Implementation of a Scalable Interactive Visualization Environment to Support Information Sharing and Decision-Making in Megadisasters*

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Abstract

In this study, we implemented a scalable interactive visualization environment to support information sharing and decision-making at the headquarters of an emergency management department using a large, high-definition, touch display. The interactive information-sharing system visualizes various contents transmitted from the Web-based information transmission system on the large, high-definition, touch display. The Web-based information transmission system enables information sharing on the large, high-definition, touch display by transmitting various contents to the Web server. To evaluate the effectiveness of the interactive information-sharing system, we conducted a survey, including 12 local government employees from the disaster prevention division and 101 local residents, who were asked to evaluate the system for operability, functionality, effectiveness, and relevance. The results of the survey indicate the subjects' overwhelmingly positive response to the system for all four measures.

Keywords: Touch Interaction, Decision Support, Information Sharing Support, High Definition Large Touch Display, Large-Scale Natural Disaster

1 Introduction

In a disaster-prone country like Japan, when a disaster is likely to occur, the heads of national and local governments will establish headquarters for an emergency management department and headquarters for an emergency alert system [15]. When large-scale natural disasters occur, municipal officials must perform various tasks, such as operation of an evacuation center, provision of relief supplies, and evaluation of the damage, in addition to normal operations. In the emergency management headquarters, information is shared among the officials of each department, including the general of the headquarters. Therefore, the officials at the emergency management headquarters make decisions for all types of disaster response. Moreover, according to the study titled "Toward strengthening functions of municipal emergency management headquarters—Disaster prevention information system application examples" [16], staff members of the emergency management headquarters are required to prepare in advance space for the emergency management headquarters conference room, the disaster prevention information system, etc., so that the headquarters is ready for emergency management officials to make decisions based on

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disaster-related information and to enrich and strengthen the emergency management department's functions. Specifically, immediately after a disaster occurs, the emergency management headquarters needs to be modified so that officials can share information using large displays, television (TV) monitors, etc. However, in day-to-day operations, the emergency management headquarters also shares information in analog form, using whiteboards and white papers. In the emergency management headquarters of the Great East Japan Earthquake and the Kanto–Tohoku Heavy Rainfall, various problems occurred as government officials attempted to make decisions. The "Verification report of the Correspondence of Kinugawa River flood in Joso-city (2015)" [3] summarized by the Joso-City Flood-Control Measure Verification Committee pointed out the following problems:

- Municipal officials could not grasp the extent of flooding and the overall situation in the city during and after the disaster because information sharing using maps was inadequate.
- Municipal officials could not grasp real-time flooding conditions during the disaster because a TV was not placed in the emergency management headquarters.
- The emergency headquarters passively received disaster-related information during and after the disaster, complicating the situation.

In our previous research, Takahagi et al. [19, 20, 22, 21] implemented a comprehensive disaster prevention/reduction information system that centrally manages disaster information. This system consists of three subsystems: a disaster information registration system for registering disaster information, a disaster information sharing system for sharing disaster information, and a disaster information transmission platform for transmitting disaster information. However, this disaster information sharing system cannot share information interactively using a large display.

Similarly, Hirohara et al. [6, 7, 8] implemented a disaster information cloud system. This system has an input function for disaster information provided by residents, a transmission function for transmitting disaster information to a dedicated application in real time, and a sharing function for interactive sharing of disaster information on a large display. However, this cloud system has no functions that can be used in normal times.

On the other hand, our proposal system provides users with function that can be used for ordinary meetings. By using this system from normal times, users can use the system smoothly even during disasters. The role of each department in the local government at the time of a large-scale disaster is defined in the disaster prevention plan. However, the emergency management headquarters is confused during an actual emergency. Under such circumstances, local government employees need to be familiar with the operation of the disaster information system. Therefore, in this study, we propose a scalable interactive visualization environment using a large display that can be used for ordinary meetings and emergency management headquarters meetings. In ordinary meetings, this system realizes quick sharing of reports and smooth progress of discussions. On the other hand, in the emergency management headquarters meetings, this system realizes quick sharing of disaster scene images and damage reports. Furthermore, this system supports comprehensive information sharing in cooperation with the comprehensive disaster prevention / reduction information system developed by Takahagi et al. and the disaster information cloud system developed by Hirohara et al.

The rest of the article is organized in the followings way. The related work are descried in section 2. The research objective is descried in section 3. The scalable interactive visualization environment is described in section 4. Section 5 evaluates the scalable interactive visualization environment and, finally we conclude our findings in section 6.

2 Related Works

Marrinan et al. [12] developed Scalable Amplified Group Environment 2 (SAGE2). SAGE2 enables sharing of Web pages and applications running on a personal computer (PC) on a tiled display and simultaneous display of multiple contents. Moreover, this system enables operations such as scaling the visualized contents on the tiled display and moving the content positions. However, SAGE2 is premised on sharing information on tiled displays, and the user has to directly enter the uniform resource locator (URL) to share information on the tiled display.

Kukimoto et al. [11] developed HyperInfo. HyperInfo enables interactive information sharing on a large display by flick operation of a smartphone. However, to use HyperInfo, the presenter and attendees have to install the application beforehand. Therefore, this system is not suitable for emergency management headquarters, where immediacy is required.

Sanada et al. [17] developed a disaster information system based on a present business model analysis. This system classifies information shared in a time of disaster into inspection progress information, facility damage information, emergency recovery information, support request information, traffic regulation information, and other information, and it shares this information using the electronic map provided by the Geographical Survey Institute and an electronic bulletin board. However, this system is not supposed to be used in normal times. Therefore, municipal officials are not familiar enough with this disaster information system to use it smoothly during emergencies.

Kubota et al. [10] developed a disaster information-sharing system using the open-source geographic information system resource WebGIS. This system includes a disaster information registration function, which registers disaster-related information on WebGIS, and a disaster information visualization function, which plots disaster-related information on a map. However, because this system does not have a function that allows it to be used in normal times, the municipal officials must find a way to become accustomed to the system before a disaster occurs.

Oat et al. [14] developed MoCHA, which can remotely control the contents on a large display through a smartphone. MoCHA can be used only by users who are close to the large display by connection authentication using a near-field communication tag or a quick response (QR) code. However, this system cannot share multiple contents simultaneously on the large display.

Klokmose et al. [9, 2] developed Webstrates, which can share screens among different terminals using a Web browser. Webstrates can share not only Web pages but also images, pdf documents, etc. However, this system cannot share contents interactively and cannot simultaneously visualize multiple contents.

Fender et al. [5] developed MeetAlive, which can project content onto all the walls of a conference room using multiple depth cameras and projectors. However, this system needs to set up devices such as a high-spec PC, four projectors, and a depth camera in order to build an information sharing environment.

Shen et al. [18, 4] developed UbiTable, which can face-to-face collaboration on a tabletop display. However, the user needs to install the application on the laptop before using UbiTable.

Alwakeel et al. [1] developed an information sharing system, which can safely share information on a large display using server-side encryption. This system realized easy connection between a large display and a smartphone by using a QR code. However, this system can only display a single content on a large display.

Comparative table between our work and related works is shown in Table 1. Our system provides interactive information sharing function, simple system setup, simultaneous visualization of multi contents, limited connection of users near the display, and information sharing using web system.

Table 1: Comparison with Related Works

Function	Our Proposal System	Kukimoto et al. [11]	Marrinan et al. [12]	Sanada et al. [17]	Kubota et al. [10]	Oat et al. [14]	Klokmose et al. [9, 2]	Shen et al. [18, 4]	Alwakeel et al. [1]	Fender et al. [5]
Disaster Information Registration Function				✓	✓					
Interactive Information Sharing	✓	✓	✓							✓
Simple System Setup	✓								✓	
Simultaneous Visualization of Multiple Contents	✓	✓	✓					✓		✓
Limited Connection only to Users near the Display	✓					✓		✓	✓	✓
Information Sharing using Web System	✓		✓			✓	✓		✓	

3 Research Objective

In this study, we describe a scalable interactive visualization environment to support information sharing and decision-making at the emergency management headquarters using a high resolution touch display. Our scalable interactive visualization environment consists of an interactive information-sharing system and a Web-based information transmission system. The interactive information-sharing system visualizes various disaster-related information and evacuation center information shared at the emergency management headquarters on the large display. And, the Web-based information transmission system transmits information from a smartphone, tablet, or PC through a Web browser to the interactive information-sharing system. The user can prompt the system to share images, pdfs, Web pages, etc., on the high resolution touch display using the Web-based information transmission system in emergencies. Since this system is a desktop application that does not require installation of a dedicated application, users can easily construct a large-scale interactive information-sharing environment in emergencies such as a large-scale natural disaster. The practical use of this system is expected to support information sharing and decision-making at the emergency management headquarters meeting.

4 Prototype System

The desktop application developed in this study runs on a PC connected to the large, high-definition, touch display. The interactive information-sharing system and the Web-based information transmission system start automatically at the same time that the desktop application starts up. The interactive information-sharing system facilitates information sharing on the large, high-definition, touch display. The Web-based information transmission system reflects the contents to the interactive information-sharing system through a smartphone or a tablet.

In this system, we have constructed an environment in which multiple users can share contents at high speeds and in real-time using WebSocket. The user can connect to the interactive information-sharing system using the Web browser of a smartphone or tablet. When the user connects, a simple connection is made by displaying the connecting QR code on the large, high-definition, touch display. In addition, from the viewpoint of security enhancement, we implemented an authentication function to allow connection only to users near the large, high-definition, touch display. The authentication code is visualized in the lower-right corner of the display, together with the connecting QR code. The user reflects the contents in the interactive information-sharing system on his or her handheld device by inputting this authentication code on the authentication screen of the Web browser.

4.1 Web Based Information Transmission System

The Web-based information transmission system enables information sharing on the large, high-definition, touch display by transmitting images, pdfs, Web pages (URLs), etc., to the Web server. The user can freely switch the screen using the menu button fixed to the lower-right corner of the screen. In addition, the user can quickly switch between menus because screen update processing is not performed at the time of screen transition. The menu consists of remote operation, content selection, content transmission, Web page transmission, content download, and Web page extension. The remote operation screen is a screen that allows the user to remotely operate the contents displayed on the large, high-definition, touch display. The user can remotely operate the contents by scrolling and pinching in and out on the remote operation screen, as shown in Fig. 1. After the user scrolls the remote operation screen, the touched coordinates are automatically transmitted to the interactive information-sharing system through the information-sharing server, and the window is remotely operated based on the touched coordinates, as shown in Fig. 2. In addition, the sequence diagram of the remote operation process is shown in Fig. 3.

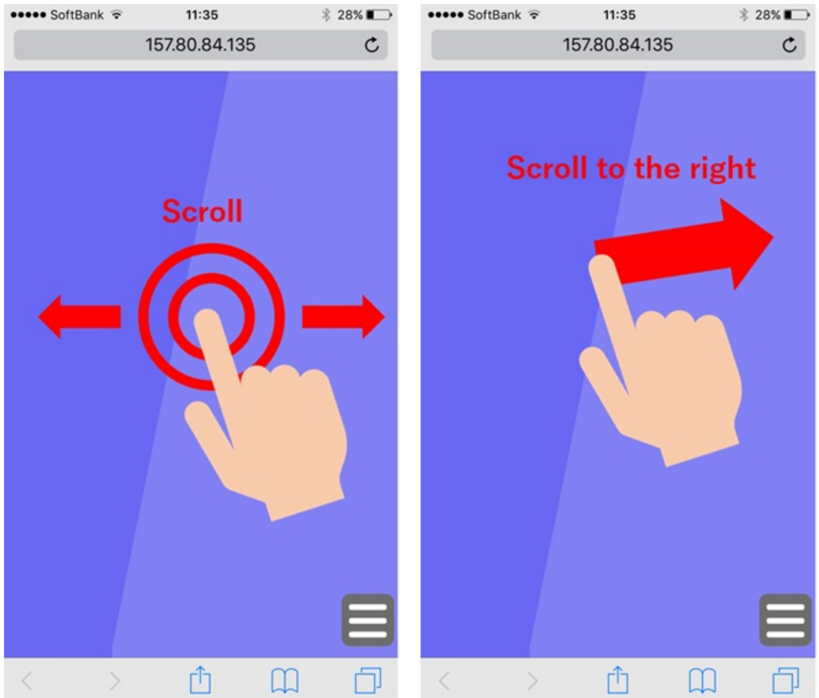

Figure 1: Remote operation by scrolling on the remote operation screen

Figure 2: Remote operation of contents on the interactive information-sharing system

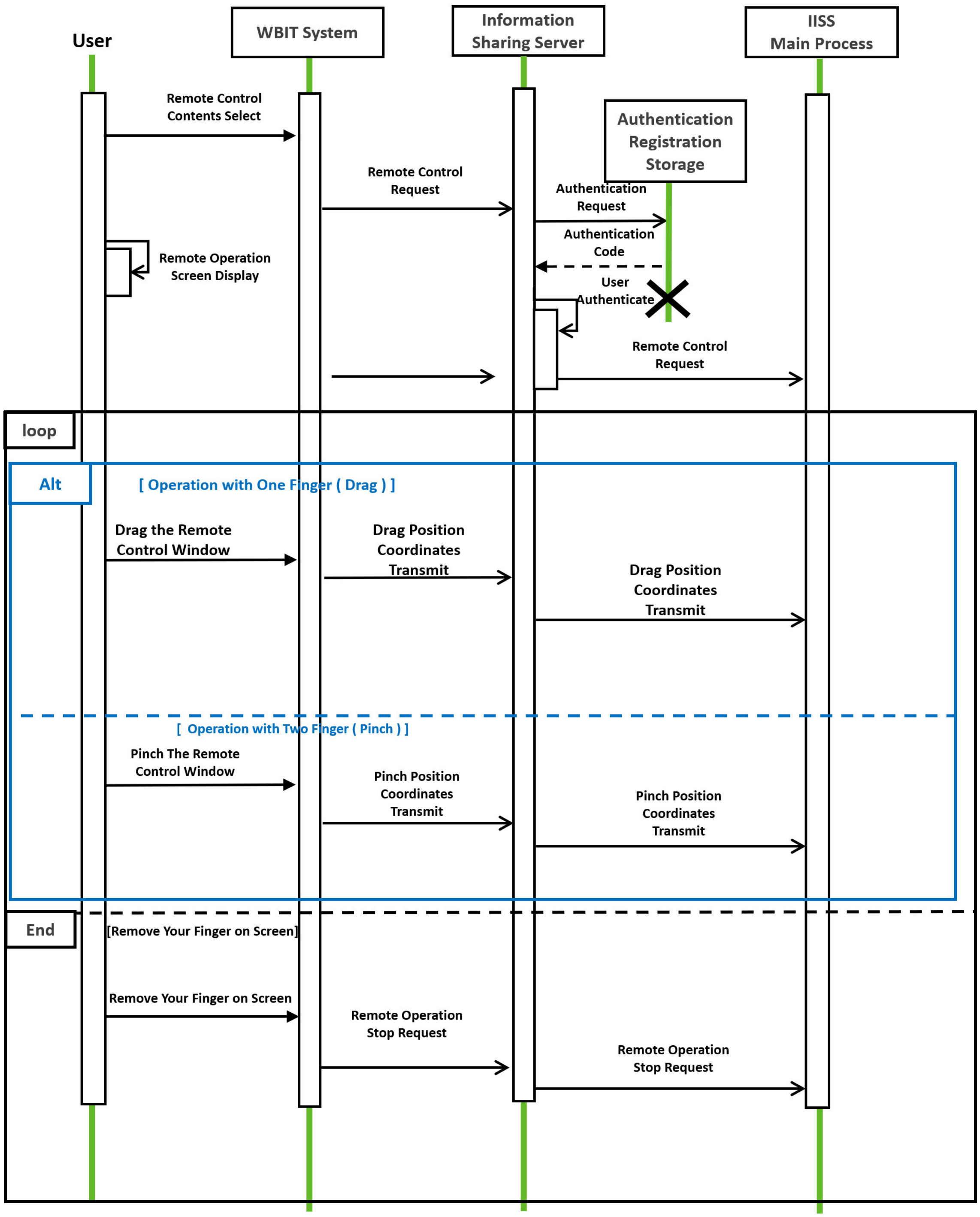

Figure 3: Sequence diagram of the remote operation process

The content selection screen allows the user to select the contents displayed on the interactive information-sharing system. When the user selects an arbitrary icon on the content selection screen, the window number corresponding to the icon is called from the session storage, and the user can remotely control the contents on the large, high-definition, touch display. The content selection screen is shown in Fig. 4.

Figure 4: Content selection screen

The content transmission screen is a screen for the user to interactively reflect the content on the interactive information-sharing system by a flick operation. After selecting an arbitrary content, the user can transmit the content by flicking upward, as shown in Fig. 5. The content is transmitted to the interactive information-sharing system through the information-sharing server by WebSocket communication. First, the Web-based information transmission system adds an authentication code to the content and transmits the content. After that, the information-sharing server collates the authentication information, and if the collation result matches, the content is visualized on the interactive information-sharing system.

In the interactive information-sharing system, the renderer process for content display is generated automatically at the same time that the main process receives the content. Thereafter, the main process asynchronously transmits the request to the renderer process by interprocess communication (IPC). After receiving the request, the renderer process renders the content on the large, high-definition, touch display, as shown in Fig. 6.

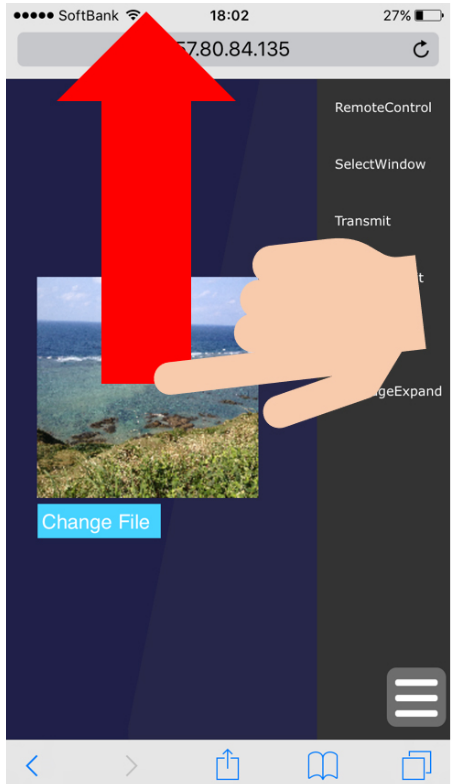

Figure 5: Transmission of contents by a flick operation

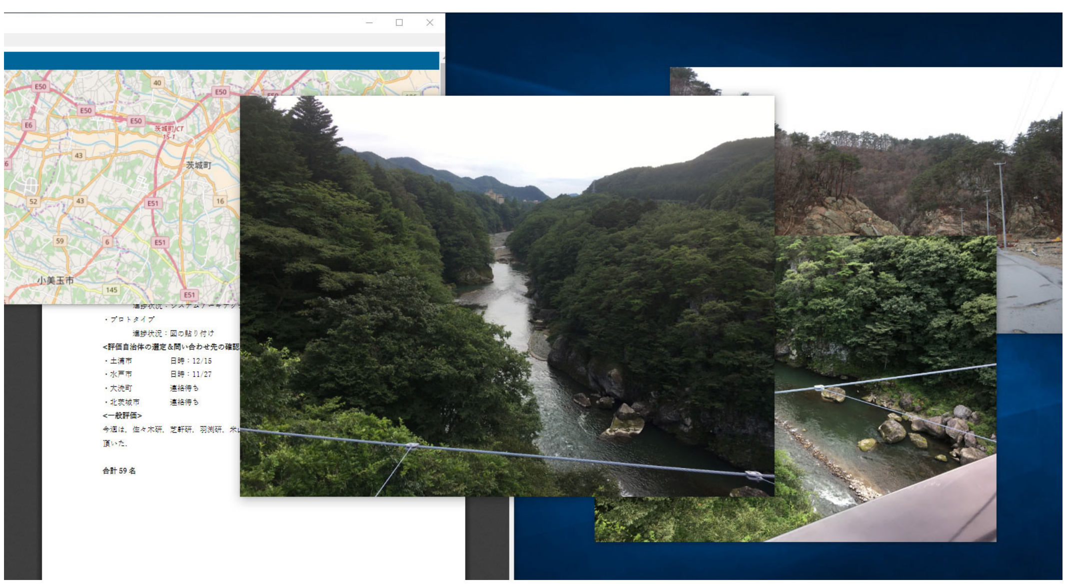

Figure 6: Image content-sharing screen

The renderer process automatically generates content icons after rendering the content on the large, high-definition, touch display. The generated icon is again transmitted to the main process by IPC. After that, the main process transmits the window number corresponding to the renderer process (which is automatically generated by the main process and recognizes each window on the large, high-definition, touch display), along with the received icon, to the information-sharing server. When the Web-based information transmission system receives the icon, that icon is automatically rendered on both the content selection screen and the download screen, as shown in Fig. 7. In addition, the window number and the icon information are stored in the session storage (the storage for the handheld terminal operated by the user). Fig. 8 shows the flow of processing in which content transmitted from the web based information transmission system is shared on the interactive information sharing system.

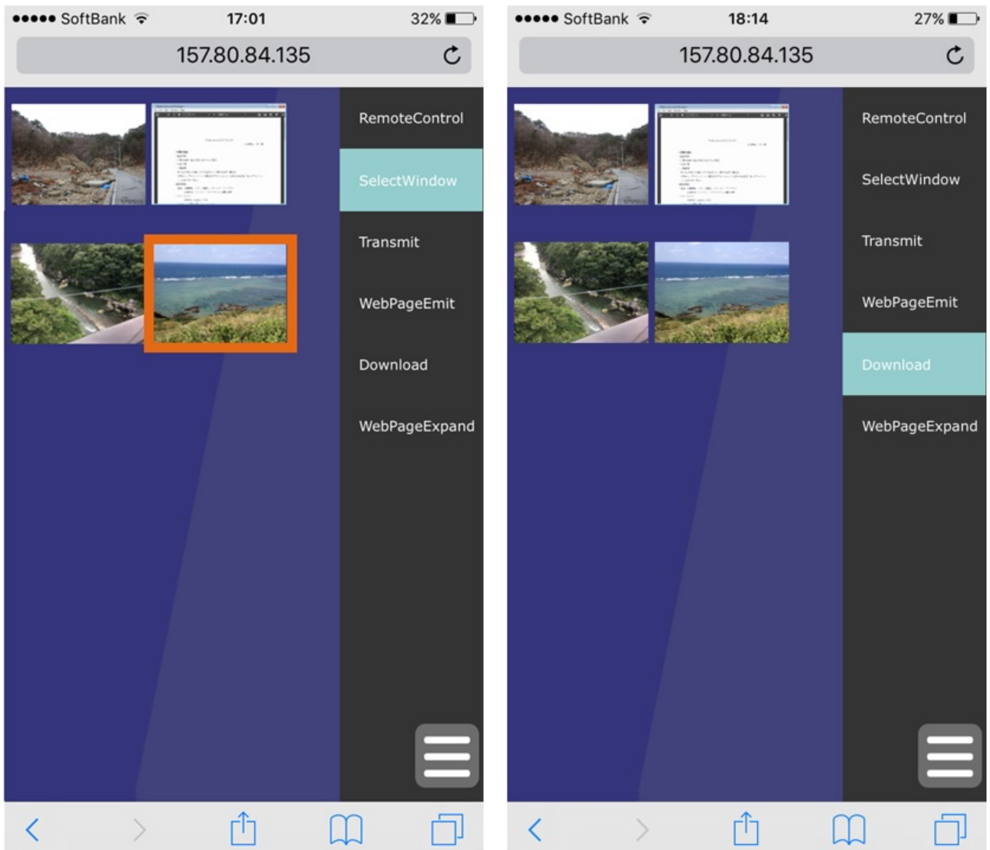

Figure 7: Icon rendered on the content selection screen and the download screen

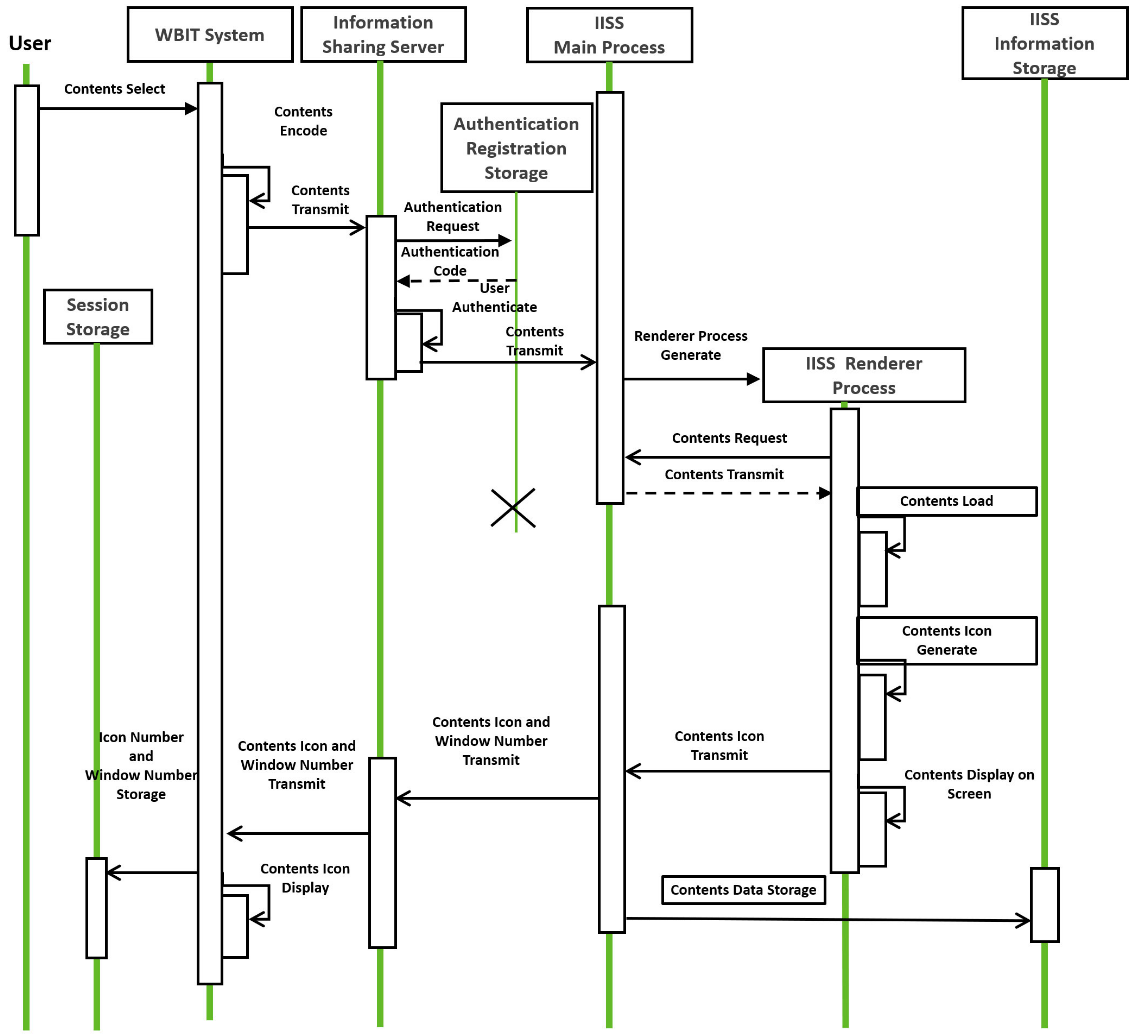

Figure 8: Sequence diagram of the content sharing

The Web page extension screen is a screen that allows the user to extend the Web page displayed on the large, high-definition, touch display. The Web page extension screen is shown in Fig. 9. Also, the sequence diagram of the web page extending process is shown in Fig. 10.

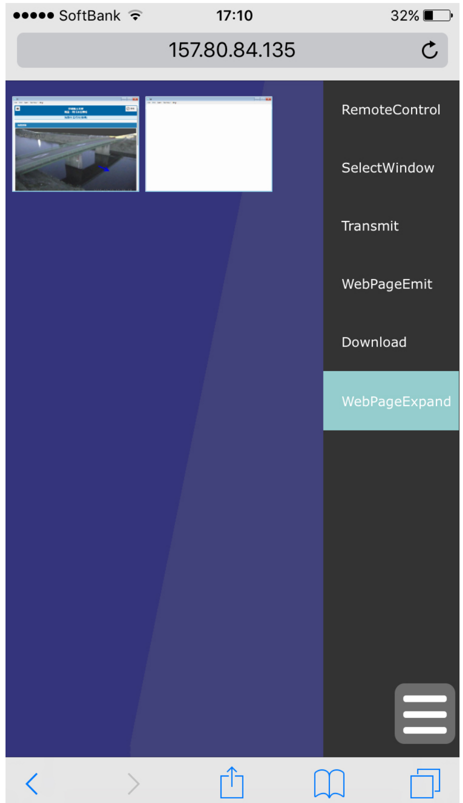

Figure 9: Web page extension screen

4.2 Interactive Information Sharing System

The interactive information-sharing system visualizes images, pdfs, Web pages, etc., transmitted from the Web-based information transmission system on the large, high-definition, touch display. For this study, we developed the interactive information-sharing system using Electron, which is a desktop application development framework. Therefore, most applications are controlled using a single JavaScript file called the main process. Moreover, window visualization and the renderer process are implemented by the main process, which generates a renderer process for each image and pdf datum. Therefore, the content received from the Web-based information transmission system, the QR code, and the authentication code automatically generated at system start-up are visualized by generating a dedicated renderer process. The flow of these visualization processes is shown in Fig. 11.

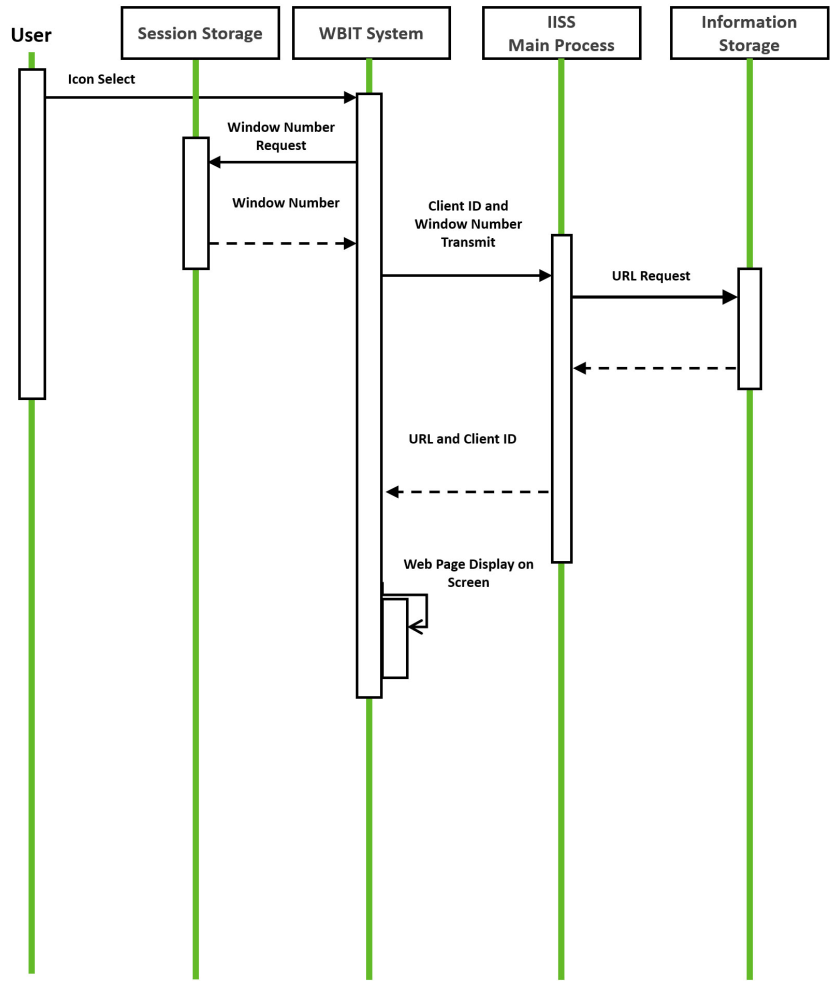

Figure 10: Sequence diagram of the web page extending process

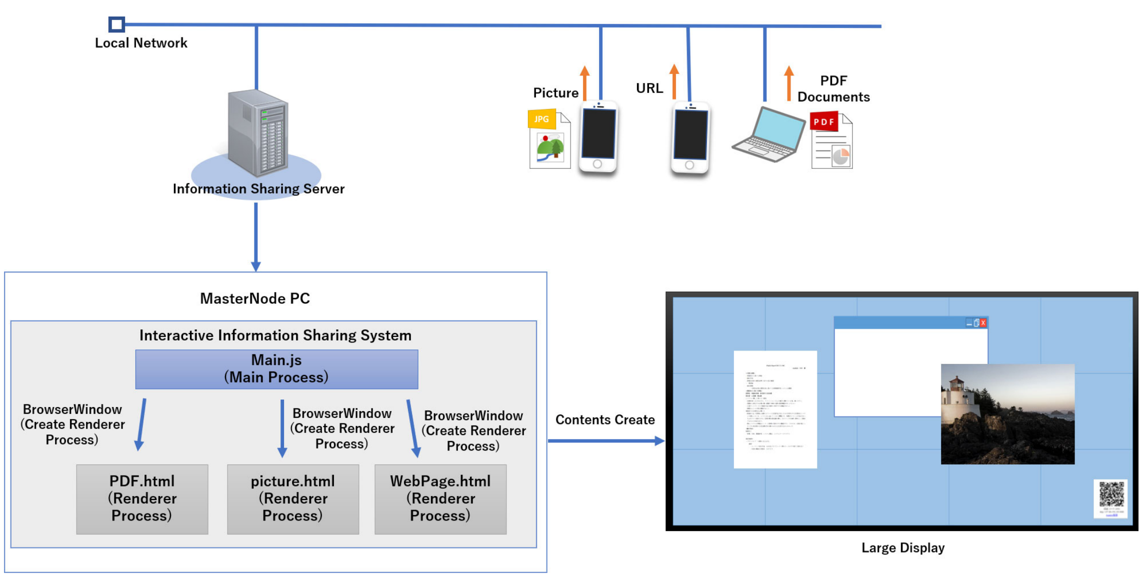

Figure 11: Flow of content sharing

5 Evaluation

We conducted a survey of our system, which included 12 local government employees from the disaster prevention division and 101 local residents, to help in evaluating the system based on the following measures: operability, functionality, effectiveness, and relevance. The following are the results of the survey. Moreover, to evaluate the performance of the system, we transmitted contents to the information-sharing screen using handheld terminals, such as smartphones and tablets, and measured the time until the transmitted contents were visualized.

5.1 Operability of the Web-based information transmission system

On the operability of the Web-based information transmission system, 92% of local government employees and 94% of residents reported that the system was easy or somewhat easy to operate, as shown in Fig. 12.

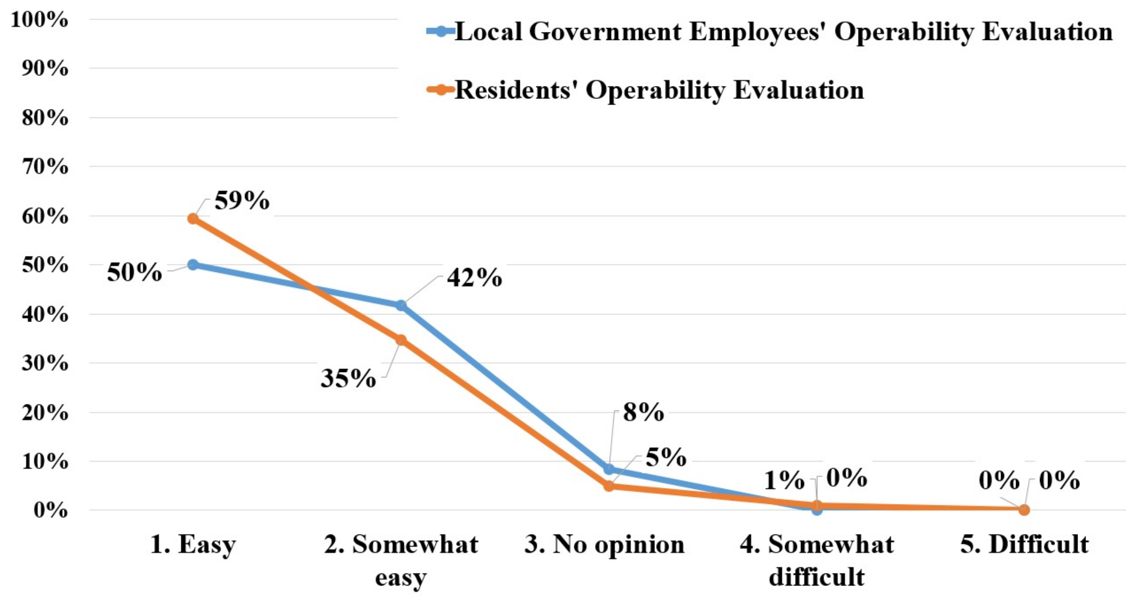

Figure 12: Operability of the transmission system as reported by local government employees (n = 12) and residents (n = 101)

5.2 Functionality of the Web-based information transmission system

On the functionality of the Web-based information transmission system, 75% of local government employees and 74% of residents indicated that they were satisfied or somewhat satisfied with the system, as shown in Fig. 13.

5.3 Effectiveness of the Web-based information transmission system

On the effectiveness of the Web-based information transmission system, 92% of local government employees and 84% of residents indicated that the system was effective or somewhat effective, as shown in Fig. 14.

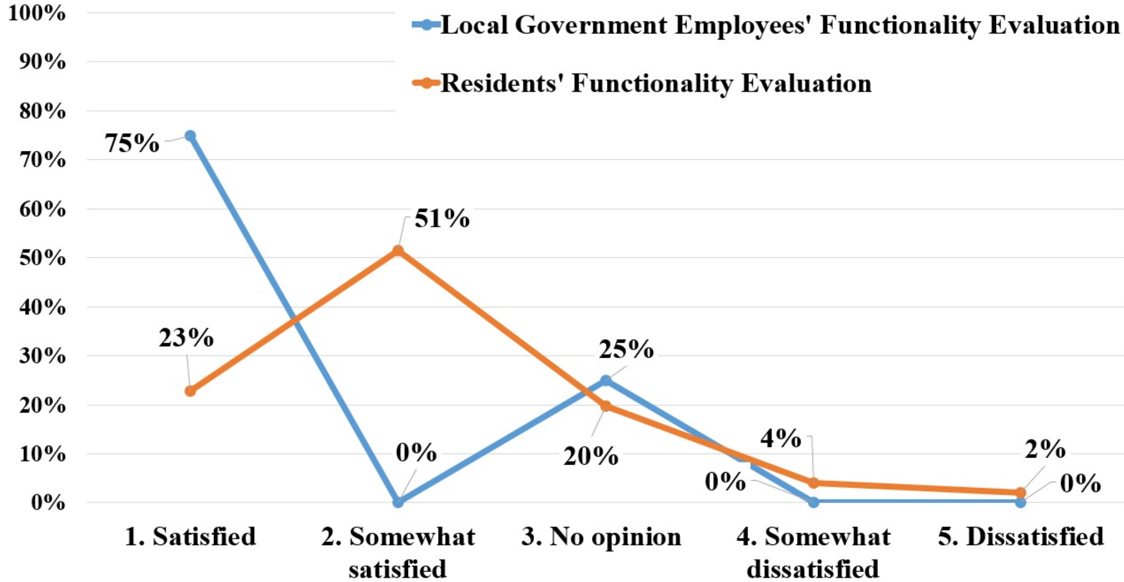

Figure 13: Functionality of the transmission system as reported by local government employees ($n = 12$) and residents ($n = 101$)

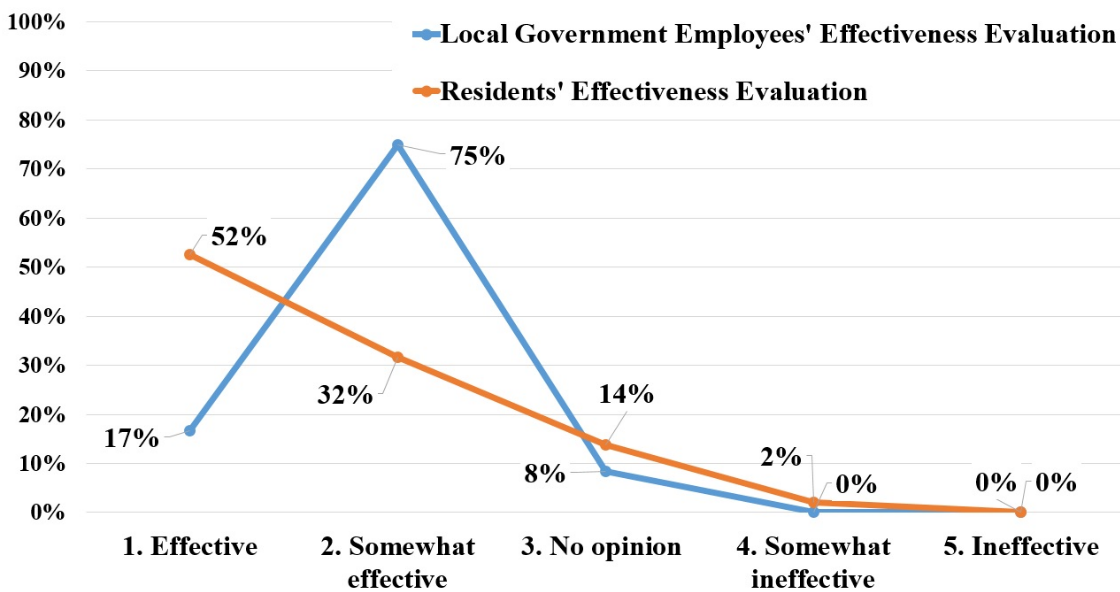

Figure 14: Effectiveness of the transmission system as reported by local government employees ($n = 12$) and residents ($n = 101$)

5.4 Operability of the interactive information-sharing system

On the operability of the interactive information-sharing system, 91% of local government employees and 88% of residents reported that the system was easy or somewhat easy to operate, as shown in Fig. 15.

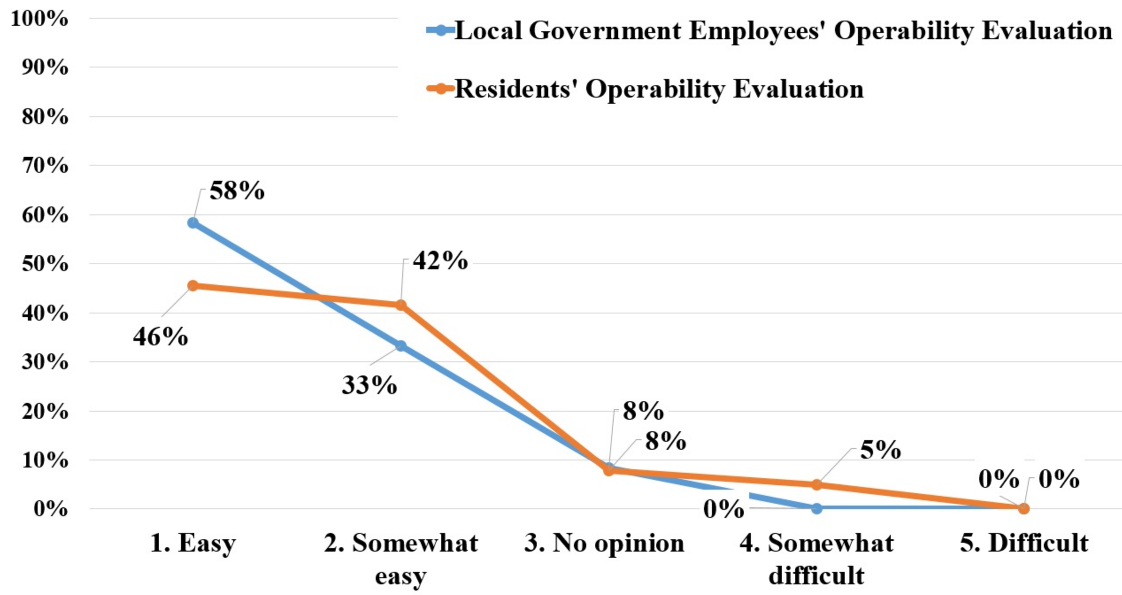

Figure 15: Operability of the information-sharing system as reported by local government employees (n = 12) and residents (n = 101)

5.5 Functionality of the interactive information-sharing system

On the functionality of the interactive information-sharing system, 100% of local government employees and 78% of residents indicated that they were satisfied or somewhat satisfied with the system, as shown in Fig. 16.

5.6 Effectiveness of the interactive information-sharing system

On the effectiveness of the interactive information-sharing system, 91% of local government employees and 89% of residents indicated that the system was effective or somewhat effective, as shown in Fig. 17. No subject reported that the system was somewhat ineffective or was ineffective.

5.7 Relevance of the interactive information-sharing system

On the relevance of the interactive information-sharing system, 58% of local government employees and 78% of residents indicated that the system was relevant or somewhat relevant, as shown in Fig. 18. However, 42% of local government employees and 20% of residents indicated that they had no opinion about the relevance of the system. This occurred because the subjects had become accustomed to conferences that use paperless materials.

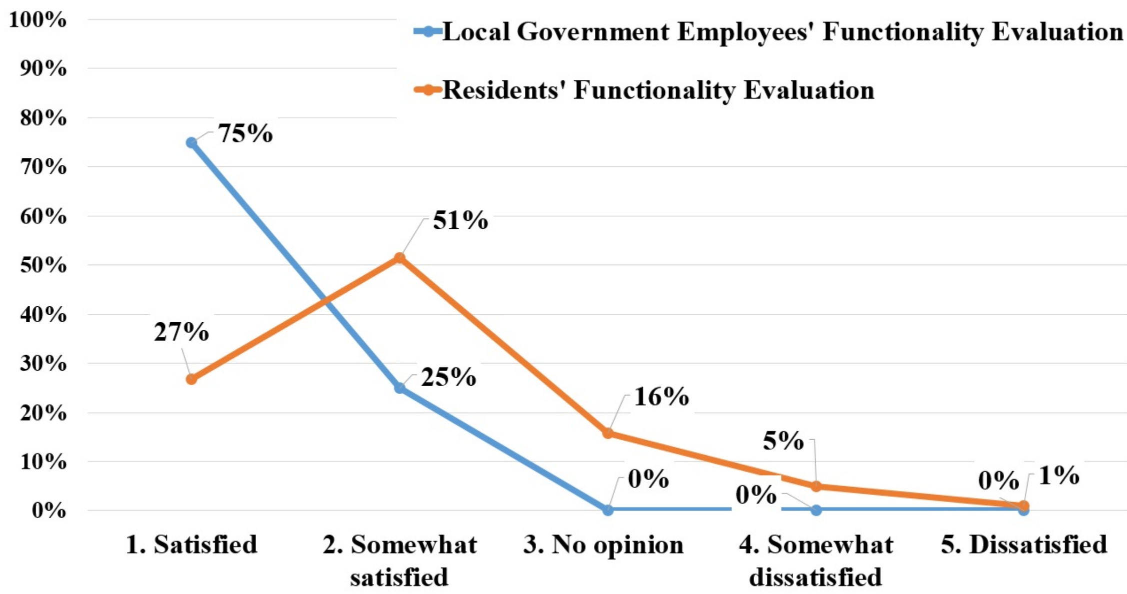

Figure 16: Functionality of the information-sharing system as reported by local government employees (n = 12) and residents (n = 101)

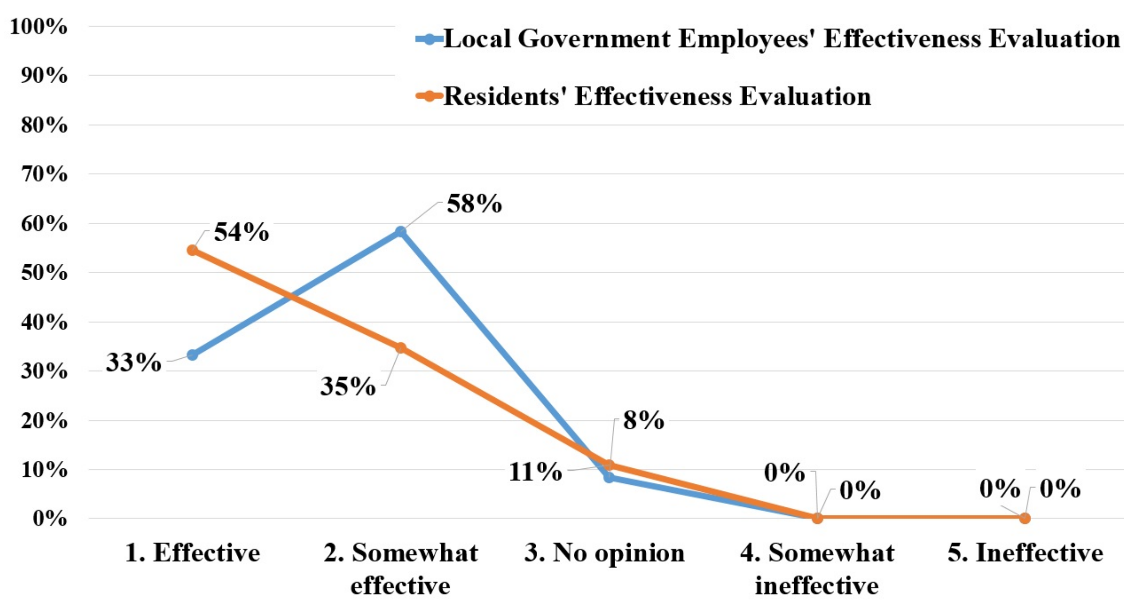

Figure 17: Effectiveness of the information-sharing system as reported by local government employees (n = 12) and residents (n = 101)

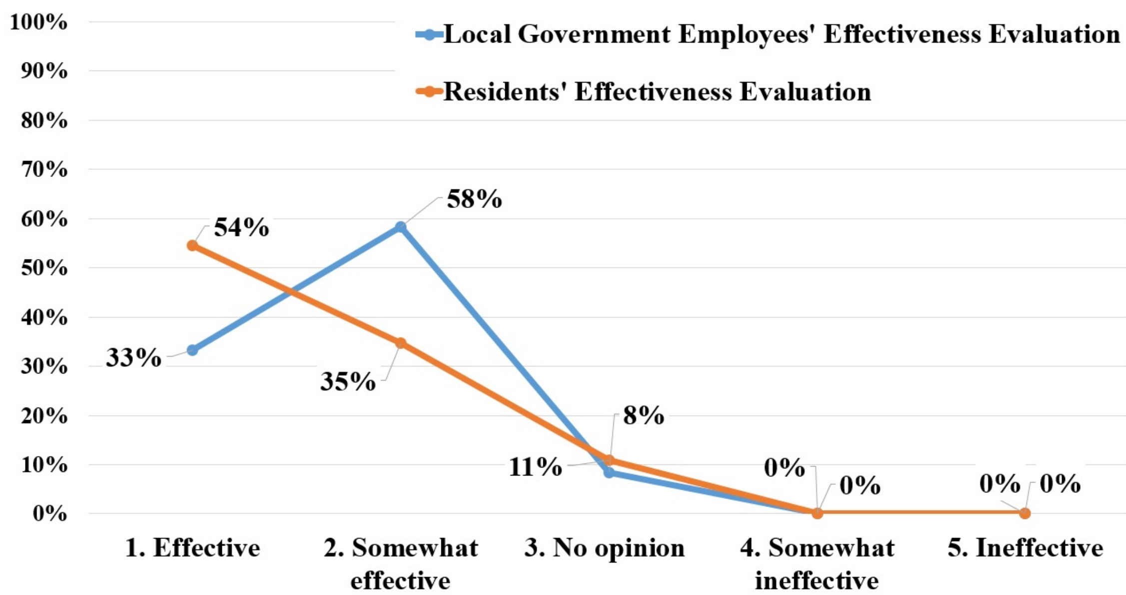

Figure 18: Relevance of the information-sharing system as reported by local government employees (n = 12) and residents (n = 101)

6 Conclusion

In this study, we implemented a scalable interactive visualization environment. This system consists of an interactive information-sharing system and a Web-based information transmission system. The interactive information-sharing system visualizes various contents transmitted from the Web-based information transmission system on a large, high-definition, touch display. The Web-based information transmission system enables information sharing on the large, high-definition, touch display by transmitting various contents to the Web server. To evaluate the operability, functionality, effectiveness, and relevance of the interactive information-sharing environment, we conducted a questionnaire survey to 12 local government employees of the disaster prevention division and 101 local residents. As a result, we were able to confirm positive responses in the evaluation of all measures.

Acknowledgments

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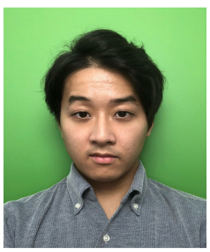
Author Biography



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