Journal of Mobile Multimedia, Vol. 10, No.1&2 (2014) 160-178

DESIGN OF DISASTER STATE PRESENTATION SYSTEM USING ULTRA HIGH RESOLUTION DISPLAY

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Management of disaster information is identified as one of the important functions in disaster countermeasure activity once large scale disaster has broken out. Since a large number of disaster information regarding with damage state in aftermath phase are reported to Counter Disaster headquarter (CDH), officers of CDH have to consolidate those to understand the state and to do decision making for quick and correct activity. In conventional, printed large maps are used for disaster management. However, the printed maps are disadvantage because a rapid and flexible reflection of disaster association between the damage state and geographical location cannot be easily attained. On the other hand, a GIS based disaster information system which represents disaster information on a standard display device is proposed and used for small number of disaster officers with relatively small scale of disasters. In this paper we propose LIVEwall by tiled displayed System based presentation and sharing platform for a large disaster case. Our system provides aggregated functions which can visually overlay the damage information on digital map for decision making in the disaster case. The damage state is managed and consolidated and displayed on the digital map on each CDH in local governments. In addition, we propose a shared workspace on the unified shared display device to show both the detail of indicated object and the perspicuity of whole wide area. We consider various interactions between users and tiled display system for both within the same CDH and inter-CDHs as design concept.

Key words: Tiled display wall, Disaster Countermeasure Operation, GIS, Disaster Information

1. Introduction

Management of disaster information is very important function in counter disaster activity once a large scale disaster has broken out. The national or local government establishes counter disaster headquarter (CDH) at the occurrence of disaster to expedite decision-making to control disaster.

Required information for counter disaster action is transformed along the axis of time. When a disaster stroke some cities or towns, their CDHs must perform many tasks including summarizing reports of resident safety information, damaged infrastructure information, acceptance and dispatching rescue team, establishment and management of evacuation center, distribution of rescue supplies, etc. These tasks need correct and rapid disaster state information from the actual disaster field. On another front, a large number of disaster related information described above are gathered into CDH in the case of disaster. Then CDH officers would be wrapped up in aggregating the information. Especially, the making connections between the reported damage state and its geographical location is very important for CDH in the aftermath of the impact.

In conventional, the CDH which is established by the local government manages the damage state and presents on large paper based map whole handwriting by marker pens. The use of paper based map has some advantages including highly intuitive interaction in a manner such as handwriting, displaying for the multiple participants who stand around the paper map, moderate in price and no electric power consumption. However, the paper based map management brings drawback. In actual disaster management, each CDH has disaster countermeasure map to indicate the disaster state over district boundary, but temporal and spatial state information on the map is not necessarily synchronized on each other. Therefore the counter disaster officer must communicate with another CDH using communication means such as satellite phone or facsimile. Besides, this approach can not precisely follow the change of disaster states on a number of occasions just after the aftermath. Also, reporting activity of disaster related information to higher level governments such as prefectural government from municipal office, and the national government from each prefectural government) is one of obligations by law. However, it was very cumbersome task for CDHs in the the case of the Easter Japan Great earthquake on March of 2011.

On the other hand, geographical information system (GIS) has become the most powerful technology for disaster visualization today by improvement of mobile device. For this reason we can find various applications and service fields such as entertainment, lifelog, public or governmental resident service fields. GIS can be useful tool even for disaster response activity to correctly and quickly understand the geographical state. Generally, GIS based hazard map[1][2] can quickly update the hazard area compared with conventional paper or PDF based hazard map. Web-GIS based information sharing service is a hot research topic as an application of GIS. There are many proposed approaches in sharing and delivering information service for residents. Therefore, GIS based system can be used as not only for usual tool, but also disaster management tool. However, the development of human-computer interface to realize suitable GIS based system for disaster management is challenging. Most of the researchers and engineers design and implement GIS based system to operate on generic device such as standard PC, mobile phone or smart devices. These devices are designed for single user at once. But in disaster management activities, multiple officers see the presentation display to deal with the comprehensive disaster tasks. Therefore the presentation device has to perform easy-to-see function for all multiple participants around the device as the case of traditional paper based map presentation. Another problem in the current GIS based system is whether multiple users can use the same system, namely, whether the GIS based disaster management system can indicate their processing results on above mentioned display device, because most of the generic device has only commonly-used input device but not intended to handle by massive users.

Physically large scale display is effective tool to do some type of tasks [3][4][5]. The needs of ultra high resolution display environment are highly expected as a demand of 2/3D visualization for various fields. Tiled display wall (TDW) environment [6-10] had been developed in past decade and now one of solutions to realize the feature described above is appeared. Typical TDW environment consists of matrix arranged conventional displays as a unified ultrahigh resolution display wall, and rendering nodes which draw designated partial area according to wall configuration. Nowadays by emerging high performance graphic card, it is not uncommon that only one graphic card can render and manage 6 displays at one time. So we can build a TDW based representation device with single render node. As result, TDW environment can be available with simple construction and much cheaper cost. Initial display wall formed by conventional liquid crystal displays has relatively wide bezel (i.e. undisplayable area on display wall), but modern display wall designed for digital signage application has narrow bezel and gives the sense of singular display and highly immersion for user.

However, even now large scale display is not popular in the actual disaster countermeasure activity. Figure 1 indicates one scene of the actual disaster countermeasure activity by territorial authority of the Ministry of Land, Infrastructure, Transport and Tourism Japan in the 2011 earthquake off the Pacific coast of Tohoku. The counter disaster officers in front of the large display deal with several types of information in this site. This organization performs operation and maintenance of roads, rivers, dams, seaports and airports in usual condition. The large display at this site displays 3 types of information; 1) Catalog of visuals of surveillance cameras from facilities under the jurisdiction; 2) Selected and Magnified view of 1); 3) Video image of television broadcasting intended to collect information with disaster from outward. In addition, the officers interact with another system operating the several terminals on the table located in front of display wall. In this usage we can find problems caused lack of bidirectional interaction between users and information, and nebulous relationship between event what happened and geographical location where the event broke out.

Figure 1. An example utilize of large scale display in large scale disaster operated by local government of Japan

In this paper, we propose a new GIS based disaster state presentation and sharing system with ultra high resolution capability using TDW environment. Using this system, a lot of disaster information with temporal and spatial relation can be displayed on the wall at the same time and many participants can simultaneously see the information in front of this wall and discuss together to correctly and quickly make a decision on the disaster activity. Thus, the ultrahigh resolution TDW can show to the multiple users simultaneously a wider area map with ultrahigh resolution without zooming and panning operation. Furthermore, this system can provide bi-directional connectivity with other CDHs to quickly respond to disaster reporting and decision making for higher level government's CDHs.

In order to easily interact with application on the TDW, we designed a user role oriented input method classified by operator's tasks, dealing information, and location of participators using standard PCs, tablet devices and smartphones. In this paper, we describe the concept of our system, system configuration and architecture, shared workspace for collaboration works, user-system interaction method and design of prototype.

2. Related Works

Many researchers addressed methods are proposed to connect the disaster damage information to the geographical information ever. LaDIPS (Large Disaster Information Portal Site) [11] is one of them which is web based integrated system that is composed of damage information presentation system and state of residents just after disaster. This system provides time-sequenced browsing feature for disaster information not just spatial one, by specifying both start and end date to show information on the map. This prototype brings all kinds of user who no matter what disaster measurement operator or residents, but the prototype is not so much collaboration method that connects mutually CDH as information service for community residents.

There is an approach regarding with replacement of paper based disaster management using tangible user interface. Kobayashi et al. [12] developed a platform for disaster management operation in disaster management headquarters. Tangible user interface allows very highly intuitive input by handwriting on paper map. However according to the prototype system, the map is displayed on tabletop using a projector. For this reason, its displayed area is limited.

A lot of techniques which are based on tiled display environment were proposed during the past decade in the context of improvement of networking technology and PC clustering technique. Those include Chromium [6], DMX [7], CGLX [8], Scalable Adaptive Graphics Environment (SAGE) [9] and DisplayCluster [10] which are tiled display platform available to construct large and ultrahigh definition display environment.

In our previous research, a human computer interaction device on large and ultrahigh definition display environment was developed and constructed a prototype system called DETAIL$^+$ system which is based on the concept of location-free in front of display wall and application independent design on large sized 2D desktop based environment by mouse input emulation feature [13]. Through the experimental evaluation, we found several drawbacks in the prototype such as lower accuracy in pointing object on the wall by wireless sensor device than by mouse input and the limited number of user access. Those drawbacks have to be essentially resolved for presentation system of disaster state information.

3. Proposed Concept

In this section, we describe fundamental design concept of our proposed system called LIVEWall (*Large-disaster Interactive Visualization Environment on Display Wall*).

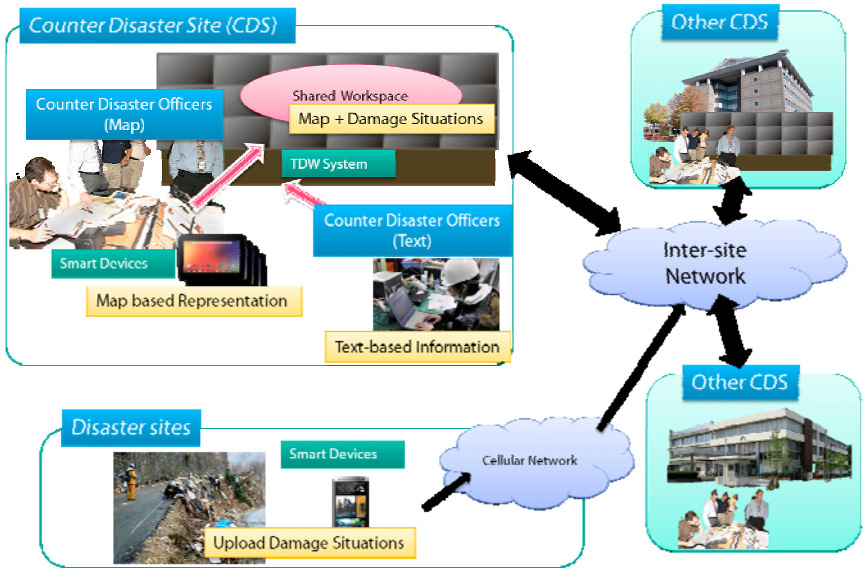

Figure 2. Concept of LIVEWall System

3.1. System Concept

Fig. 2 shows the system concept of LIVEWall which is a GIS-based disaster state presentation and sharing platform to share the disaster state information collected and accumulated on each CDH connected each other by robust information network such as satellite or wireless resilient networks.

On each CDH, a large display system with ultrahigh resolution capability is prepared so that disaster counter officers can work for the collection and accumulation of disaster information and decision-making to respond to the disaster state. On the large display system, disaster information presentation area called shared work space is displayed. The images regarding with the disaster state and the graphical shapes show the disaster area.

The primary objective of LIVEWall is to rapidly respond to the initial counter disaster activities by supporting decision-making process based on summary of deluged information in CDH, especially the relationship between the reports of damaged locations and their states. Our system deals this information on digital map displayed on a unified large scale display with for multiple user interactions at the same as the conventional paper map based damaged state management in the actual DCH.

In our LIVEWall, each CDH has a TDW environment as a shared working display with other CDH as well as other users in front of the same display. The shared display shows damage state by overlaying pictures or graphical shapes on the digital map like typical GIS based application. We called it *Shared Workspace* in this system. Using the shared workspace, the disaster officers discuss and make their decisions to react the disaster. Each officer can interact to the content on the map by add, remove, relocate and resize operations. Through the inter-site network, the other CDH uploads the content and react to the location on map coordinate to sync working space on the screen. The inter-site network is organized by multiplexed communication networks to ensure connectivity even in large scale disaster occurred and some of the network are seriously damaged. This network configuration will be described in Section 3.3. A report of the damage state from the disaster site helps rapid responding by mobile terminals such as smartphones and smart tablet with camera and VoIP functions.

As we described above, LIVEWall system is designed as premises for the officers who react to the different tasks and information. Then operators to perform LIVEWall functions are classified into three types including Information Mapping operators, Text Information operators and On-site Spotters.

Information Mapping Operators manage and update the relationship between disaster information and location where the damage has been occurred and manipulates the pictures and graphical contents by removing or deletion on the workspace, and drawing graphic such as lines, ellipses, rectangles and so on. The Information Mapping Operators deal their tasks via tablet device called *LIVEWall Portal Device* to interact with contents on the shared workspace. Multiple input acceptances by multiple Information Mapping operators are considered in our system.

Role of Text Information operator is to commit LIVEWall with text based information which is reported from other organization such as police, fire department or branch officers of national government to local government. Text based information is not suited from the viewpoint of intuitively understanding but frequently used in actual site. Text based information is also required to link with damaged location. This interaction is performed by Information Mapping operator after Text Information operator commits it using application called *Liaison Terminal*.

On-site Spotter works for the task of reporting of damaged state of infrastructure from the actual disaster area. In LIVEWall, On-site Spotter will report the damage state using smartphone called *Spotter's Gadget* and conducts his task by taking and sending pictures to the CDH. Spotter's gadget automatically appends geographical coordinates where those pictures have been taken. Those pictures are available on Shared Workspace in CDH, and then appeared by manipulating Information Mapping Operator.

3.2. Use of Scenario

LIVEWall system can be also used at usual case for traffic load surveillance, environmental monitoring, such as for roads, rivers, lakes, forests, seaports monitoring, local event broadcasting and digital signage. In case of early phase of disaster occurrence, CDH conducts information gathering operations. LIVEWall directly provides a reporting function by directly receiving damage information from disaster site via regional wireless network, cellular network, or satellite network. For instance, if a load observer discovered falling rock or road destruction on some location whole paroling, then he can immediately send the picture and GPS data by his spotter' gadget. Thus, this information is displayed on the shared workspace of LIVEWall. Eventually CDH can quickly respond to the damaged state.

Also, if CDH received text-based damage information from other organization, Text information operator can respond to this using Liaison Terminal. For instance, the road observer reported washed-away of the bridge at some location by wireless transceiver or cellular phone, the text information operator commits to record as literal based information.

Then, officers at CDH consolidate and organize damage information. LIVEWall performs this process by connecting between damage information and its location. In this phase, the information mapping operator interacts and overlays the contents onto digital map to record the damaged state in the moment. Text-based information is also connected to the content on the map by the information mapping operator.

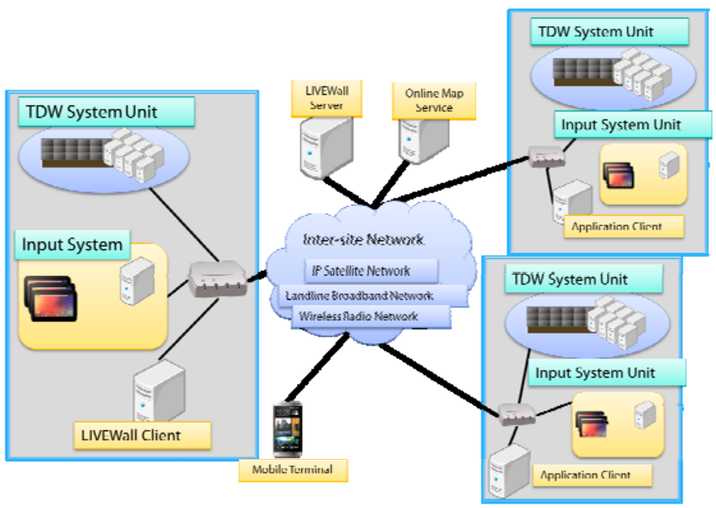

Figure 3. Connectivity and component of proposal system

3.3. System Configuration

Figure 3 indicates system configuration of LIVEWall which is based on client and server system. Each CDH site is consisted of Application client, TDW system unit, Input system and mutually connected by inside communication network. Each CDH is also connected to Internet to receive digital map service from the GIS site and disaster information from disaster area through wireless network, satellite network or cellular networks.

The LIVEWall client in each site provides Shared Workspace, receives interactive operations from users through Input System, displays the digital map image from the GIS server and overlays disaster information from LIVEWall server. On other hand, LIVEWall server is allocated on the safe place and performs management of each Shared Workspace and provides database management function for disaster information.

TDW system unit contains a master node and several rendering nodes depending on the number of display walls. Input system consists of a Liaison Terminal and the same number of Portal Devices. Through these devices, the user can access to the shared workspace of LIVEWall.

The network connectivity between the DCH sites is very critical element of disaster information system which targetes in aftermath. Just after occurrence of disaster, the network availability is quite uncertain due to network disconnection, congestion of communication and failure of communication nodes. We are developing so called Never Die Network (NDN) which takes into consideration of multilayered redundant cognitive wireless networks with different communication characteristics such as 2.5G/3G/3.9G cellular or IEEE 802.16 WiMAX, and IP satellite network[20]. The NDN can autonomously selects the optimal path between the each site even though the some of the network links and nodes are damaged.

4. Shared Display and Workspace

Figure 4. Indication of disaster information on Shared Workspace

4.1. Shared Workspace

As mentioned, LIVEWall provides Shared Workspace which is displayed on a large scale shared display based on TDW environment considered to browse and interact by multiple CDH officers. LIVEWall manages a disaster as a *session* and can contains one or multiple Shared Workspaces in a single session. CDH officers can create multiple workspaces for different types of damaged information and can provide seamless representation for multiple Shared Workspaces without switching screen. Unlike a conventional disaster presentation system, LIVEWall can visualize the damage information, render the damaged state directly on digital map. Figure 4 is an example of disaster information on Shared Workspace which is constructed by several images with the damage in urban area, and a polygon graphics which expresses flood of tsunami. Information mapping operators deploy and arrange the disaster information on digital map by interaction with their items.

4.2. Object Mangement

The damage state image data on Shared Workspace are defined ad *Objects* in our system. In addition to image data, the objects include metadata as shown in Table 1. The objects are not only preserved on each LIVEWall client but also managed with their arranged positions on the by LIVEWall server.

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Table 1 Shared Workspace on ultra large scale display

FIELD	DESCRIPTION
GUID	Unique ID that identifies an object
Disaster name	Name of disaster
Disaster ID	Unique ID that identifies specified disaster
Author	Author of content
Date time of creation	The date and time that specified content was created
Date time of added to WS	The date and time that specified content was added to Shared Workspace
Deployed WS	Name of this Shared Workspace that object was deployed
Deployed ID of WS	Unique ID of this Shared Workspace that object was deployed
Joined group	If this object joined to any Shared Workspace, unique ID of workspace
Annotation	Text annotation of this content

4.3. Layer Construction and Rendering

Shared Workspace is organized by two layers including Objects layer and Digital map layer as illustrated in Figure 5. The Objects layer is rendered on digital map layer constantly.

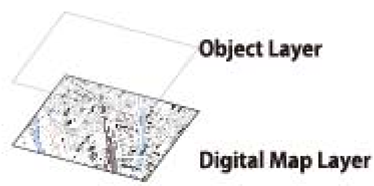

Figure 5 Layers of Shared Workspace

Figure 6 Shared Workspace on TDW

Rendering process of both layers on TDW is executed in the following manner; At First, LIVEWall client obtains digital map from digital map server.

Its size is identical to the resolution of display wall. Next, LIVEWall client requests objects layer from LIVEWall server which is formatted as GeoJSON[14] file. On another front, LIVEWall server generates a file from the object database and pushes it to respond to LIVEWall client's request. Then LIVEWall client migrates the digital map and objects as web browser components which include GUI framework such .NET Framework, GTK+[15] or Qt[16]. Finally, LIVEWall client renders contents displayed on web browser to local display wall through middleware of TDW environment. Thus user can see Shared Workspace on TDW system as shown in Figure 6.

4.4. Grouping Objects

Shared workspace can represent a large number of disaster information geographically in wide area. However many objects which describe the damage state of near area can be aggregated into the same location. In order to avoid overlapping large siza images on the shared workspace, our proposed system can conduct these close objects as a group on shared workspace illustrated as figure 7. This area contains 4 objects included in circular shaped group object in default. When a user wants to expand the group, user interacts and includes this object into the group object. The conditions that the object should be joined in the group object is decided depending on whether the geographical distance between the objective object and the nearest closest object and another object is less than threshold which is set in advance. At this time, the system asks whether this object should be joined to the group. Creation of the group is also available in manually by the operator on Shared Workspace.

Figure 7 Grouping presentation in Shared Workspace contains 4 objects

5. User Interaction with System

Interaction between user and application on a large scale display is significant and challenging over the years. There are several users in front of display wall. As we described as mentioned previously, three different users access to LIVEWall and require the best interaction methods individually depending on their dealing information style, location, and officer's skill related information technology. Figure 8 indicates overview of our interaction design for LIVEWall.

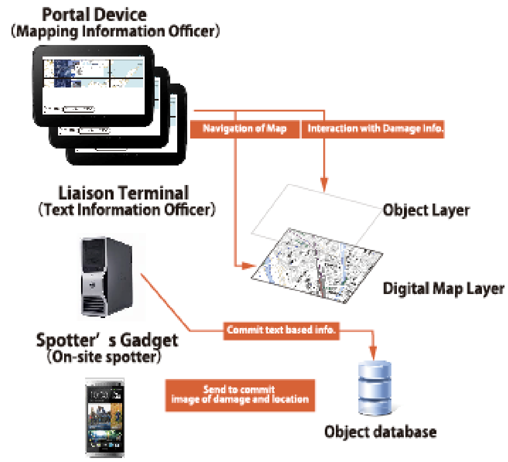

Figure 8 Design concept of human computer interaction on LIVEWall

5.1. Information Mapping Operators

For Information Mapping Operators, LIVEWall provides Portal Device to interact with workspace. The operators require highly intuitive interaction through wireless input device. We designed input device using tablet terminal for Information Mapping Operator which is called as *Portal Device*. It manipulates Shared Workspace through thumbnailed Shared Workspace called *Portal Area* on tablet device in user's hand. The thumbnail is completely mirrored and synchronized with actually workspace. So user can interact with workspace or objects like touch interaction on display wall in directly to manipulate objects from any distance in front of display wall. Figure 9 shows flow of Portal Device. User can draw or move objects by tap and drag operations, and pinch-in/out manipulation brings change of size for objects, like modern smart devices with touch sensor. Moreover, manipulation of digital map can be provided through Portal Area, such as swiping for panning of map, pinch-in/out for changing of scale size.

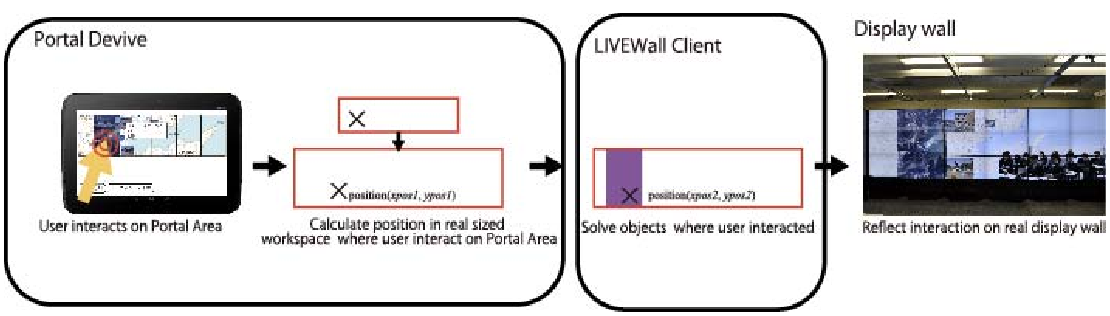

Figure 9 Process flow of interaction has been occurred for be reflected it

Technically, Portal Device behaves as translator of interaction from user's manipulation to actual size of shared workspace. First, the device translates interaction and screen coordinate where interaction has been occurred. Next the result is sent to local client to reflect on the Shared Workspace.

The client relays it to server in effort to synchronize the shared workspace. Portal Area will be reflected the result of interaction by other user or site, hence, Portal Device performs like a controller of workspace.

5.2. Liaison Terminal

Liaison Terminal deals disaster information based on text data which is committed from Text Information Operator. The role of liaison terminal provides interface to text annotation which is relevant to some metadata fields of disaster state. In Table 1, *Disaster name*, *Author* and *Annotation of* the metadata fields are important elements to precisely describe the disaster state not only just digital archives. Liaison Terminal is implemented as GUI desktop application on dedicated PC . We assumed that Text Information operator should have average computer literacy and can use a pair of generic keyboard and mouse as input devices.

When the information with the disaster state is reported from the organization, Text Information operator commits it. For example, when a police reported that he discovered the detached residences in somewhere, the operator should input this report in the annotation field of the metadata. This information will link to the related information input by Information Mapping Operator, for instance, marking the location where the detached residences were discovered on the digital map.

5.3. Spotter's Gadget

The objective of Spotter's Gadget is to report disaster state to jurisdictional CDH from disaster site. However this device should consider easy-to-use design because local government officers are not always good at skilled information technology.

A major reason why the smart device is used as Spotter's gadget is that it provides touch panel interaction by easy-to-use design concept. We designed an interface which consists of 2-tap operations to report disaster information. First, on-site spotter can activate a camera by tapping 'Camera activate' button on the application interface. Then the officer takes a picture and geolocation coordinate using camera and GPS receiver and taps on 'Send to CDH' button to send. Thus easy-to-use design would be realized to reduce burden of use new device for counter disaster officer in the scene.

6. Prototype Environment

In order to verify the functionality and performance of the proposed system, we constructed two types of LIVEwall prototype systems including 16 tiles and 27 tiles using Scalable Adaptive Graphics Environment (SAGE) 3.1 as a middleware of TDS as described in Table 2. The shared workspace as an application is developed using C++ language. The digital map system is developed based on Digital Japan Portal Web System and QtWebKit[17] of Qt 5.1 using C++ and JavaScript.

Table 2 Configuration of two prototype TDW

	16 Tiles	27 Tiles
Wall scale	20" 4x4 (@1,600x1,200px)	46" 9x3 (@1,366x768px)
Real size[m]	2.1x1.8	6.15x2.2 + 3.1x2.2 (L-shaped)
Maximum Resolution of screen[px]	6,400x4,800	12,294 x 2,304
Platform	Ubuntu Linux 12.04	Ubuntu Linux 11.10
Unable to render distance by display bezel [mm]	36 (Single display)	7.6 (Single display)
Remarks	Master node and 8 render nodes are heterogeneous	L-shaped deployment from top side view (3x3 + 6x3 configuration)

7. Feasibility Experiment

The amount of data of ultrahigh resolution image is exceedingly huge. However, in the actual disaster case, the communication bandwidth is limited and the quality of service is forced. Especially, since LIVEWall initially retrieves the digital map through Internet, the performance of network transmission must be critical when network is down or connection is extremely limited. For this reason, we initially measured the data volume of data of ultrahigh definition digital map image to confirm whether our approach can be reasonably useful or not.

Table 3 Experimental scenarios and parameters

Scenario Area	Coordinate of center of map	Zoom level
Japan	36.421,138.340	8
Iwate-pref	39.725,141.465	11, 12
Otsuchi	39.338, 141.910	13, 14, 15, 16, 17
Rikuzen-takata	38.970, 141.630	13, 14, 15, 16, 17
Kitano-maru	35.694,139.750	13, 14, 15, 16, 17
Hashira-jima	34.016,132.416	13, 14, 15, 16, 17

We made several experiment scenarios in which the various full-sized images with the different conditions such as different terrains on different rural and urban areas are displayed.

We set 23 experiment scenarios in 6 areas including the sea shores, urban areas and islands. 2 or 3 or 5 different zoom level at each area is shown in Table 3. The digital maps used in this experiment are shown in Figure 10. We repeated the experiment 3 times for each scenario totally 69 trials. The results for each scenario are averaged.

(a) Japan (8)

(b) Iwate-pref. (12)

(c) Otsuchi (17)

(d) Rikuzen-takata (15)

(e) Hashira-jima (15)

(f) Kitano-maru (15)

Figure 10. Example of digital map sized 8,196 x 2,304 pixels

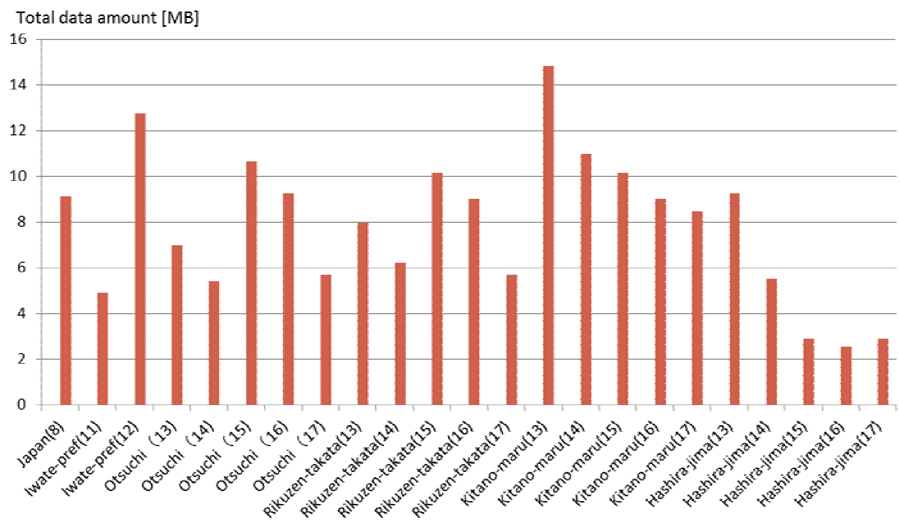

Figure 11 Sent and received data amount of 8Kx4K sized digital map

Method of experiment is described as following procedures:

1. Set the central coordinate (latitude, longitude) and zoom level of the digital map to static JavaScript code.
2. Activate the packet capture application on LIVEwall client
3. Execute evaluation and set the JavaScript code to the application on testbed PC
4. Wait until workspace is filled with the digital map
5. Observe the transmission time of the digital map and record the total amount of data.

Some examples of 8Kx2K sized digital maps used in the experiment are shown in Figure 9

For performance evaluation, 6x3 tile configuration with 8,196x2,304 pixels among 9x3 tile configuration in Table 1 was used. As the LAVEwall client, Intel Xeon W3520 processor, 4GBytes memory based on Ubuntu Linux 11.10 operating system was used. The available network bandwidth between the LAVEwall client and the digital map GIS platform, Digital Japan Portal Web System Version 4 with OpenLayers capability on the Internet, was 100Mbps. It is reminded that Digital Japan Portal Web System can provide equivalent 1:200,000 scaled map in zoom level 12, and 1:25,000 scaled map in zoom level 15.

The result of the experiment is illustrated in Figure 11 and indicates amount of data transmitted in each scenario. The average amount data of all over scenarios is 7.84MBytes with 8,196 x 2,304 pixels resolution. The maximum amount is recorded in scenario Kitanomaru and its zoom level is 13 equivalent to 14.81MByetes. In addition, the amount data of the digital map decrease as the level of the zoom level of the digital map increase. We also observed the largest mount of digital map data when the zoom level was 13 in any area.

We have found a memorable result that the amount of the digital map data varies depending on the feature of terrain even though at the same zoom level. Urban area contained much larger amount of the data than that of the island area. For instance, in the same zoom level 16, Hashira-jima belongs to island area contained 2.53 Mbytes while Kitano-maru belongs to urban area contained 9.01Mbytes. This means 3.6 times difference even in the same scale. We estimate that this difference is due to the ratio of the surface of the sea painted as light blue on the Digital Japan Portal Web System. It is conceivable that the amount of digital map data with blue painted area is less than that of the urban district due to the image compression on GIS server side.

Through the previous experience of serious disasters, it is predicted that the available network bandwidth is very limited at just after occurrence of disaster, and temporary recovered disaster network can only have several Mbps[18,19]. However, our approach based on the ultrahigh resolution map can basically be acceptable on such network. Also, we assume that once the digital map was downloaded, the perpetual changing of map area is not a very occurred; hence our suggested system can be reasonably used even though the available network bandwidth is not sufficient compared with the normal case.

8. Discussions

As we described in section 7, we suggested feasible LIVEwall to realize the ultrahigh resolution digital map presentation even though the limited network. In actual case, our approach might require traffic control. For instance, control message and text based information should have higher priority, while high definition digital image of damage state should be set to lower priority when the available network bandwidth is quite narrow. In addition, applying of Software Defined Network (SDN) for disaster countermeasure networking becomes popular over the past few years [20][21]. Those techniques are helpful to design and evaluation of adaptive network for actual operation of LIVEWall.

Also we should consider human computer interaction in LIVEWall to improve the hands free human computer interaction method by applying RGB-depth device such as Microsoft Kinect. Advantage of this method brings users to provide highly intuitive interactions with skill-independency. However in contrast, the present RGB-D device application has weakness in interaction accuracy. Our approach uses the handheld tablet device as an input device which could have great advantage of providing correct and easy interactions.

9. Conclusions

In the actual disaster countermeasure operations, a large amount of disaster information on the counter disaster site is required to quickly perform decision-making. Paper based disaster management is difficult to respond to the temporal and spatial changes of disaster state. Also the conventional GIS based disaster information system has an issue on interaction by multiple users.

In this this paper, we proposed LIVEWall system which can manage disaster damage information based on GIS application using ultrahigh definition display environment. In our proposed system, three different operators are classified according to their roles and features of information. We also proposed a human computer interaction method to realize secure effective input function on physically large scale disaster environment. The tablet based input device is used for the operator who deals with map related tasks. The generic PC based terminal is used for the operator who deals with text based disaster information. And smartphone based input device is used for the operator who sends the disaster related images from the actual disaster location.

We also defined functions and roles of the Shared Workspace in which the disaster contents are indicated on the LIVEwall display. Our prototype system can provide one or more workspaces at the same time. This feature makes possible so that users can deal with the disaster information in the layered presentation.

Through the prototype system, we evaluated amount of the map image data obtained the from GIS server through Interne. From the experimental result, ultrahigh resolution map images contain several Mbytes to ten Mbytes depending on the feature of terrain in the map. Hence this result requires priory policy or QoS based network transmission particularly on the limited bandwidth just after occurrence of disaster.

As future work, we are implementing all of the functions of LIVEwall and evaluating function and performance such as subjective functional evaluation of the shared workspace and usability of the actual operator in the local governments which encountered the East Japan Great Earthquake by comparing our suggested system and the conventional GIS system.

Acknowledgements

This work is partially supported on Regional Industry-Academic-Government Collaborative Service Location Development Project (Iwate-2, Iwate-11) of Japan Science and Technology Agency.

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