

Verification of the usefulness of SRDM through a case study of smart robot development

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Abstract—In recent years, the demand for service robots has increased rapidly due to the aging population and the labor shortage. However, service robots have not been widely used because they require design improvements even after their introduction. Therefore, a tool named the Service Robot Design Matrix (SRDM) has been developed to support the design of service robots. However, SRDM has not been verified for its usefulness because it has not been applied to many cases in the current situation. The purpose of this study is to verify the role and usefulness of SRDM by analyzing the vital measurement service, one of the services provided by the AIREC smart robot in development, using SRDM. After clarifying the flow of services to measure vital data and organizing and extracting the parameters of the service system as well as the parameters of the robotic system, the dependencies between the parameters were defined and the system was modularized. As a result, the impact of changes in one parameter on the other parameters can now be understood to some extent. In addition, we were able to understand how the actual implementation of the robot interacts with the service system. This example showed that SRDM can serve as a link between service design and robot design.

I. INTRODUCTION

In recent years, the demand for service robots has increased significantly, largely driven by the growing medical and care needs of an aging population and the challenge of labor shortages. The provision of services by service robots depends on the interaction between the constituent parameters of the service system and the robotic system. Therefore, continuous improvement of service robots after their deployment is essential. However, a systematic methodology to improve the design of service robots while simultaneously adjusting the parameters associated with the service system and the robotic system has not yet been established. Consequently, a tool named the Service Robot Design Matrix (SRDM) has been developed to facilitate the design of service robots[1].

Despite the large number of projects to design and develop service robots that have been conducted, there has been a lack of methodologies that facilitate the design of a service robot, including the design of the service component. Therefore, the robot designer must anticipate and gather requirements for situations that may arise when the robot is deployed in a service environment with variability. The SRDM clarifies the needs of the target users and the role of the robot in the service system from the perspective of the service overview,

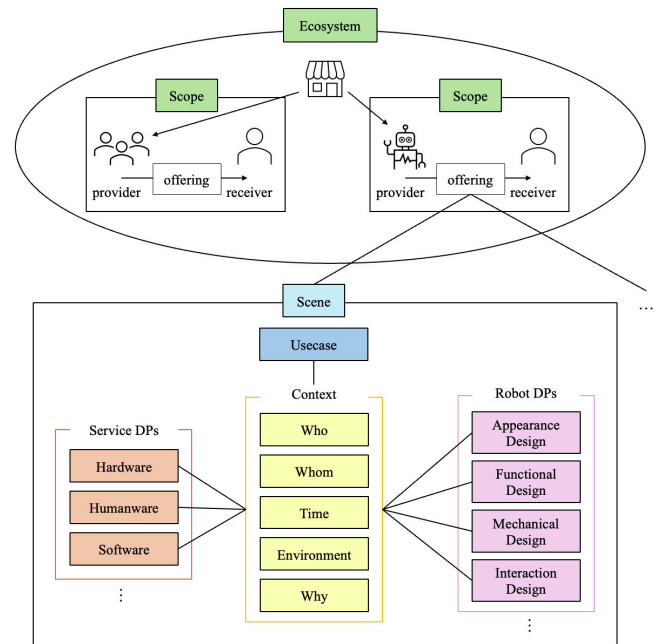


Fig. 1. Service Robot Design Model

thus identifying the required functions for the service robot. According to this approach, the constituent parameters of the service system and the robotic system are organized and grouped into highly interactive modules. This facilitates the integration of service design and robot design, which have been conducted as separate processes, while providing support for robot design to improve post-implementation changes.

However, the utility of SRDM has yet to be validated due to the lack of empirical evidence on its current applications. This paper presents an analysis of the vital measurement service, one of the services provided by the smart robot, AIREC, which is being developed under the Moonshot R&D project (Goal 3) using SRDM. This aims to conduct a proof-of-concept in the SRDM by organizing the design of service components and the relationship between the service system and the robotic system and clarifying interfering factors for post-implementation improvement design. In light of the results of our analysis, we have undertaken an examination of the role that SRDM plays in the domain of service robot design and its utility.

Section 2 provides an overview of SRDM and its usage. Section 3 presents the methodology and findings of the

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TABLE I
CATEGORY LIST

Category	Subcategory	Definition
Ecosystem	Scope	People and organizations involved in the service system
Offerings	Offering	Description of services within each scope
Task	Usecase	Unit of work performed by the system
Context	Who	The person performing the task
	Whom	Beneficiary of the task
	Time	Time at which the task is executed
	Environment	Task execution environment
	Why	Purpose of performing the task
Service DPs	Hardware	Product and equipment design parameters required to perform the task
	Humanware	Attributes required to perform a task in the one performing the task (who) or in the recipient of the service (whom)
	Software	Attributes of data and data processing capabilities involved in performing the task
Robot DPs	Appearance Design	Design the look and feel of the robotic system
	Functional Design	Functions of the robotic system required to execute the task
	Mechanical Desing	Mechanical design of the robotic system to achieve the functionality required to perform the task
	Interaction Design	Design of interactions that occur between the robotic system and the beneficiary

TABLE II
CRITERIA FOR DEFINING DEPENDENCIES

Points	Definition
1	Adjustment between parameters is not necessary
3	Adjustment between parameters is desirable
5	Adjustment between parameters is essential

analysis of the smart robot that provides vital measurement services using SRDM. In conclusion, a summary is provided.

II. SERVICE ROBOT DESIGN MATRIX

A. Overview of SRDM

The Service Robot Design Matrix (SRDM) was developed to organize the parameters that make up a robotic system and the service system in which the robotic system is deployed and to comprehensively express the relationship between them. The provision of service is performed through the interaction of various parameters of the service system and the robotic system. Therefore, a modularized design of service robots that includes service parameters by clarifying the relationships among the parameters can improve the ease



Fig. 2. Smart Robot:AIREC[6]

of modification of the service robot design. In addition, the design of the service and the design of the robot that provides the service are often not performed by the same designer, and the service robot is affected by the elements that frequently change at the service site. Therefore, the quality of a service robot depends on the robot designer's ability to anticipate possible situations that may occur at the service site and to obtain related information from the service designer in advance. Therefore, This tool determines the service outline, which is the upstream part of the service robot design, and clarifies the composition of the service robot when it is introduced into the service system. This makes it easy to envision elements that may interfere with each other and possible situations and enables the collection of requirements without relying on the robot designer's prior knowledge and skills. In other words, SRDM also serves as a link between service design and robot design.

B. Procedure of SRDM

This section describes how to use SRDM.

1) *Service Design*: First, the designer decides what services the robot will provide. Then they determine the target personas for the service and use those personas to create the customer journey map and the service blueprint. The customer journey map is a visual representation of all the steps that a customer goes through when interacting with a service or product, helping the customer understand how the service is used and which touchpoints are important[3]. The Service Blueprint is a tool that visually represents the entire service flow. By dividing the service flow into the "front stage", where customers are directly involved, and the "back stage", which is invisible to customers, the tool aims to design and improve services and understand problems in the service process[4]. By visualizing how service robots are

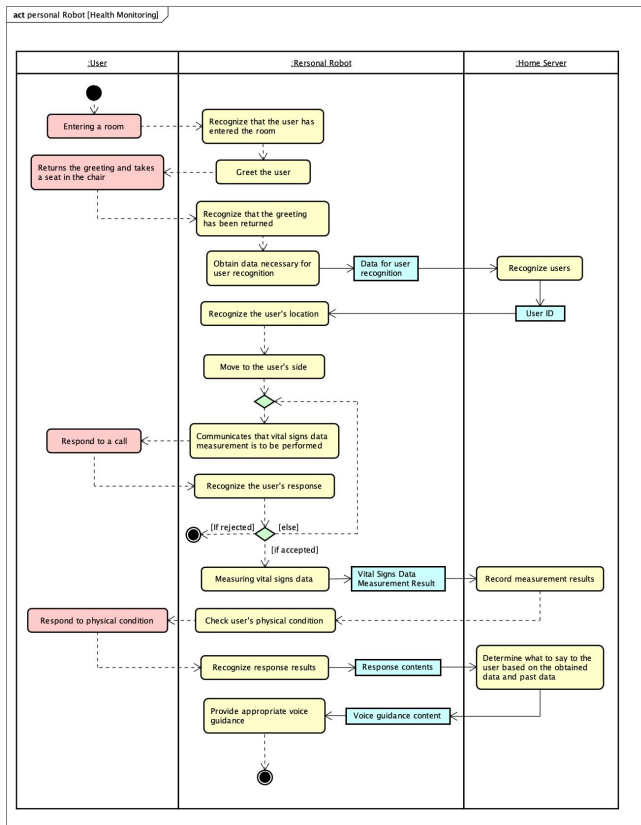


Fig. 3. Activity diagram

involved in service provision and clarifying their needs, it is possible to derive the functions necessary to realize the services to be provided.

2) *Building service robot design models*: To provide the specified service, a service robot design model (Fig. 1) is constructed to organize the parameters of the service system and the robotic system involved. The parameters that make up the service robot design model are shown in Table I.

3) *Definition of dependencies*: The dependency analysis is performed on the basis of the model of the built service robot design. The parameters to be analyzed for dependencies belong to design parameters, and these are displayed in a matrix to determine the dependencies of the corresponding parameters. Dependencies are defined between parameters that share one or more contexts. The criteria for defining dependencies are shown in Table II.

4) *Modularity through clustering*: Clustering and modularization are performed after entering the dependencies of the parameters displayed in the matrix. Parameters within a single module are grouped according to their respective deep dependencies, and dependencies between modules are minimized.


III. ANALYSIS OF SMART ROBOTS USING SRDM

A. Smart robot AIREC

The smart robot, AIREC is being developed as a general-purpose AI robot that can work together with humans in

Persona

- **Name:** Kinuyo Sato
- **Age:** 77 years old
- **Gender:** Female
- **Family Composition:** Herself, daughter, and son-in-law (with grandchildren)



Recent Situation:

- Lives in a quiet residential area in Tokyo.
- Her husband passed away a few years ago, and she now lives alone in a Tokyo apartment complex.
- She is friendly and caring, often looking after her friends in the apartment complex. However, she is also forgetful and somewhat crass, and struggles with tasks that require precision.
- She currently has diabetes and visits the hospital regularly. She has been instructed to monitor her vital signs and take medications at home.

Goals:

- To accurately measure vital signs at home.
- To be able to detect any abnormalities in her body from vital signs data, even without specialized knowledge.

Fig. 4. persona

fields such as welfare and medical care, where there is a shortage of human resources is a problem (Fig. 2). The goal is to use AI to perform a wide range of tasks, from customer service and housekeeping to nursing and medical care [5]. One of the services offered by this smart robot is a health monitoring service. The goal of this service is to collect biometric information and manage health in a natural way through natural contact in people's daily lives. One of the functions to accomplish this is the measurement of vital data. This service is designed for users who need to monitor their health status on a daily basis, such as three generations of people living together, elderly people living together, or people living alone. Designed for use in the home, the system measures vital signs such as body temperature, blood pressure, pulse, and blood oxygen from the user's arm. It also has a communication function that greets users and checks their physical condition, a function that calls users according to the collected data and their physical condition, and a function that prompts users when medical treatment is needed. In addition, because the robot is connected to the server of an external electronic medical record system, users can be identified, facilitating individualized medical treatment. The activity diagram of a smart robot is shown in Fig. 3. An activity diagram is a Unified Modeling Language (UML) diagram that shows the data objects that are consumed or generated and the order in which the various actions are performed [2].

We analyze the services provided by this service robot using SRDM and modularize them for improved design after installation.

B. Analysis by SRDM

1) *Service Design*: First, we created a persona as the intended recipient of the services of the smart robot. The persona is an elderly woman who visits the hospital for diabetes and needs to have her vital signs measured regularly. This persona currently lives alone and does not use nursing services, but requires daily health monitoring. The main persona information is shown in Fig. 4.

The customer journey map and service blueprints are shown in Fig. 5 and Fig. 6.

2) *Service robot design model*: Based on the category table shown in Table I, we organized the parameters that make up the smart robot and the environment in which it is deployed, and constructed a service robot design model (Fig. 7). The function deployment was used to organize the design parameters. Function deployment identifies the functions and parameters necessary to realize the service to be provided by decomposing them[7]. The parameters obtained from this process have been classified as design parameters in the category table. From the "Task" described in the blue labels, the "Context" representing the scenario in which it is executed, and the "Design Parameters" required to execute it are connected.

3) *Dependency definition and clustering*: Finally, we plotted the design parameters constructed in the service robot design model on a matrix to define the dependencies between parameters that share the same context. The cluster analysis grouped the 24 parameters into 5 modules. The clustering results are shown in Fig. 8. The five modules represent a set of parameters to perform the functions of voice recognition, user identification, robot movement, user physical condition monitoring, and vital signs data measurement, respectively. This module oversees the parameters organized by scene in the service design phase from the perspective of the entire service system and represents them in the form of a matrix.

C. Analysis Results

1) *Design of services using SRDM*: Although the smart robot can perform a series of operations to measure vital data, the service part of the system to be introduced and provided was not designed. Therefore, when defining the dependencies, personas were set up as specific target images, and the series of services to be provided were concretely understood to clarify how the smart robot would be incorporated into the service system and how the services would be provided.

Services have heterogeneity in that even if the provider is the same, the content changes depending on the recipient[8]. In addition to the personas created this time, many other users can be used as target users. By creating multiple personas and imagining different situations, the required features and services become clearer.

2) *Modularization of parameters using SRDM*: By designing a service robot design model for a smart robot using a predefined category table, we could express the relationships between the parameters of the service system and the robotic system required to provide the service. In addition, by modularizing the parameters with deep dependencies, it was possible to capture, to some extent, the effect of a change in one parameter on the other parameters. For example, let us focus on the "Presence of steps", one of the Service Design Parameters classified as an element to be introduced. This parameter is included in the module that defines the robot's movement function, but depending on the presence of steps, the robot's "Mobility mechanism", classified in the same module, can be of the wheeled or

walking type. In addition, the determination of the movement path included in the "Autonomous movement function" is also likely to be affected by the presence of steps. The difference between modular design and robot design is that the service design parameters are not parameters of the service robot, and therefore they are assumed to change. Therefore, it is necessary to have redundancy in the robot design parameters that can respond to changes in the Service Design Parameters. This makes it possible to predict, to some extent, which parameters will interfere with the robot when the service robot is introduced, and it is expected that unexpected interferences will be avoided in advance. Thus, the study of design specifications for the realization of services is performed from different perspectives, and these modules support the study by presenting dependencies.

In this study, we have dealt with vital data measurement services, but smart robots can provide a variety of other services. As the number of functions increases, the system becomes more complex, but SRDM can be used to fully express complicated parameter relationships and is expected to facilitate understanding and design.

3) *Link from service design to robot design*: When designing a service, it is important to focus on the customer experience to improve the quality of the service[9]. However, although the flow of the vital measurements can be captured in the activity diagram of Fig. 3, the part that integrates this flow into the overall service system has not been designed.

SRDM evaluates the service flow from the user's perspective, using the system perspective represented by the activity diagram and the methods used in service design, such as the customer journey map. The relationships between the parameters of the service system and the robotic system are then visualized. In addition, modularization is expected to improve the ease of designing the improvements that are needed after the robot is introduced into the service system and to serve as a link between the robotic system and the service system. This will help to link robot design and service design.

This paper focused on vital data measurement services, but in order to accurately evaluate the usefulness of SRDM, it is necessary to apply SRDM to various other services, to increase the number of examples, and to verify SRDM by actual services and robot designers.

IV. CONCLUSION

We used SRDM to analyze a service for measuring vital data provided by AIREC, a smart robot under development. We designed the service part of the smart robot by determining how it would be integrated into the service system and how it would provide the service sequence. By organizing the relationships between the parameters of the service system and the robotic system, we tried to modularize the system and improve the ease of designing improvements. These results show that SRDM can be used to connect a service system and a robot system in the case of a vital data measurement service.

Phase	Exchange greetings	Retrieve user information	Move to the user's side	Obtain consent to measure vital signs data	Measuring vital signs data	Check user's physical condition	Provide appropriate voice guidance
Touch Points User behavior	Robot greets user when it detects entry, and user greets back	Robot recognizes user and obtains individual ID	Robot moves closer to the user	Asking users to consent to vital signs data	Robot measures vital signs data from user's arm	The robot asks the user about his/her physical condition.	Judges the user's condition based on vital signs data and physical condition, and calls out to the user.
User's thoughts	• I live alone, so when someone greets me, I feel like I'm with someone else and it makes me happy.	The robot is moving, so let's just sit tight.	• The robot is moving, so let's just sit tight.	• I feel reassured because the robot confirms my consent each time it measures my vital signs.	• The robot measures with just the right amount of force, so it is painless and probably more accurate than doing it yourself. • I appreciate it because it takes a lot of preparation and time and effort to do it myself.	• Thanks to the checkup, I can take time to face my condition.	• Thanks to the robot's ability to determine my condition by combining my physical and vital signs data, I can notice any abnormalities even when I am unaware of them.

Fig. 5. Customer Journey Map

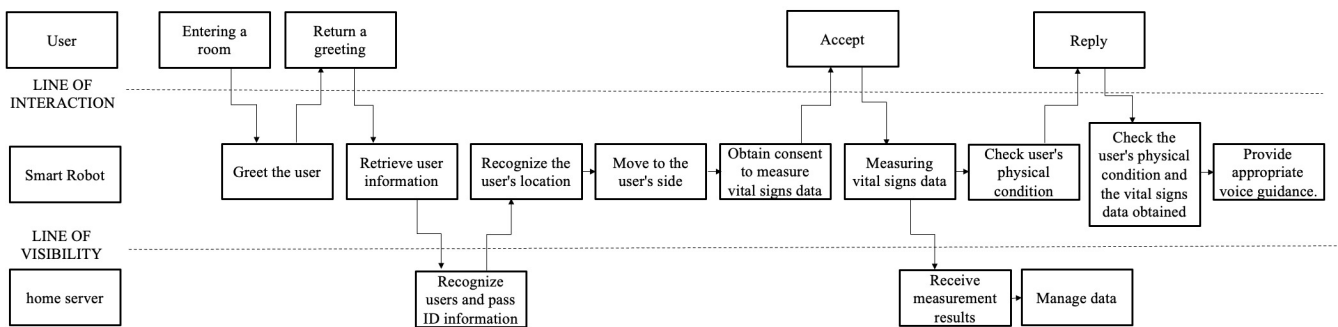


Fig. 6. Service Blueprint

In the future, the usefulness of SRDM should be further verified by increasing the number of cases in which SRDM is adapted by actual designers and by using it in the design of new robots instead of existing robots.

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