

# Basic Research on the Development of Space Standards for the Use of Service Robots in Housing Using the Urban Renaissance Agency's Housing Complex

**Ren Matsuoka**

*Graduate School of Engineering, Kyushu Institute of Technology,  
1-1 Sensui-cho, Tobata, Kitakyushu, Fukuoka, 804-8550, Japan*

**Kanon Nonoshita,**

*School of Engineering, Kyushu Institute of Technology,  
1-1 Sensui-cho, Tobata, Kitakyushu, Fukuoka, 804-8550, Japan*

**Naoto Ishizuka**

*Graduate School of Engineering, Kyushu Institute of Technology,  
1-1 Sensui-cho, Tobata, Kitakyushu, Fukuoka, 804-8550, Japan*

**Ryohei Kobayashi, Akinobu Mizutani, Hakaru Tamukoh, Hirofumi Tanaka**

*Graduate School of Life Science and Systems Engineering, Kyushu Institute of Technology  
Research Center for Neuromorphic AI Hardware, Kyushu Institute of Technology,  
2-4 Hibikino, Wakamatsu, Kitakyushu, 808-0196, Japan*

*E-mail: matsuoka.ren711@mail.kyutech.jp, nonoshita.kanon733@mail.kyutech.jp*

## Abstract

This study conducts basic research on developing space standards for integrating home service robots in residences, using a room in an housing complex from Urban Renaissance Agency as a model. The study compares these spaces with existing robot mobility standards to identify issues. The robot-friendly level of the room was evaluated using RFA standard. Results showed that most rooms fell into Level C, the lowest of three levels, in areas such as “fixture width” and “steps.” Furthermore, when operating two types of home service robots, the study uncovered unique robot behavior issues in the housing that were not anticipated by RFA standard.

*Keywords:* Living space, Home service robot, Steps, Aisle widths, RFA standards, Urban Renaissance Agency

## 1. Introduction

In Japan, not only industrial robots but also service robots with independent mobility have begun to spread in recent years. Examples include guidance robots, transport robots, and cleaning robots for offices, public facilities, and commercial facilities. Cleaning robots, monitoring robots, pet robots, and small transport robots that can operate in the home are also commercially available. The safe and comfortable operation of these service robots can be considered mainly from the perspective of controlling the robot and maintaining the environment in which the robot operates.

This study examines the safe and comfortable operation of service robots from the viewpoint of environmental arrangements related to the robot's

operation, i.e., the performance of the space in which the robot operates.

In Japan, the Robot Friendly Asset Promotion Association standard (RFA standard) (Fig.1) established by the Robot Friendly Asset Promotion Association is a standard for the safe and comfortable operation of robots in buildings. RFA standard is intended for public facilities, commercial facilities, and offices. It sets a Robot Friendly Level for each item, such as the size of steps, based on Japanese barrier-free laws and several service robot operation experiments. However, RFA standard does not assume the interior of homes and residences as the target space in its establishment process. We consider the difference between a house and a public facility. Generally, a house consists of private rooms such as living room, dining room, kitchen, and bedroom, and a corridor connecting them. Rooms are separated from

each other by doors, and the width of these doors is usually around 900 mm. The width of corridors is generally around 780 mm based on architectural design modules, since there is little need to consider passing each other.

In that corridor, for example, consider the case of operating the Human Support Robot (HSR), which is being developed as a home service robot. [2] The footprint of HSR is 430 mm, so when a person and a robot pass each other, the passage width for the person would be 350 mm, which is quite narrow and would interfere with daily life. In addition, it is impossible for robots to pass each other. On the other hand, in commercial spaces that are public facilities, doors and other fittings that limit the entrance are not provided, and the frontage is generally large, in anticipation of the passage of an unspecified number of users. In addition, according to the Building Standard Law, corridors with rooms on both sides must be at least 1.6 m wide in floors of 200 m<sup>2</sup> or more. Thus, there is a large difference in standard dimensions between residences and public facilities due to the difference in the number of people using the space. In addition, many houses with many fittings have steps on the floor due to the sashes of the fittings, footwear slides, and guttering materials. On the other hand, the Barrier-Free Law requires public facilities to have as few steps as possible, and ramps to eliminate steps are easier to install in commercial facilities with a larger floor area than in residential facilities.

Therefore, environmental conditions for the safe and comfortable operation of home service robots may differ from those in public facilities, commercial facilities, and offices. Consequently, this study will organize issues on whether RFA standard can be used as an appropriate standard when aiming for the diffusion of home service robots. This is basic research on the standardization of

space for the diffusion of home service robots in residences.

## 2. Outline and subject of this study

### 2.1. Outline of this study

In this study, we used a room in an housing complex of Urban Renaissance Agency (UR) as a model and conducted a measurement survey in the area where the thresholds are specified in RFA standard. Through this investigation, we verified where the modeled room was placed in RFA standard's Robot Friendly Level. This survey verified the relationship between robot friendliness level and actual home service robot behavior.

### 2.2. Subject of this study (1)-RFA standard

RFA standard was established in 2024 by the Robot Friendly Asset Promotion Association (RFA). This standard evaluates environmental factors that affect robot operations and quantifies them into three “Robot Friendly Levels” (Levels A through C). In developing the standard, environmental factors affecting robot operation were first identified through a literature review and on-site survey. In the literature review, factors such as passage widths, slopes, steps, and illumination were extracted based on building codes, barrier-free codes, and fire codes, and specific numerical standards were established. Next, a demonstration experiment was conducted using three meal delivery robots sold by Softbank Robotics. This experiment confirmed the presence or absence of problems caused by environmental factors and verified the validity of the robot-friendly level hypothetically defined in the literature survey.

RFA Standard (Facilitation of Service Robot Mobility - Classification and Indicators of the Physical Environment - Buildings and their Premises RFA B 0003: 2024)

Annex G “Robot-Friendly Level Definition List”

Item	summary	Level A	Level B	Level C	Rationale and Considerations
		The robot's mobility is even greater than in Level B. Desired level	Level of robot mobility without facility renovation	Refurbishment of facilities, review of operations, etc. Level at which the robot becomes mobile	
a) Steps	Excluding door sill of fittings.	6mm or less	-	More than 6mm	Refer to JIS T9251 (Regulations concerning the shape and dimensions of projections of guide blocks for the visually impaired and their arrangement) and “Guidelines for the Design of Housing for the Elderly”.
b) Groove	The width should be sufficiently wider than the robot, and should be set for the width and depth directions, assuming wheel slip-off.	Width: less than 10mm Depth: -	Width: 10mm or more but less than 20mm or Depth: 5mm or less	Width: 10mm or more but less than 20mm or Depth: 5mm or less	The standard is based on whether the casters fit or fall 5mm. The minimum caster width is 20 mm in JIS S 1038:1994 (casters for office chairs) and JIS B 8923:2015 (casters for industrial use). Since the curved ground surface, the caster may fit in the groove direction at robot-friendly level B. Robot-friendly level A is set regarding fine grating.
c) Aisle width	Set both sides of the aisle as vertical walls, about the width direction.	1.8m or more	1.2m or more but less than 1.8m	Less than 1.2m	1.2m is assumed to be the width necessary for a service robot and a person to pass each other, based on the Barrier-Free Act's facilitation standard. 1.8m is assumed to be the width necessary for robots to pass each other based on the Barrier-Free Law's facilitation and guidance standard. The induction standard has an effective dimension of 900 mm for entrances, exits, and flapper gates.
d) Fittings width and specifications	Set the effective width of doors and other openings for the robot to pass through, and the type of door, such as whether it can open and close automatically.	Width of fittings: 0.9m or more and Specifications: Automatic opening and closing door	Fittings width: 0.8m or more but less than 0.9m and Specifications: Automatic opening and closing door (Server integration functionality is required when security is involved.)	Fittings width: Less than 0.8m or Specifications: Not automatic opening and closing door	The effective width is the narrowest width including doorknobs and other protrusions. The 0.8m width of the fittings is based on the Barrier-Free Law's facilitation standard, and the 0.9m width is based on the same guidance standard.

Fig. 1 Excerpt of sizes that define the friendly level of the RFA standard [1]

### 2.3. Subject of this study (2)-UR

UR was established in 1955 as the Japan Housing Corporation to solve the severe housing shortage immediately after World War II. After its establishment, the demand for housing was for quantity for 20 years, including a period of high economic growth. [3] However, it changed from quantity to quality from around 1975, and from around 1995 to the revitalization and utilization of estate stock. And now, UR owns approximately 1,400 estates with a total housing stock of 700,000 units (as of March 2024). [4] However, due to the semi-public nature of these units, UR housing is currently difficult to replace. In addition, UR's management policy is to utilize housing complexes built after 1979 without demolishing them in principle. A survey by MLIT [5] is a comprehensive statistical survey of housing planning and spatial conditions in Japan. However, there is no statistical survey on details such as the existence and size of steps, which is necessary to verify consistency with RFA standards.

In UR housing, spatial conditions such as the existence and size of steps are different from one room to another. However, there exist specifications for UR housing that are referred to as models or standard designs. There are also standard specifications for materials and construction methods. Therefore, there is a possibility that some statistical analysis can be performed in the future. Because of these peculiarities of UR housing, we selected UR housing as the subject of this case study.

### 3. Field survey at Edamitsu estate

The subject of this survey is a room in the Edamitsu estate, a housing complex operated by UR (address: 4-14 Edamitsu, Yahatahigashi Ward, Kitakyushu City, Fukuoka Prefecture). The estate is a five-story reinforced concrete structure, and the subject room is located on the fourth floor of Building No. 14. The layout of this room is 3DK with an area of 65 m<sup>2</sup>. In this survey, measurements were made for the items of “steps,” “gutters,” “passage width,” and “fixture width” among the environmental factors specified in RFA standard. The results are summarized in Fig. 2 below.

In addition, Table 1 shows the results of applying these values to the Robot Friendly Levels of RFA standard. Items such as “fixture width,” “steps,” and “groove depth” fell into Level C, the lowest of the three levels, in the majority of the houses.

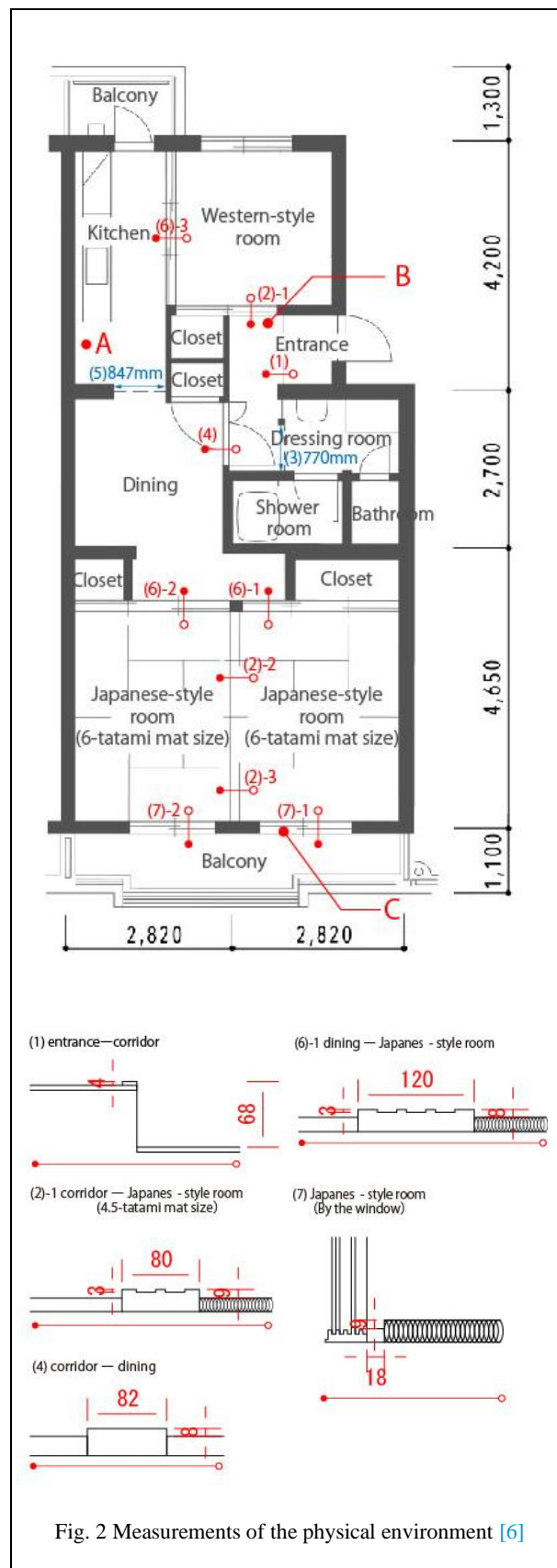


Fig. 2 Measurements of the physical environment [6]

Table 1. Color-coded by level of RFA standard

		Level A The robot's mobility is even greater than in Level B, Desired level	Level B Level of robot mobility without facility renovation	Level C Refurbishment of facilities, review of operations, etc. Level at which the robot becomes mobile		
		Step width	Step height	Groove	Fittings width / Aisle width	
(1)	entrance — corridor		Outside → Inside: 68mm			
			Inside → Outside: 4mm			
(2)-1	corridor — Japanes - style room (4.5-tatami mat size)	80mm	9mm	3mm	880mm	
(3)	corridor — dressing room				770mm	
(4)	corridor — dining	82mm	8mm		1020mm	
(5)	kitchen — dining				847mm	
(6)-1	dining — Japanes - style room	120mm	8mm	3mm	838mm	
(7)-1	Japanes - style room (By the window)	34mm	9mm			
		18mm	40mm			

#### 4. Robot operation experiment

We also conducted operational experiments with two types of home service robots, Luna (Loona Blue, A34A0) and Roomba (Roomba Combo 10max, RCA-Y2), in the same room. For Roomba, we set up a station at Fig. 2 position A and used the mapping function to move the robot around the entire room. Roomba was unable to enter the shower room, which had a large step up. Roomba did not stop at any of the steps or widths we measured, except for the step at the entrance. At the step at the entrance, the step detection function was activated and Roomba did not fall. However, at a slight difference between the entrance and the Western-style room (Fig. 2 position B), Roomba was unable to escape and had to be moved by our hand.

Luna can perform any of its pre-defined actions, such as “summoning” and “returning to the charging station,” by voice input. However, due to the characteristics of the AI used, it does not always perform as instructed. For this reason, we used a controller to make the robot perform arbitrary actions in this operation experiment. Luna was unable to enter the shower room, which had a large step up. Luna did not stop at any of the steps or widths we measured, except for Fig. 2 position C. At the step at the entrance, it did not detect the step and fell to the entrance dirt floor side. It can be pointed out that if the front door is released, Luna could exit the dwelling unit. In the situation where the opening on the terrace side was open and the screen door was closed (Fig. 2 position C), a wheel fell into the groove and Luna was unable to escape and had to be moved by our hand.

One issue related to movement that RFA standard does not seem to anticipate, which is unique to the house and unique to Japan, is the removal of shoes. For example, Luna can descend to the entrance earthen floor. When the difference in level is lowered due to a barrier-free dwelling, for example, it can be assumed that Luna will come up again from the entrance earthen floor to the flooring. It can be pointed out that dirt from the entrance dirt floor may be brought into the flooring.

#### 5. Conclusion and Prospect

In this study, using one room in the Edamitsu estate, an estate of UR, we confirmed the Robot Friendly Level in RFA standard. The results showed that the majority of the rooms in the housing fell into Level C, the lowest of the three levels, for items such as “fixture width,” “step height,” and “groove depth. By running two different types of home service robots, we also discovered a challenge related to the robot's movements unique to the not believe is contemplated by RFA standard. UR owns many housing units with specifications similar to those of the Edamitsu estate. In other words, they represent a large proportion of the housing stock. The results of this paper showed that physical barriers at level C of RFA standard may not impede the movement of home service robots. If the development standards for home service robots are set to level A, the design would be over-specified for robots used in homes. What are the appropriate specifications for a home service robot? We believe that indicators for home service robots can be set by subdividing Level C of RFA standard.

As for prospects based on the results of this study, it is necessary to clarify the physical conditions under which the home service robots experience operational difficulties. We plan to conduct such movement experiments in the future.

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**Authors Introduction**

**Mr. Ren Matsuoka**



He received his bachelor's degree in Engineering in 2024 from the Faculty of Engineering, Kyushu Institute of Technology in Japan. He is currently a master student in Kyushu Institute of Technology, Japan.

**Ms. Kanon Nonoshita,**



She is currently a bachelor's student in school of Engineering, Kyushu Institute of Technology, Japan.

**D r. Naoto Ishizuka**



He received the B.E., M.E., and Ph.D. degrees from the Yokohama National University, in 2010, 2013, and 2019, respectively. He was an Assistant Professor with the Kyushu Institute of Technology, from 2018 to 2024. His research interests include architectural design. He is a member of the Architectural Institute of Japan and The Japan Institute of Architects.

**Mr. Ryohei Kobayashi**



He received his Bachelor's degree in Engineering in 2024 from the College of Engineering, Tamagawa University in Japan. He is currently a master student in Kyushu Institute of

Technology, Japan.

**Mr. Akinobu Mizutani**



He received his B.Eng. and M.Eng. degrees from Kyushu Institute of Technology, Japan in 2020 and 2022, respectively. He is currently a doctoral course student at Kyushu Institute of Technology, Japan. His research interests include brain-inspired artificial intelligence and environmental design for home service robots. He is a student member of IEEE, IEICE, and RSJ.

**Dr. Hakaru Tamukoh**



He received the B.Eng. degree from Miyazaki University, Japan, in 2001, and the M.Eng. and Ph.D. degrees from the Kyushu Institute of Technology, Japan, in 2003 and 2006, respectively. He was a Postdoctoral Research Fellow at the Kyushu

Institute of Technology, from April 2006 to September 2007. He was an Assistant Professor with the Tokyo University of Agriculture and Technology, from October 2007 to January 2013. He is currently a Professor with the Graduate School of Life Science and Systems Engineering, Kyushu Institute of Technology. His research interests include digital hardware design, neural networks, and home service robots.

**Dr. Hirofumi Tanaka**



He completed his doctorate in materials science by studying the structural and magnetic properties of ferromagnetic nanoalloys at Osaka University in 1999. Then, he moved to a national laboratory, RIKEN, as a postdoc researcher and then joined the Research Center for Molecular-Scale Nanoscience at the Institute for

Molecular Science in 2003 as an assistant professor. He moved to the Department of Human Intelligence Systems, Graduate School of Life Science and Systems Engineering, Kyushu Institute of Technology (Kyutech) as a full professor in 2014. He concurrently became a director of the Research Center for Neuromorphic AI Hardware, Kyutech, from 2020. He was awarded an honorary degree from Suranaree University of Technology, Thailand, in 2021, and received the degree certificate directly from Thai HRH Princess Sirindhorn. He also became a visiting professor of Universiti Putra Malaysia in 2024. His broad knowledge of materials, from metals and inorganic materials to organic materials, and techniques for measurement and fabrication helped lead efforts in molecular electronics and in combining many kinds of nanomaterials to realize a new world of "materials intelligence".