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

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Introduction

Finding out optimal conditions for service fields (construction, maintenance, remodeling) Accompanied by human cost and risks of disturbing normal operations

Need intervention in actual service fields

Alleviating this problem by virtually providing service fields
The purpose of the Service-Field Simulator (SFS) is to re-create the repetition of locomotion by walking and relatively simple work in service fields. It also involves information sharing by conversation between service providers and receivers, as well as information sharing & work support by handheld devices, papers, and other materials. The virtual reproduction of frequent occurrences in the service providers and receivers leads to the realization of pre-evaluation for service fields based on the understanding of human behaviors.
System Overview for Sensing Behaviors in AVEs

Characteristics of the SFS

Visual presentation of an AV environment by the omni-directional display

Control system by walking in-place and body rotation
- Preserving the sense of absolute orientation
- Hands-free state

Structure occupying less space relatively and making duplication easily

Information sharing by the conversation

AV environment: Augmented Virtuality environment, VR: Virtual Reality, RE: Real Environment
System Overview for Sensing Behaviors in AVEs

Service-Field Simulator (SFS)

Server
- Generating Virtual Environment
- Processing Sensor data for Navigation
- Sending Sensor data

PDR Sensor
- Detecting Behaviors (Walking, Rotation)
- Watching User using a Camera

Service Provider
- Extracting Feature using a Camera

Virtual Service Field
- Navigate

Service Receiver
- Communicate

Photo-Realistic Avatar
- Superimposed in VE

4 Projectors
- Resolution: 1024(W) x 768(H)
- Displaying on Screens

160cm x 120cm
- 4 Screens
- Experiencing Service Field in Simulator

160cm x 76cm
- 4 Screens
- Displaying on Screens

270cm

270cm
System Overview for Sensing Behaviors in AVEs

Service-Field Simulator (SFS)

- Server: Generating Virtual Environment, Processing Sensor data for Navigation
- PDR Sensor: Detecting Behaviors (Walking, Rotation)
- Service Receiver: Watching User using a Camera, Communicating
- Virtual Service Field: Navigate
- Service Provider: Communicating
- Photo-Realistic Avatar: Superimposed in VE

4 Projectors
Resolution: 1024(W) x 768(H)

Experience Service Field in Simulator
Displaying on Screens
System Overview for Sensing Behaviors in AVEs

Service-Field Simulator (SFS)

- Server: Generating Virtual Environment, Processing Sensor data for Navigation
- PDR Sensor: Detecting Behaviors (Walking, Rotation)
- Service Provider: Watching User using a Camera
- Photo-Realistic Avatar: Extracting Feature using a Camera
- Service Receiver: Communicate
- Virtual Service Field: Navigate

4 Projectors
Resolution: 1024(W) X 768(H)

160cm x 160cm x 270cm
4 Screens
System Overview for Sensing Behaviors in AVEs

Service-Field Simulator (SFS)

Server
- Generating Virtual Environment
- Processing Sensor data for Navigation

PDR Sensor
- Detecting Behaviors (Walking, Rotation)

Virtual Service Field

Service Receiver
- Watch User using a Camera
- Extracting Feature using a Camera
- Communicate
- Superimposed in VE

Photo-Realistic Avatar

Service Provider

4 Projectors
- Resolution: 1024(W) X 768(H)

Experience Service Field in Simulator

Displaying on Screens

Sending Sensor data

Navigate
• Subjects
  – 5 volunteers (male: 2, female: 3)
  – No experience of virtual environments and devices related VR

• Apparatus
  – PDR sensor module
    • Detecting walking and turning
  – EMR-9
    • Tracking subject’s gaze

• Environments
  – Constructing the AV environment as similar as possible to RE
    • By using the interactive 3D indoor modeler
  – Carrying out experiments in the same conditions

• Evaluation
  – By using Questionnaire (NASA-TLX, IPQ, Post-Evaluation) and Behavior Data (PDR, EMR-9)
Experiments for Comparing Behaviors in the RE & AVE

- **Description**

  - **Session 1**
    - in the Real Environment
    - Real Environment
  
  - **Session 1**
    - in the AV Environment
    - AV Environment

  - **Session 2**
    - in the Real Environment
    - Real Environment
  
  - **Session 2**
    - in the AV Environment
    - AV Environment

  - **Session 3**
    - in the Real Environment
    - Real Environment
  
  - **Session 3**
    - in the AV Environment
    - AV Environment
### Observational Results

- **Session 1**

<table>
<thead>
<tr>
<th>Similarity</th>
<th>Real Environment</th>
<th>AV Environment</th>
</tr>
</thead>
<tbody>
<tr>
<td>✓ Locomotion time reduction by the lapse of time</td>
<td>✓ No caution in surroundings</td>
<td>✓ Keeping a watchful eye on the front</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Difference</th>
<th>Real Environment</th>
<th>AV Environment</th>
</tr>
</thead>
<tbody>
<tr>
<td>✓ Watching out for preparing the contingency</td>
<td>✓ No caution in surroundings</td>
<td>✓ Keeping a watchful eye on the front</td>
</tr>
<tr>
<td>✓ Perceiving some objects</td>
<td>✓ Watching out surrounding</td>
<td></td>
</tr>
</tbody>
</table>

**Observational Results**
- **Watching out Surroundings**
  - Real Environment
  - AV Environment
- **Perceiving Objects**
  - Real Environment
  - AV Environment
# Observational Results

## Session 2

<table>
<thead>
<tr>
<th>Similarity</th>
<th>Real Environment</th>
<th>AV Environment</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>✓ Attention to the instructor’s face during the explanation</td>
<td>✓ Continuously staring at the instructor’s face regardless of the instructor’s gesture</td>
</tr>
<tr>
<td></td>
<td>✓ Attempt to take eye contact with the instructor</td>
<td>✓</td>
</tr>
<tr>
<td></td>
<td>✓ Way-finding by map</td>
<td>✓</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Difference</th>
<th>Real Environment</th>
<th>AV Environment</th>
</tr>
</thead>
<tbody>
<tr>
<td>✓ Changing of eye direction toward the pointing direction by the instructor</td>
<td>✓</td>
<td></td>
</tr>
</tbody>
</table>

## Attention to the Instructor

- **Real Environment**
  - Images of attention to the instructor in the real environment.
- **AV Environment**
  - Images of attention to the instructor in the AV environment.

## Way-finding by Map

- **Real Environment**
  - Images of way-finding by map in the real environment.
- **AV Environment**
  - Images of way-finding by map in the AV environment.
## Observational Results

### Session 3

<table>
<thead>
<tr>
<th>Similarity</th>
<th>Real Environment</th>
<th>AV Environment</th>
</tr>
</thead>
<tbody>
<tr>
<td>✓ Preservation of the sense of absolute orientation</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Difference</th>
<th>Real Environment</th>
<th>AV Environment</th>
</tr>
</thead>
<tbody>
<tr>
<td>✓ The measurement of the longest readable distance following subject’s eyesight</td>
<td></td>
<td></td>
</tr>
<tr>
<td>✓ The shortening of the longest readable distance caused by dropping the resolving power without reference to subject’s eyesight</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Observational Results: Indicating the destination**

- **Real Environment:** Subject 1 (eyesight: 1.5), Subject 2 (eyesight: 0.9)
- **AV Environment:** Subject 4 (eyesight: 0.2)
### Questionnaire Results

#### The Task Load of Each Session

- **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 photorealistic 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

#### Evaluation Result of the AV environment

<table>
<thead>
<tr>
<th>Item</th>
<th>Mean (SD)</th>
<th>Anchors</th>
</tr>
</thead>
<tbody>
<tr>
<td>Concentration</td>
<td>4.4 (0.89)</td>
<td>not at all ~ very much</td>
</tr>
<tr>
<td>Difficulty of the direction adjustment</td>
<td>4.6 (1.52)</td>
<td>very easy ~ very hard</td>
</tr>
<tr>
<td>Discordance of a photorealistic avatar</td>
<td>2.0 (1.22)</td>
<td>fully accordance ~ fully discordance</td>
</tr>
<tr>
<td>Consciousness of apparatus</td>
<td>1.6 (0.89)</td>
<td>not at all ~ very much</td>
</tr>
<tr>
<td>Degree of freedom</td>
<td>2.8 (1.30)</td>
<td>fully restrict ~ fully free</td>
</tr>
<tr>
<td>VR sickness</td>
<td>1.4 (1.67)</td>
<td>did not feel ~ very felt</td>
</tr>
</tbody>
</table>
• Results of Verification
  – The concordance of each item among replies of subjects
    • Using Friedman test which is nonparametric method
      – $X^2=27.555>19.675=X^2(11, 0.05), p=0.004<0.05$
    • High ranked items have consistency among subjects
      – Consciousness of apparatus, VR sickness, Realism, Discordance of AVATAR
    • Low ranked items have a wide difference between individuals
      – Concentration, TLX for session 2, Difficulty of the direction adjustment

<table>
<thead>
<tr>
<th>Items</th>
<th>Average Ranking</th>
<th>Items</th>
<th>Average Ranking</th>
</tr>
</thead>
<tbody>
<tr>
<td>Consciousness of apparatus</td>
<td>3.10</td>
<td>TLX of Session 1</td>
<td>7.40</td>
</tr>
<tr>
<td>VR Sickness</td>
<td>3.30</td>
<td>Spatial Presence</td>
<td>7.50</td>
</tr>
<tr>
<td>Realism</td>
<td>3.80</td>
<td>Involvement</td>
<td>7.90</td>
</tr>
<tr>
<td>Discordance of Avatar</td>
<td>3.80</td>
<td>Concentration</td>
<td>9.20</td>
</tr>
<tr>
<td>DOF of Body</td>
<td>5.30</td>
<td>TLX for Session 2</td>
<td>9.60</td>
</tr>
<tr>
<td>TLX of Session 3</td>
<td>7.20</td>
<td>Difficulty of the direction adjustment</td>
<td>9.90</td>
</tr>
</tbody>
</table>
• Results of Verification
  – The correlation between paired items of questionnaires
    • Using Pearson correlation coefficient
    • Confirmed 5 paired items with significant correlation and inverse relation

<table>
<thead>
<tr>
<th>Paired Items</th>
<th>Coefficient</th>
<th>p-value &lt; 0.05</th>
</tr>
</thead>
<tbody>
<tr>
<td>Consciousness of apparatus, Concentration</td>
<td>-1.0</td>
<td>0.000</td>
</tr>
<tr>
<td>Difficulty of the direction adjustment, Involvement</td>
<td>-0.822</td>
<td>0.044</td>
</tr>
<tr>
<td>Spatial Presence, TLX for Session 1</td>
<td>-0.888</td>
<td>0.022</td>
</tr>
<tr>
<td>Spatial Presence, TLX for Session 3</td>
<td>-0.810</td>
<td>0.048</td>
</tr>
<tr>
<td>Involvement, TLX for Session 1</td>
<td>-0.949</td>
<td>0.007</td>
</tr>
</tbody>
</table>
Discussion

Reproducibility of AV environment displayed by the SFS

- The possible provision of the sense of “being there” in general, and the sense of involvement and presence
  - By offering the immersive environment with the omni-directional structure
- The limitation of the visual effect
  - Caused by the resolution of the projector and the current structure of the SFS
Discussion

Reproducibility of user’s behavior

- The possibility of keeping the sense of absolute orientation and preventing VR sickness
  - Owing to provide the synchronized scenes
    - with user’s body rotation and walking-in-place using PDR sensor
    - omni-directional display
  - Subjects did not feel discordance as compared with common behavior
  - Nevertheless equipping with devices on their body
- The difficulty of direction adjustment in the SFS
  - Caused by delaying the process of the PDR sensor data

Navigation in AV environment
Reproducibility of user’s behavior

The possibility to obtain or to provide information
- By paper materials
  - owing to provide hands-free state by the control system
- By conversation with the photo-realistic avatar in real time
  - the possible provision of verbal communication as well as nonverbal communication
  - the possible provision of extemporaneous response

The acquisition of information
Conclusion

• Developed the Service-Field Simulator
  – For pre-evaluating service fields by reproducing as an AV environment
• Performed the experiments to compare behaviors in the real and AV environment
• Carried out the feasibility study for the SFS
• Confirmed some defect of the current SFS
• Confirmed the possibility of pre-evaluation for service fields using AV environments

The realization of the pre-evaluation for service fields using the SFS
Future Works

• The improvement of the locomotion method in AV environments
  – 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 for detecting walking & rotation

• The improvement of involvement and realism
  – By introducing the system for high resolution and stereoscopic vision
  – Need consideration of the trade-off between the merit of improved performance and the cost

• The realization of the specialized environment and pre-evaluation for the target service field
Thank you for your attention!!!