Service-Field Simulator using MR Techniques:
Behavior Comparison in Real and Virtual Environments

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ABSTRACT

We developed the *Service-Field Simulator* (SFS) for virtually providing us with service fields in which the users can walk and perform relatively simple work repeatedly that is frequently seen in actual service fields, and for realizing pre-evaluation for supporting service-field design based on understanding conscious and unconscious behavior of the subjects. In this paper, we report a feasibility study to examine the effectiveness of the SFS by comparing behaviors of users in both of a real environment and augmented virtuality (AV) environment. In this study, we observed the behaviors and eye movements of the subjects through simple tasks. Especially, we evaluated the preservation of sense of absolute orientation by omni-directional display, the hands-free control by footfall and body rotation, and the communication function with others by a photo-realistic avatar. Consequently, we found that the subjects felt high spatial presence and high involvement despite low realism and high task load in the AV environment. Most of all, we confirmed that they kept their sense of absolute orientation and could share information by papers (e.g. maps, indications) and by the photo-realistic avatar in both environments. Also, we found the capability of the SFS for the pre-evaluation of the service fields reproduced in AV environments. We expect that the SFS will be useful to pre-evaluate service fields.

KEYWORDS: Service-field simulator, behavior comparison, augmented virtuality, omni-directional display, hands-free, avatar.

INDEX TERMS: H.5.2 [Information Interfaces and Presentation]: User Interface—Evaluation/Methodology; I.3.7 [Computer Graphics]: Three-Dimensional Graphics and Realism—Virtual reality; I.6.7 [Simulation and Modeling]: Simulation Support Systems—Environments

1 INTRODUCTION

Service has four characteristics consisting of intangibility, inseparability of production and consumption, heterogeneity, and perishability [16]. Each characteristic refers to the total lack or perception of a service's characteristics before and after it is performed, the simultaneous production and consumption of services, the potential for high variability in the performance and the quality of services, and the fact that services cannot be saved, stored, resold or returned, respectively.

Some of them arise from the fact that service providers and service receivers have many different demands in service fields depending on different situations. When the service providers try to find out optimal conditions in case of construction, maintenance, and remodeling of service fields considering those characteristics, intervention in actual service fields is often required. However, it is inevitable that such intervention is accompanied by human cost and risks of disturbing normal operations.

Our first approach for alleviating this problem is to virtually providing service fields in which we can walk and perform relatively simple work repeatedly that is frequently seen in actual service fields.

In this paper, we first introduce our simulator, referred to as the *Service-Field Simulator* (SFS), to pre-evaluate service fields by realizing virtual or augmented virtuality (AV) environments. Then we report the feasibility study of the SFS through experiments to compare subject's behavior in a real and AV environment.

2 RELATED WORKS

Recently, Mixed Reality (MR) technology is using to support a simulation for architectural design, military exercises, education, medical facility, and so on. Especially, we had views on an approach using MR technology to apply various service fields [15][1]. It can help to try various methods for filling many different demands of users about services without a field study. Most of all, we have to consider an immersive environment for giving the sense of presence to users when constructing virtual environments (VEs). For providing immersive environment to users, many research use immersive displays such as the HMD, the CAVE [4], the Garnet Vision [5], the Ensphered Vision [6], the *blue-c* [7], the Cyber Dome [8], and so on.

The HMD, the six-sided CAVE, the Garnet Vision, and the Ensphered Vision surround the user completely, and support the feeling of "being in" that full immersive environment. But, the HMD has the limitation of the FOV and the problem of eye fatigue. And, users are not able to watch their real body, and cannot obtain any information by handheld devices or maps while wearing the HMD. In the case of the six-sided CAVE, it is required a large space because of the rear and down projection, and difficult to set up on any place. Since the Garnet Vision was built with dodecahedron screen and 12 projectors and the Ensphered Vision was built with a spherical screen and convex and plain mirrors, it is fairly difficult to develop and leas to cost.

The *blue-c*, the Cyber Dome, and 3-5 sided CAVEs have only support immersive environment during "looking at" a virtual environment (VE), but have limits as the freedom of movement because these are not omni-directional. So, if users turn to the back, they don't receive any graphical information because the environment of their back is not a VE but a real environment (RE). So, they feel discordance of their behavior in VEs.

Navigation is one of the most common activities in VEs. Also, Locomotion by walking is one of the frequently happened

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[1]The *Service-Field Simulator* (SFS) was named the *Walk-Through Simulator* (WTS) [3, 15] before changing it in this paper.

behaviors, for instance, when customers do window-shopping or way-finding in service fields. Navigation devices such as the Walking-Pad [9], the ODT (the Omni-Directional Treadmill) [10] were developed in order to navigate by walking in VEs. The Walking-Pad based on the pressure sensor can detect the movement by the foot position on the sensor. However, the boundary of walking space is very restricted. The ODT use a treadmill to synchronize VEs with step motion, and the step speed is reflected in navigating VEs. But, it is not safety when a user walks on the device, thus he/she should grab additional safety devices.

3 SYSTEM OVERVIEW FOR SENSING BEHAVIORS IN VES

The *Service Field Simulator* (SFS) was developed for virtually providing us with service fields in which the users can walk and perform relatively simple works repeatedly that is frequently seen in actual service fields, and for realizing pre-evaluation for supporting service-field design based on understanding conscious and unconscious behavior of the users as shown in Figure 1.

These can be denoted simple works in service fields as follows:

• *Watching*: window-shopping, information gathering by papers (e. g. a map, a catalogue, a menu, a poster, a handbill, or a sign), check for arranging merchandise, and so on.

• *Communication*: an order, a way-finding, a sale, a purchase, asking a place, a question, an answer, and etc.

• *Behaviors*: selecting goods, opening a door, pushing a button, distributing handbills, and etc.

We need to restrain the noise mixture on the evaluation data that is the cause of the difference between a real and AV environment on the user test using virtual service fields. For instance, the locomotion by walking is frequently occurred behavior with the clues based on the sense of absolute orientation and the surrounding environment in daily lives. And then, persons obtain the visual information synchronized that situation. Moreover, they also obtain the information by the communication with other person, and by handheld devices or papers (e.g. sign-board, bulletin, map, etc.) on the hand-free state. With these human behaviors, we need to get accurate results by reducing the difference between a real and AV environment in the user test as providing similar situation and sense in the AV environment. Also, we need to consider the cost for the construction and the maintenance of the simulator in itself in order to reduce the reconstruction cost of the AV environment. Besides, we should be relieve the limitation of the feasible place for the evaluation experiment because one of the maximum costs in case of performing the experiment is the constraint of subjects, especially service providers. For satisfying these requirements, we developed the SFS by considering the characteristics as follows:

1) Visual presentation of an AV environment by the omni-directional display
2) Control system by walking-in-place and body rotation
3) Information sharing by the conversation
4) Structure occupying less space relatively and making duplication easily

As shown in Figure. 2, walking-in-place and body rotation of a user are detected by using PDR sensor module [1, 2], and then the user perform the locomotion and the changing direction in AV space. This control system can help the reproduction of supporting works and obtaining information by handheld devices or papers owing to be hands-free. The PDR sensor module is used to gain the position and direction of pedestrians and to provide personal navigation services in real environment [1, 2]. But we introduced the PDR sensor module for detecting walk-in-place and body rotation in AV environments. Therefore, we can consider to realize the control system dovetailed with more actual feeling by examining the relationship of the characteristic between walking in the RE and walking-in-place in the SFS targeting same user as a result of using same sensor.

AV environment is displayed on 4 screens distributed equally by the front projection using 4 projectors. The simulator becomes the omni-directional immersive environment by this structure, and then it can be support to offer the visual information synchronized with user's movement. Also, users can preserve the sense of absolute orientation thanks to offer the locomotion method by walking-in-place and body rotation.

Moreover, we offer the communication function with other users using the photorealistic avatars [3] based on image processing techniques in which are generated real-time, because the communication between service receivers and providers is one of the important factors for the investigation research of the information sharing. We use two cameras which one is for extracting the feature of the real person taking a role of an avatar,

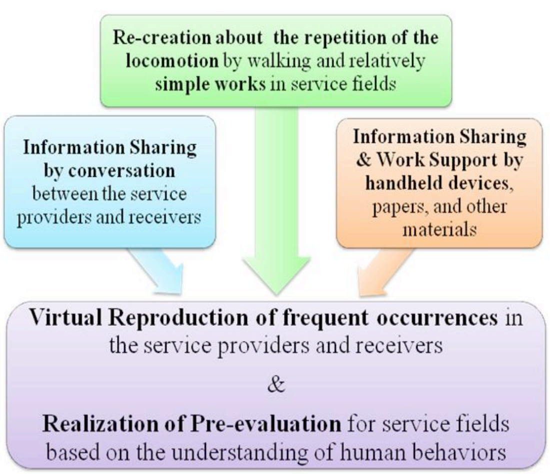


Figure 1. The purpose of the Service-Field Simulator

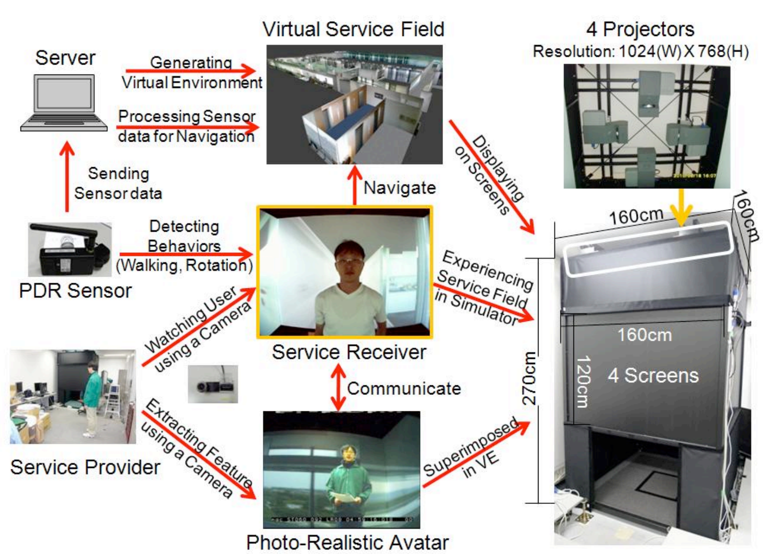


Figure 2. The Service-Field Simulator (SFS)

and the other is for watching the user in the SFS. As a result, service providers and receivers can have a face to face conversation with each other in virtual service fields as shown in Figure. 2.

In addition, we implemented the easiness of the reproduction by compact and simple structure for improving the social implementation.

So, it has the possibility for the experiment at near the service fields, potentially.

4 Experiments for Comparing Behaviors in the Real and Virtual Environments

We performed the feasibility study as comparing subject's behaviors in the real and virtual environment for verifying the validity of the SFS in itself. The experiments were consisted of three sessions including six tasks in the RE and AV environment. And, each experiment was conducted under the same environment, condition, and tasks in respect of both environments. So, we considered the evaluation about the applicable scope, the reproducible possibility, and the effectiveness of the information sharing by communication, maps, signs, and so on.

We carried out each session about three aspects consisting of navigation, communication, and spatial recognition. And also, we analyzed the task load of both environments and the sense of presence in the AV environment using the NASA Task Load Index (TLX) [12]. For evaluating the AV environment, we used the Igroup Presence Questionnaire (IPQ) [13] and the post-evaluation questionnaire. Particularly, we observed the behaviors and eye movements of the subjects in the RE and AV environment. Subjects were tested individually under the same condition equipping with same devices. Finally, we estimated behaviors of each subject using their eye movement by video from the center camera of the EMR-9 (Eye Mark Recorder, NAC Co.) and activity patterns marked by PDR sensor data.

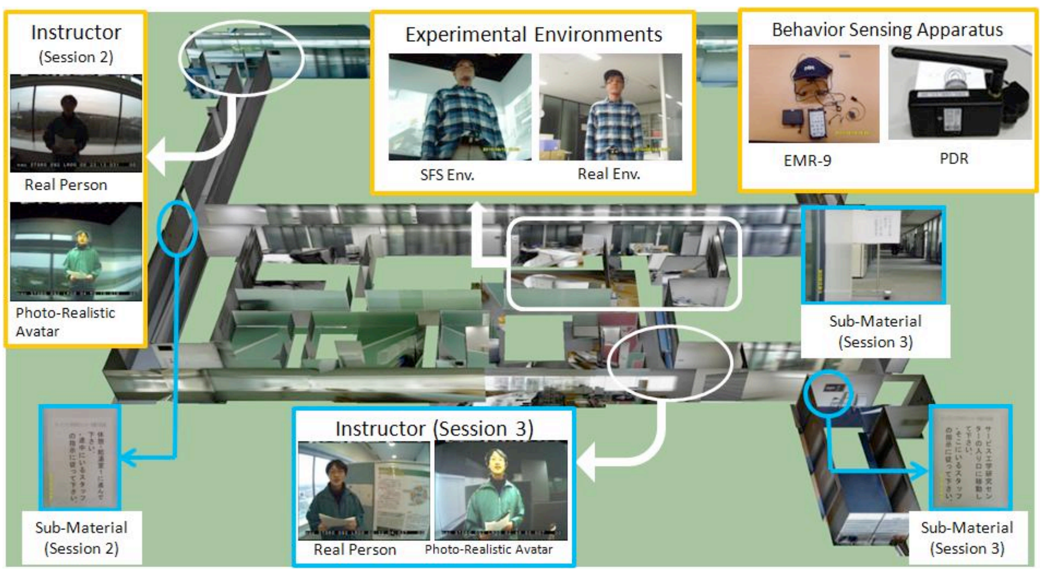


Figure 3. Experimental Environment and Apparatus

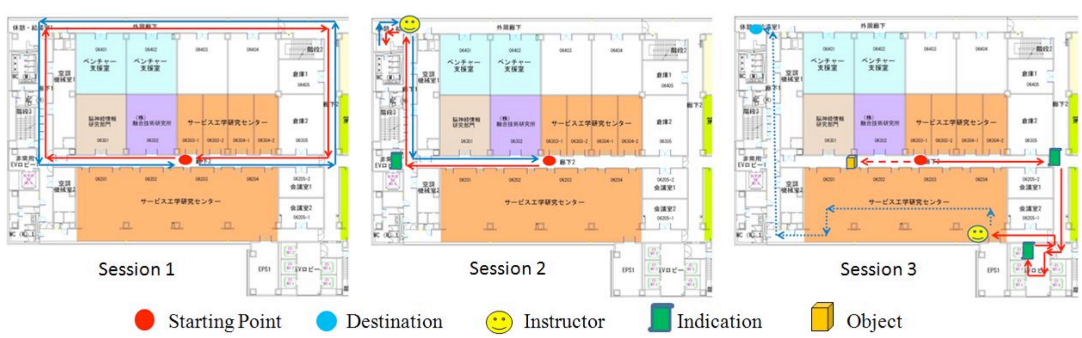


Figure 4. Procedure of Each Session

4.1 Experimental Method

4.1.1 Participants

The subjects were five volunteers, with a male to a female ratio of 2:3. The age of them was from the twenties to the fifties. They have had no experience of the virtual environments and little used devices related to virtual reality techniques. Three of the subjects were stranger in the experiment place.

4.1.2 Apparatus

Subjects equipped with some devices for experiments on their body (Figure 3-top-right). For tracking their gaze, we used the EMR-9. Subjects put on the cap attached one camera for tracking the watching direction, and two cameras for tracking the eye movement. And they attached the PDR sensor module on the center of the belt for detecting walking and turning as shown in Figure 3-Behavior Sensing Apparatus. We gave user a map as shown in Figure 4 which is specified not the route but the name of each place. And we served subjects instructions using indications and photo-realistic avatars (Figure 3-Instructor). We used several posters for indicating next tasks or measuring the longest readable distance (Figure 3-Sub-Material).

4.1.3 Environments

We constructed the AV environment as similar as possible to the RE using the interactive 3D indoor modeler [11] as shown in the base image of Figure 3. And then, we carried out the experiments in the same conditions.

Figure 4 indicates the procedure of each session. Subjects performed each experiment following the routes, but the given map to subjects was unexpressed the routes. The dotted line of session 3 is meant the free-selection route by themselves.

4.1.4 Description

Table 1 indicates the description of experiments consisted of three sessions and six tasks.

Table 1. The description of experiments

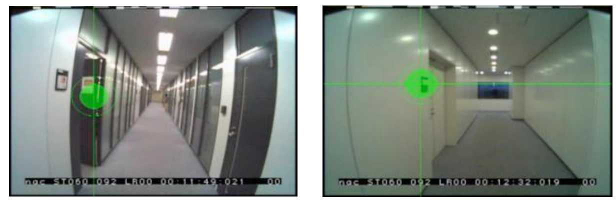
Experiments	Details	
Session 1	• Confirming the difference of the navigation between the RE and AV environment	
	Task 1	Carrying out locomotion by taking a walk around the corridor
Session 2	• Checking up the difference of the information gain process • Estimating the communicational function between a subject and an instructor	
	Task 1	Walking and searching the poster, and confirming the detail
	Task 2	Putting a work into operation at the instructor's dictation
Session 3	• Confirming the spatial recognition and the information gain by a map	
	Task 1	Measuring the readable distance as far as they can read a poster
	Task 2	Indicating the direction of the destination without a map
	Task 3	Comparing the selected route by making subject's own decision

4.2 Results

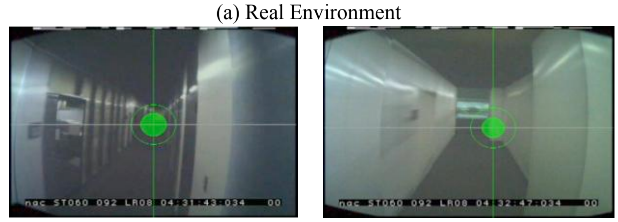
4.2.1 Observational Results

Session 1

We found some patterns when subjects navigate both environments. Totally, subjects took the total spending time of navigation in the AV environment longer than in the RE, because they have had no experience in the AV environment. But, locomotion time was shortened with the lapse of time in the both environments. It indicates that they adapt themselves to devices and environments.



(a) Real Environment



(b) AV Environment

Figure 5. Watching out the surrounding circumstance

(a) Real Environment (b) AV Environment

Figure 6. Perceiving Objects

In the RE, they watched out around as preparing for any contingency such as suddenly open a door, bump into a person coming around a corner, and so on. But, they did not attend the surrounding circumstance in the AV environment as shown in Figure 5.

And also, they perceived objects in the RE, but kept a watchful eye on the front in the AV environment as shown in Figure 6.

Session 2

We prepared a poster and an instructor for testing information sharing. In this session, we wanted to confirm behaviors while subjects obtained information from indications or instructors. Because service receivers get information by signs, maps, indications and guiders, or obtain information by having a conversation with other person in service fields.

Subjects performed tasks on instructions of the posters and the instructor as shown in Figure 3-Instructor and Sub-Material. Especially, we used a photorealistic avatar instead of a real instructor in the AV environment (Figure 7 (b)). We observed that they paid attention to the instructor's face during the explanation, and tried to take eye contact in both environments as shown in Figure 7. But, there was the difference that subjects turned their head toward direction indicated by the instructor in the RE, on the other hand, they still stared at the instructor's face despite of the instructor's gesture for pointing at other place in the AV environment. And, there was no significant difference about time for moving the next stage after finding out indications between the RE and AV environment.

(a) A instructor in the RE

(b) A instructor in the AV environment

Figure 7. Giving an eye to an instructor

(a) Real Environment (b) AV Environment

Figure 8. Confirming a map for finding a route

Figure 8 indicates that subjects watch a map for finding a route from current position to destination. It means that they can get information on hands-free condition in the SFS like real environment.

Session 3

Subjects were tested their sense of spatial recognition in the RE and AV environment by measuring the readable distance, indicating the direction of the destination, and freely selecting the route from the current position to the destination.

Subject1 (eyesight:1.5) Subject2 (eyesight:0.9) Subject4 (eyesight:0.2)

(a) Real Environment

Subject1 (eyesight:1.5) Subject2 (eyesight:0.9) Subject4 (eyesight:0.2)

(b) AV Environment

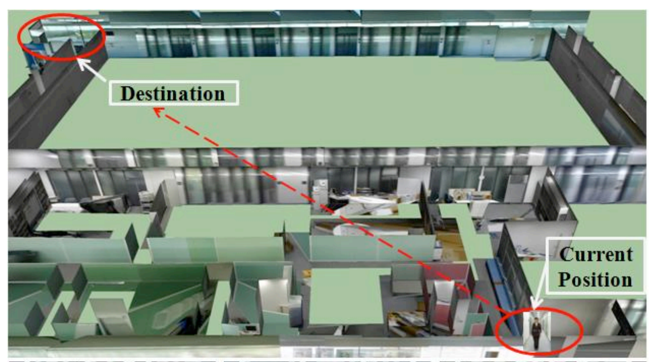
Figure 9. Longest Readable Distance

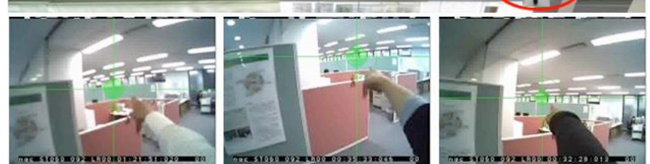
Figure 9 indicates the experiment for measuring the readable distance. The eyesight of three persons among the subjects has 1.5 and two subjects have each 0.9 and 0.2 vision in both eyes. The readable distance was differently measured per their eyesight in the RE (Figure 9-(a)), whereas it was approximately measured as the same distance despite different eyesight in the SFS (Figure 9-(b)).

The screen size of the SFS is set as 160cm (width) * 120cm (height) because aspect ratio of projected image is 4:3, and the resolution of each project is 1024 (width) * 768 (height), i.e. 4:3. In the case of person with 1.0 vision, the minimum resolving power is about 1 minute (1/60 degree) as the optic angle. Therefore, to be effective the same eyesight with 1.0 in the RE, we have to provide a user with the resolution of 5400 * 4050 when user stand the center of the SFS that is 80 mm apart from the screen. Consequently, the resolution of images displayed in the SFS became the resolving power of about 0.19 times against the RE, and user with 1.0 vision in the SFS watched the scenes with approximately 0.19 visions weaker than their eyesight in the RE. Thus, the longest readable distance was shortened in the SFS more than in the RE.

We requested that subject pointed a finger at the direction of the destination following instructor's denotation after walking around the appointed area in the RE and AV environment as shown in Figure 10.

All of subjects indicated the correct direction without any hesitation and confusion. On the basis of their selection, we deducted that they could keep the sense of absolute orientation in both environments.





(a) Real Environment

(b) Virtual Environment

Figure 10. Test for Sense of Absolute Orientation

On the task for comparing the selected route when subject freely decided a locomotion path by themselves, they selected the same route in both environments.

4.2.2 Questionnaire Results

Subjects answered to fill in the questionnaire of the NASA-TLX after finishing each session, and to complete questionnaires of the IPQ and the post-evaluation after finishing all experiments in the RE and the AV environment inside the SFS.

Figure 13 indicates the total result of the task load per each session. Totally, the tasks in the SFS were measured higher than in the RE about physical demand, effort, and frustration. This means that subjects needed more strenuous exertion and more effort to achieve tasks in the SFS. And also, they were under stress in the SFS. However, we have to reconsider because there is a wide difference between individuals in the VE as shown in Figure 12-(b).

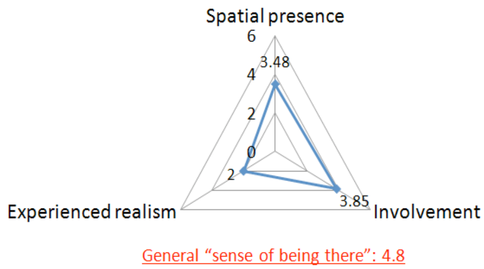
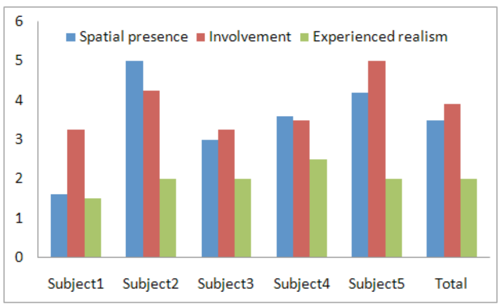
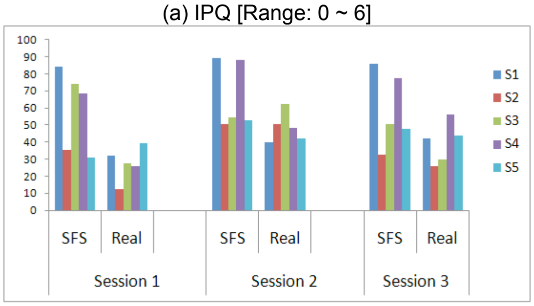


Figure 11. Result of IPQ [Range: 0 ~ 6] (Spatial presence (mean: 3.48, SD: 1.29), Involvement (mean: 3.85, SD: 0.76), Experienced realism (mean: 2.0, SD: 0.35))



(a) IPQ [Range: 0 ~ 6]



(b) NASA-TLX [Range: 0 ~ 100]

Figure 12. The result of the questionnaire per each subject

All of subjects felt the general "sense of being there" in the AV environment reproduced by the SFS respectively. And, most subjects felt the sensation as if they were surrounded by the virtual space and were present in there. But, they were mostly apt to think of the AV environment as just 3D CG images as shown in Figure 11.

Subjects who felt high presence and high involvement in the AV environment were comparatively showed better performance than others who did not as shown in Figure 12.

Table 2. The result of the post-evaluation questionnaire about the experiments in the VE [Range: 0 ~ 6]

Item	Mean (SD)	Anchors
Concentration	4.4 (0.89)	not at all ~ very much
Difficulty of the direction adjustment	4.6 (1.52)	very easy ~ very hard
Discordance of a photo-realistic avatar	2.0 (1.22)	fully accordance ~ fully discordance
Consciousness of apparatus	1.6 (0.89)	not at all ~ very much
Degree of freedom	2.8 (1.30)	fully restrict ~ fully free
VR sickness	1.4 (1.67)	did not feel ~ very felt

Table 2 indicates the result of the post-evaluation questionnaire about the experiments in the AV environment inside the SFS. Subjects were showed high concentration in the AV environment. And they did not nearly feel the sense of physical disorder by the photorealistic avatars. Practically, they also did not feel discordance as compared with common behavior, and were scarcely conscious of attaching devices. Moreover, nevertheless equipping with devices on their body, most subjects answered that they could almost freely navigate in the AV environment without feeling unnatural. And, they scarcely felt the VR sickness except one subject.

4.2.3 Verification of the Questionnaires

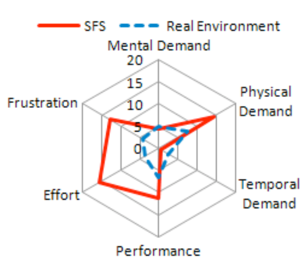
We carried out verification about the concordance of each item on the questionnaires among replies of subjects using Friedman test which is nonparametric method. And, we used the result of the NASA-TLX about the SFS for verifying the result of questionnaires because the IPQ and the post-evaluation are the questionnaire about the AV environment. So, we setup the hypothesis for verifying the concordance as follows:

H0: *The ranking of the items is not in discord with the reply among subjects.*
H1: *The ranking of the items is in accord with the reply among subjects.*

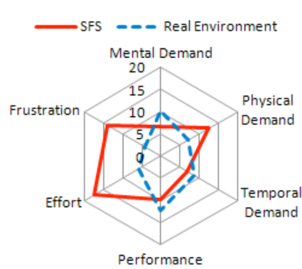
We got the result that each item has consistency among subjects, and the result allowed us to test the result for statistical significance through the chi-square test.

($\chi^2 = 27.555 > 19.675 = \chi^2(11, 0.05)$, p=0.004<0.05)

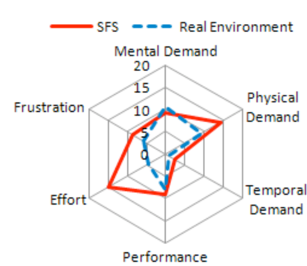
Thus, Rankings of the items have the concordance of the reply among subjects because H0 was rejected by p<0.05.



(a) Session 1



(b) Session 2



(c) Session 3

Figure 13. The Task Load of Each Session [Range: 0 ~ 100] ((a) Real: Mean 27.5 (SD 9.8) SFS: Mean 58.7 (SD 23.9) (b) Real: Mean 48.6 (SD 8.9) SFS: Mean 67.1 (SD 19.7) (c) Real: Mean 39.5 (SD 12.0) SFS: Mean 58.9 (SD 22.2))

We could know that the ranking of "Consciousness of apparatus" is the highest and the ranking of "Difficulty of the direction adjustment" is the lowest as shown in Table 3. It means that the items of the high ranking were scarcely different the result of subjects, but the items of the low ranking had difference of the result among subjects. So, we knew that the items of the low rankings had a wide difference between individuals, actually we can confirm to Figure 12.

Table 3. The average ranking of each items on questionnaires

Items	Average Ranking	Items	Average Ranking
Consciousness of apparatus	3.10	TLX of Session 1	7.40
VR Sickness	3.30	Spatial Presence	7.50
Realism	3.80	Involvement	7.90
Discordance of Avatar	3.80	Concentration	9.20
DOF of Body	5.30	TLX for Session 2	9.60
TLX of Session 3	7.20	Difficulty of the direction adjustment	9.90

Moreover, we carried out analysis about the correlation between paired items of questionnaires using Pearson correlation coefficient. As the result, we confirmed 5 paired items with significant correlation as shown in Table 4. All of the paired items have a minus sign for the correlation coefficient. It means that one item decreases as the other item increases. So, for example, if users are conscious apparatus, their concentration is dropped.

Table 4. Paired items with significant correlation (p<0.05)

Paired Items	Coefficient	p-value
Consciousness of apparatus , Concentration	-1.0	0.000
Difficulty of the direction adjustment, Involvement	-0.822	0.044
Spatial Presence, TLX for Session 1	-0.888	0.022
Spatial Presence, TLX for Session 3	-0.810	0.048
Involvement, TLX for Session 1	-0.949	0.007

Also, we tested the significant difference between both environments about the task load for each session using F-test and T-test. We got the results that the significant difference among subjects appeared the task load about the session1 (F=0.113 > 0.05, T=0.013 < 0.05) and the session2 (F=0.152 > 0.05, T=0.045 < 0.05). But, we found that the task load about the session3 was not significantly different among subjects (F=0.262 > 0.05, T=0.062 > 0.05).

4.3 Discussion

The main purpose of above-mentioned experiments is to ascertain whether we can perform the pre-evaluation about virtual service fields reproduced in the SFS or not.

So, we discuss the following categories from the results of experiments.

1) Reproducibility of AV environment displayed by the SFS
2) Reproducibility of user's behavior
   i) Navigation in AV environment
   ii) The acquisition of information

• Reproducibility of AV environment

The reproduced virtual environment has to be provided users with immersive environment and a sense of presence for an accurate analysis of the target service fields.

We confirmed that our simulator can provide the immersive environment by the omni-directional structure, and knew that user can feel involvement and a sense of presence.

In the experiment of the session 3 for measuring the readable distance, we found that the eyesight of the subject had gotten bad in our simulator comparing with the RE due to low resolution of projectors. So, we could not give subjects visual effect on the same level as the RE. So, they did not perfectly fascinate by the AV environment, nevertheless they were hardly conscious of surrounding the RE when subjects navigated in the AV environment.

Thus, considering the current structure of the SFS and the resolution of the projector, the SFS has the limitation of the visual effect for offering more realism.

In the result of the correlation between the paired items, we verified the correlation that the task load influenced the spatial presence and involvement. So, we have to consider the minimization of the task load for providing high sense of presence and involvement in AV environments.

• Reproducibility of user's behavior

- Navigation in AV environment

Persons ordinarily move by walking as the method of the locomotion without attaching any device in service fields. Hence, we have to check DOF of body movement, unnaturalness of behaviors, and discordance by apparatus in order to navigate the virtual service fields comparing with the real service fields.

Also, people can approximately determine their current position and direction toward destination by maps, signposts or surroundings in RE. It means that they can keep the sense of absolute orientation. So, we need to offer them this situation in AV environments.

In the presented experiments, we confirmed that subjects did not feel discordance as compared with common behavior, and were scarcely conscious of attaching devices nevertheless equipping with devices on their body. We knew that the consciousness of apparatus affects their concentration on the AV environment. And, they could kept the sense of absolute orientation, and did not feel VR sickness because the SFS provided subjects the scenes synchronized with their body rotation and walking-in-place by using PDR sensor and omni-directional display.

But, we found the difficulty of direction adjustment in the AV environment caused by delaying the process of the PDR sensor data. Therefore, subject felt much task load in the AV environment that the RE. This problem is regarded as the cause of the method sending by wireless after buffering the sensor data.

- The acquisition of information

It is important whether information sharing by communication or by handheld materials can be provided in the SFS because information sharing is one of the frequently happened simple works in service fields.

We confirmed that subjects could obtain information through posters and could find the route by the map, and then we observed that subject correctly performed tasks. We can say that subjects could use the papers owing to provide hands-free state by the control system with walking-in-place and body rotation using the PDR sensor module in the SFS.

Moreover, subjects could gain information by conversation with the photo-realistic avatar in real time as they got information from the instructor in the RE. Also, they did not nearly feel a sense of physical disorder by the photo-realistic avatar. The photo-realistic avatar for communicating between service providers and service receivers can be processed verbal communication as well as nonverbal communication in real time, but 3D CG avatar or other 2D image avatar is difficult to process nonverbal communication in real time and is needed additional process for that.

Totally, we could confirm the possibility of pre-evaluation for service-field by virtualization, and could find the limitation of the SFS. Service fields are very wide sector and have many demands of service providers and receivers. Thus, above all we need to consider the supply of the specialized environment and pre-evaluation for the target service field.

And, we have to consider the improvement of the locomotion method in AV environments such as the method combined translation and rotation for fulfilling more intuitive control system, the adjustment of the locomotion in AV environments based on corresponding to the characteristic of the walking in a RE and AV environment, introduction of new sensor, and so on. Furthermore, we should consider the improvement of involvement and realism by introducing the system for high resolution and stereoscopic vision. However, we must consider the trade-off between the merit of improved performance and the cost.

5 Conclusion and Future Works

We developed the *Service-Field Simulator* (SFS) for pre-evaluating service fields by reproducing as an AV environment. Through presented experiments, we confirmed that subjects felt the sense of presence and the sense of involvement in the SFS. Also, we observed that subjects could preserve the sense of absolute orientation by walk-in-place and body rotation using the PDR sensor module and by omni-directional display of the SFS. Besides, subjects could communicate with a photo-realistic avatar without feeling sense of incompatibility and they were able to navigate with a map in the AV environment on hand-free condition.

On the other hand, we have to improve the performance of the PDR for controlling in accordance with user behavior. And we need extra-experiments for giving realism to users because in these experiments we did not provide subjects with situations such as contingencies, interaction with 3D objects, and so on. Moreover, we need to verify whether pre-evaluation results affect real service field or not in case of actually applying to real service field.

Our system provides the communication function by man to man, but we will look forward to share information among multi-user using a great number of the SFS thanks to convenient duplication by the compact and easy mechanism.

We expect that virtually re-creative environment to perform the pre-evaluation using the SFS will be able to use as a feasibility study for service fields, and our approach will be possible for supporting a primitive design of service processes, signs, and layouts simultaneously. And, the SFS will be useful for pre-evaluation, if it supports the functions of the multimodal manipulation and the selection.

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