architectural and external factors in nonfunctional requirements strongly affect this combination. Moreover, a change in the need for these use cases may occur. Although this uncertainty of requirements is unavoidable at the early stage of system development, it is important formally to manage the traceability of requirements related to nonfunctional requirements in a system.

We have proposed a method for model-driven requirements analysis [4] [5] using UML. We have also presented an iterative cycle of analysis and verification in which the requirements specification of a system was defined incrementally [6].

If the user does not clearly recognize the effectiveness of ICT, it is more difficult to acquire their requirements for a system to improve their business by ICT. In this case, even if a use-case model is useful to define an expected system, it is difficult to extract and define suitable use cases. The basis of a use case is a normal flow that consists of behaviors and data with preconditions and postconditions. Data has invariant conditions for a system, so it causes exceptional flows in a use case. To acquire user-centric useful requirements, we think the following two things are important points to specify in fundamental use cases at the early stage of the requirement analysis phase:

- Essential data required in executing the domain tasks must be clarified; however, these data often involve the implicit knowledge of the user. Therefore, we must obtain these data via a method, such as ethnography [9] as sufficiently and as far as possible.
- As a system must not obstruct the task process in the actual work site for the users, the requirements should specify the behavioral flows by following a traditional task process.

This paper proposes a method to acquire user-centric useful requirements incrementally at the early stage of system development. Fundamental scenario analysis based on use-case components makes it possible to acquire user-centric useful requirements by clarifying the confirmation points on the models. These points can be used in analysis by requirements elicitation methods such as the ethnography method.

The rest of this paper is organized as follows. Section II describes problems in improving the business of a small-scale company that is behind in introducing ICT technology. Section III explains how to define a UML requirements analysis model and a way to validate user satisfaction using UML models. Section IV explains a case study. Finally,

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Section V discusses our results, conclusions, and future research directions.

II. Problems in Improving Business of Small-Scale Companies

A. Barriers to Business Improvement by ICT

It is difficult to introduce a basic management system at work sites, such as small manufacturing industries because of the work environment, a low number of employees, or inexperience in ICT. In such work sites, only responsible people can manage the work process, and they use a whiteboard and paper notes attached to the product parts for process management. As a person's knowledge of process management is their implicit knowledge, this is not the explicit and formal knowledge of the company. Forming implicit knowledge into common specified knowledge is important for business improvement by the utilization of information technology; however, it is difficult to acquire implicit knowledge from the users.

We think that modeling fundamental use cases contributes to formulating implicit knowledge into common specified knowledge that is related to the model elements.

B. Outline of Example Subject

In response to overseas industrial policies such as "Industry 4.0," in Japan, we make efforts to solve solutions using the Internet of Things toward the future innovation of industrial structures. However, in a small-scale manufacturing company, delays in IT conversion are obstacles to such efforts.

This study covers issues in nonmetal products manufacturing companies that are centered on casting technology and are celebrating their centenary in 2018. These companies primarily deal with construction hardware ordered by building material manufacturers, who specialize in small lots of various kinds. As there are fewer than 20 employees, it is a small factory. By using manufacturing technology possessed by each cooperating factory scattered in the area, we provide consistent services from product manufacturing to processing. Cooperation with a factory with a useful and a profit is a strength. However, as many parts move between cooperating factories, leading to various kinds of commercialization, it is difficult to manage these work processes.

While manufacturing a product, it is necessary to request multiple companies to cooperate in order to process many parts to complete the product. Parts that are to be delivered between the parent company and the cooperating companies are placed in returnable boxes that are transported by full-time drivers. The transmission of information about processes and products is carried out by telephones, messages to drivers, and meetings. Although process and product information are the basis of the work, they are implicit knowledge possessed only by the responsible person at the parent company. Sharing such important implicit knowledge is the goal of introducing a system.

C. Difficulties in Requirements Analysis

Ethnography is a qualitative orientation of research that emphasizes the detailed observation of people in naturally occurring settings. It is drawing a considerable amount of attention because it is useful in marketing. The ethnography method is used for observation of work sites and in interviews with the person in the company who is responsible for requirements acquisition; however, it is important that the interviews are carried out by whom which has both domain knowledge and system knowledge. It is important that the project manager or developer is familiar with information technology. However, few people are familiar with both types of knowledge.

We think that modeling fundamental use cases contributes to extracting useful observations and interview questions for the person who use the ethnography method.

III. User Characteristics Validation in User Scenario

A. Use-Case Component

A use-case analysis is an effective method to clarify functional requirements. We propose a method for model-driven requirements analysis using UML. A use-case model is a fundamental component of the requirements defined formally by UML. This method is defined based on a requirements analysis model, as shown in Figure 1.

Figure 1 shows an outline of a requirements analysis model. The relation between the use cases in the specified use-case diagram is expressed by an activity diagram that includes some subactivity nodes corresponding to the use cases. An activity diagram defines each use case. An activity diagram specifies not only normal and exceptional action flows but also data flows that are related to these actions. An action is defined by an action node, and data is defined by an object node that is classified as a member of a class that is defined in a class diagram. Accordingly, these two kinds of diagrams enable us to specify application process flows in connection with the data. The interaction between a user and a system includes requisite flows and data on user input, conditions, and output to execute a use case correctly.

The second feature of this model is an activity diagram that has three types of partitions: user, interaction, and system. These partitions enable ready identification of the following activities: user input, interaction between a user and system caused by the conditions for executing a use case, and the resulting output. Object nodes in the user, interaction, and system partitions represent input data, output data, and entity data, respectively. The requirement analysis model is defined using the modeling tool Astah*[7].

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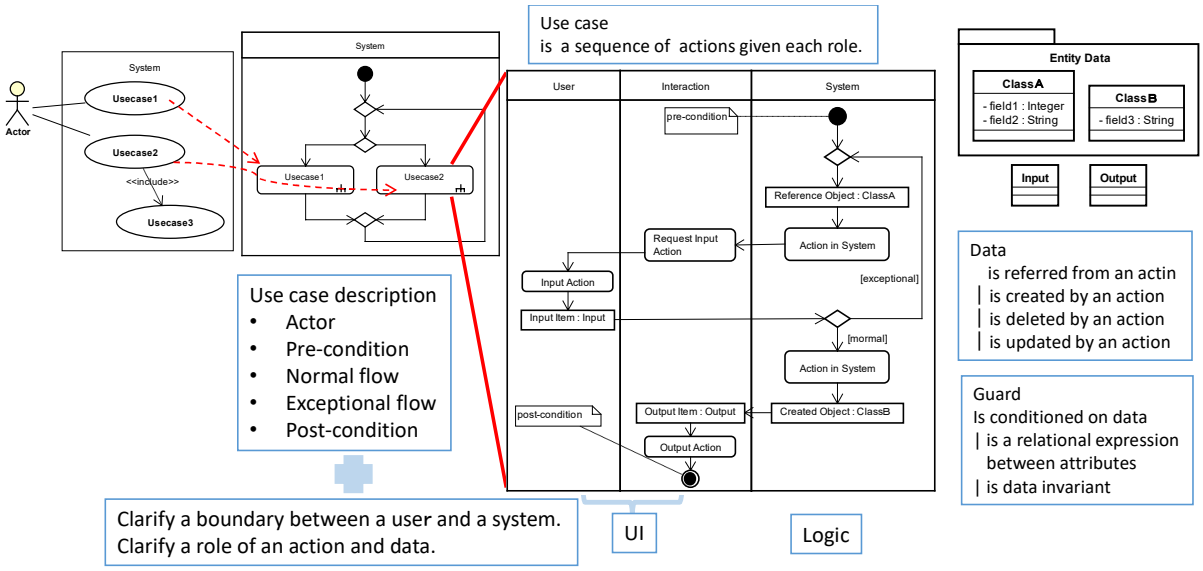

Figure 1. UML requirements analysis model

When user requirements are uncertain owing to users who are unfamiliar with ICT, we must develop a system from the fundamental use case to improve the business. To introduce ICT into the company, it is important that fundamental use cases need to be validated on the benefits. The user scenario consists of these use-case components, and we evaluate whether it satisfies the requirements of each stakeholder by a state machine diagram that represents the state of user recognition.

B. Use-Case Analysis Process

Based on Chapter 4, "Considerations for Producing Good Software Requirements Specifications (SRS)," and Chapter 5, "The Parts of an SRS," in IEEEstd.8300-1998 [8], we focus on the following parts of nonfunctional requirements and propose an iterative requirements analysis process, as shown in Figure 2 [6].

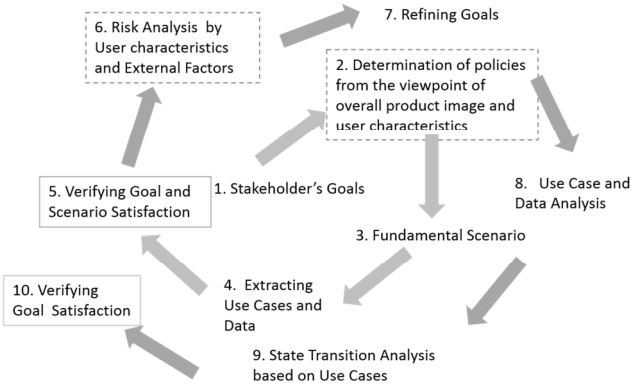

Figure 2. Iterative requirements analysis process

The process indicates that the functional requirements of a system can be specified by fundamental use cases that satisfy "the effective and useful scenarios in the system usage" in order to meet "the goals of the system." We focus on the following internal and external factors of the software:

1) Goals of the stakeholders
2) Overall product image based on the following two external factors:
   a) External interfaces with the user, hardware, software, and communications.
   b) User characteristics that are general characteristics of the intended users of the product, including educational level, experience, and technical expertise, which affect the system usage.

As mentioned in Section II, to solve the problems in a small-scale company, the first factor is often not concrete, and the second factor strongly affects the acceptable system.

In contrast to the standpoint of managers or workers, the goals of stakeholders are significantly different. Furthermore, if there are parent-child relationships between companies, the expected goals of the system are also different. Therefore, first, we set the goals of the manager of the parent company and build a basic scenario. We extract use cases and data models for the fundamental goal, and an activity diagram defines a scenario where all workers operate their tasks using the target system.

C. Definition of Implicit Information

Based on nondigital information on a whiteboard or paper notes attached to the product parts for process management that are given by a responsible person, the actual used information required for process management can be defined by a class diagram, as shown in Figure 3. Figure 3 shows the following things: a product consists of several parts and a process treats one or more target returnable boxes and the factory being in charge and the

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eight date managed in the process. A task schedule is a sequence of processes.

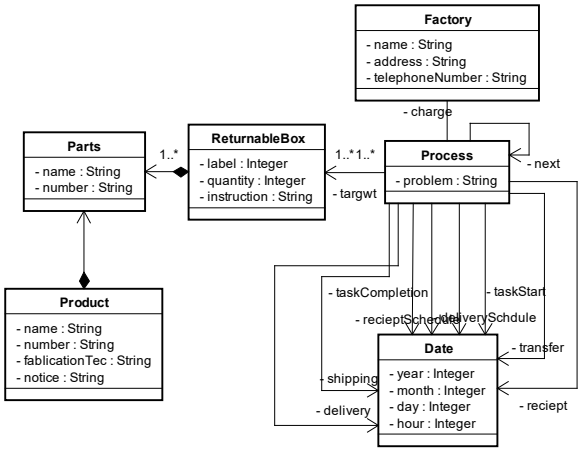

Figure 3. Class diagram

D. Fundamental Scenario

Next, consider a use case that is necessary to satisfy the goal. The basic information for sharing implicit knowledge is the process information and product information, as shown in Figure 3. Based on the fundamental Create, Read, Delete, and Update (CRDU) functions, a use case is extracted, as shown in Figure 4. In this case, there are three actors such as a worker in a parent company and a cooperative company, and a driver.

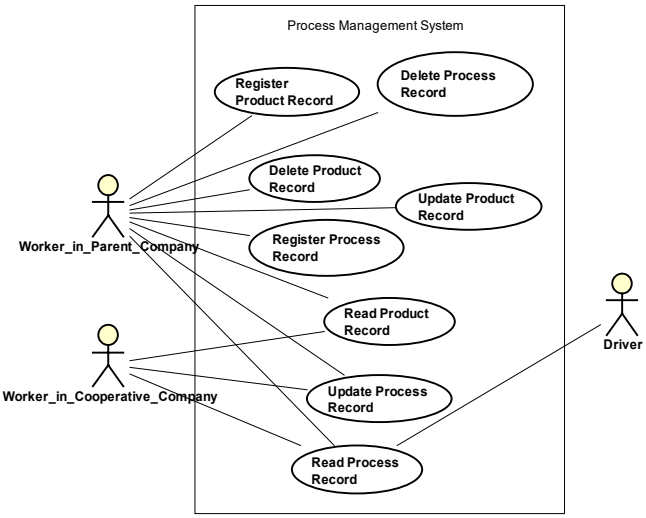

Figure 4. Use-case diagram

Based on these use cases, we defined the workflow of one step of work, as shown in Figure 5. A workflow expresses a scenario where all workers actually operate their tasks in the real world using the developed system. Here, we have not yet assumed the hardware to use. As a premise of the workflow, it is assumed that both the product information and process information as a plan are already registered.

The workflow scenario as shown in Figure 5 is defined under the conditions that the other use cases are completed, for example, that the registration is completed by the "register process information" use case.

The partition represents each worker in this company. That is, the action within the partition limits the action of each worker. The action written in the behavior call action of "read process information" and "update process information" represents a use case. Colored actions represent the following tasks:

- Work done by workers in each partition while using the *Process Management System* with the use case in Figure 4.
- Actual work regardless of the system.

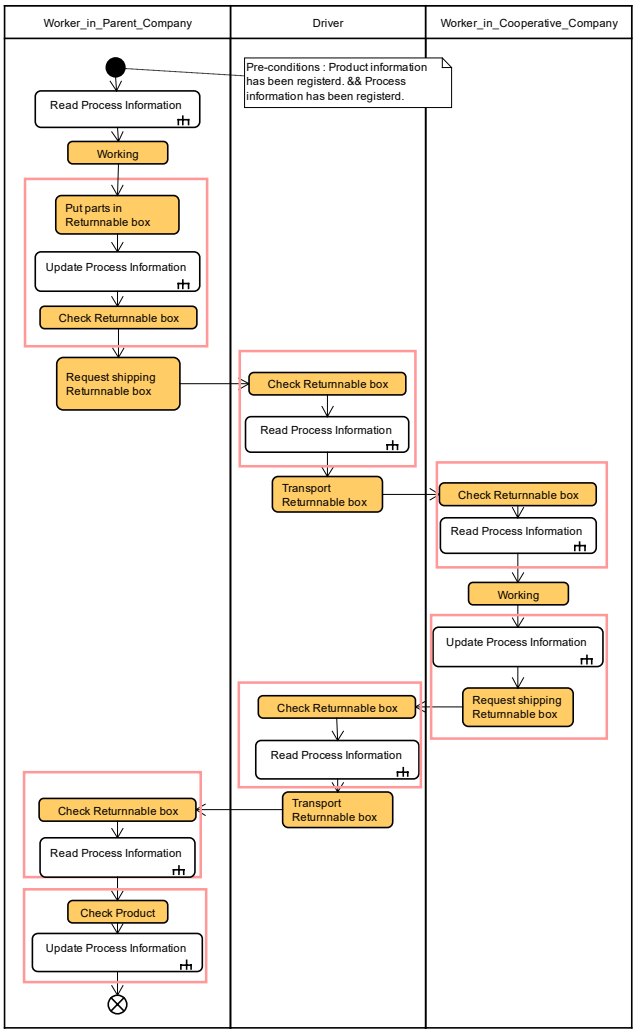

Figure 5. Fundamental scenario

The part surrounded by a rectangle is the work of the former and is necessary to determine the hardware configuration to create merits for the worker by using the

system. The merits for workers are their respective goals, but it is important that the introduction of the system itself does not harm their tasks. The user characteristics of the workers need to be sufficiently considered.

Figure 5 shows a workflow in which the process control function, which uses a computer, is introduced into the present work done in the real world. The conditions for satisfying the goals of stakeholders by process control are as follows:

1) Information required for process information (see the class diagram in Figure 3) is valid. This means that the entity in the real world and the information in the system are consistent with each other.
2) It is required to confirm the degree of satisfaction of each goal. For example,
   a) If responsible people can acquire the dates related to a process they want to know as management information, they can "grasp the work situation" by sharing information with other workers.
   b) The efficiency improvement of information transmission can be accomplished by sharing information even without using a telephone so that the next work can be started and the instruction content of the work can be known.
   c) Regarding the driver's goal, the responsible person can confirm with the process chart that the product was delivered to the correct place.

E. Use-Case Scenario Validation

The grasp of the work situation of the abovementioned condition 2) in Section III-D is modeled using a state machine diagram as shown at the upper left of Figure 6.

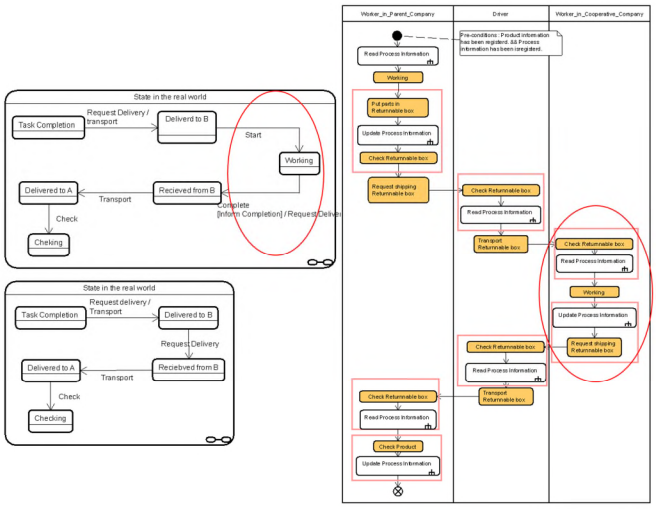

Figure 6. Relationship between work situation and workflow

An activity diagram and a state machine diagram express the behavior of a system from different viewpoints. The former expresses a sequence of actions, and the latter expresses a graph of the system state. Thus, we can see that the column of each state in the real world corresponds to each partition of the workflow.

In the state of the real world at the upper left, we modeled how we can recognize the work performance of each worker in the system by the workflow task of each worker. The part indicated by a red circle represents the state that the worker of the cooperating company can recognize by using the system. Considering the user characteristics, if we do not introduce a system to cooperating companies, they cannot recognize this achievement state, that is, the model in the lower left will be understood in the real world when the parent company uses the system. In the workflow after introducing the system, by associating information that is understandable by the user through the system with the state machine diagram of the actual state arising from the work of the workflow, it is possible to intuitively grasp the merit of introducing the system and to evaluate the value of systemization.

IV. Case Study

We conducted a joint lesson in two master courses of System Engineering & Science and Engineering Management at our university over two years. The students in the Engineering Management course researched the visualization and sharing method of technology and skill succession by extracting tasks from an actual situation based on field observations for small and medium manufacturing companies.

A subject with a realistic problem was given to students in the System Engineering & Science course who had some system development skills with UML. They were given the subject and the research results that were observed in the workplace of a small manufacturing company based on the ethnography method. Then, the students analyzed the system by ICT to contribute to the improvement of the business. The purposes of this lesson were as follows:

- To understand that the analyst has to specify a useful scenario that the user can accomplish by using the system during the actual work. This is because they make the users understand the merit of introducing the system into their work.
- To understand how to check the validity of the requirements defined using the UML requirements analysis method based on the use-case components and the state machine diagrams. This is because it is difficult for the user to confirm whether the assumed scenario has satisfied the goal.
- To understand and organize the viewpoints of various requirements analyses by analyzing the problems of a small-scale metal manufacturing company as an example of a real problem.

V. Conclusion

This paper presented a method for the user characteristics validation of a UML requirements analysis model. Regarding this experience in the master course lecture, we discussed the problems in acquiring user-centric

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requirements considering the user characteristics, as follows:

- If the user cannot master the system convenience, there are often discrepancies between the information within the system and the states in the actual workflow. This causes damage to the effectiveness of the system. Thus, as there are workers unfamiliar with the operation of IT equipment, that a suitable confirmation function should be implemented with the user characteristics is indispensable.
- Although it seemed to some extent that the information the users wanted to manage was gathered through investigation by ethnography, it was not verified whether this is sufficient for developing some functions to improve the current work. This is because, when interviewing or observing, there are times when the observer does not see the points that the analyst wants to clarify from the analyst's point of view.
- As the users may be unfamiliar with the IT environment, they tend to hesitate when introducing a system into their work, and it is necessary to consider the following measures:
  * First, present the initial system where the effects are clear.
  * Consider a system configuration that makes the walls of use as low as possible.
  * Although it is necessary to clarify the actual work process, observation and interview alone are not sufficient. Measures are needed to clarify what the users want to achieve in their work, and we need to develop a prototype that allows the users to check the scenarios directly.

In this case, a requirements analysis model and incremental-model-driven development are useful for generating a prototype efficiently and improving the system gradually at the early stage of development. A fundamental scenario is useful to analyze the system behaviors that are strongly affected by the user characteristics and to present a suitable usage of input and output devices such as sensors. We implemented a prototype system according to a validated UML requirement analysis model, and we are planning to evaluate this prototype system with the users.

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