Implementation of a Web-Based and Cloud-Based Participatory GIS System to Certify Property Damage due to Tsunami

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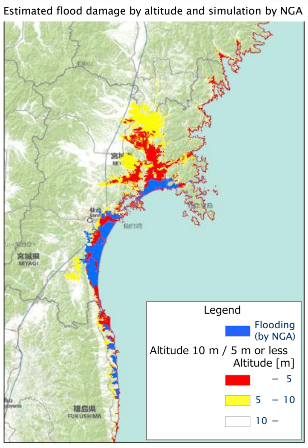
Abstract—**The objective of this research was to develop the cloud-based participatory WEB-GIS system constructing the common operational picture in order to facilitate the decision-making process of disaster response. The team set the research aim to create the web service of certifying property damage due to Tsunami. Using developed service the team conducted the demonstration experiment to survey to identify buildings that were washed away in the three afflicted prefectures of Iwate, Miyagi, and Fukushima by Tohoku Earthquake.**

Keywords-component;; WEB-GIS services; cloud based collaborative; common operational picutre; builiding inspection

I. Introduction

High-quality disaster responses can not be provided without constructing a common operational picture and organic collaboration among stakeholders. To this end, it is effective to visualize damages and responses using a Geographic Information System (GIS), which facilitates decision-making based on visualized data. In reality, however, during the chaotic days immediately following a disaster, the collection and consolidation of data for visualization is insufficient. The absence of data to be visualized hinders our efforts to construct a common operational picture.

The Tohoku Earthquake on March 11, 2011 generated massive tsunamis that washed away many buildings. Our research team initially organized building point data according to altitude in a geographic space to create a big picture of damages. We then estimated the number of damaged buildings in each region alongside the height of the tsunamis in these regions (as reported by the Japan Meteorological Agency). The results indicated that 270,000 buildings were damaged in three prefectures of Iwate, Miyagi, and Fukushima. Figure 1 shows the results of our information analyses, which were shared with the disaster response workers.



Most tsunami damages occurred in three prefectures in the Tohoku region

Estimated number of buildings damaged by the tsunami
↓
About 270,000 buildings are needed to surveyed

Prefectures	~5m	5~10m	Total
Iwate	14,981	27,821	42,802
Miyagi	135,410 (70,787)	–	135,410 (70,787)
Fukushima	52,603	40,807	93,410
Total	202,994 (138,371)	68,628	271,622 (206,999)

Figure 1. Estimated number of buildings damaged by the tsunamis

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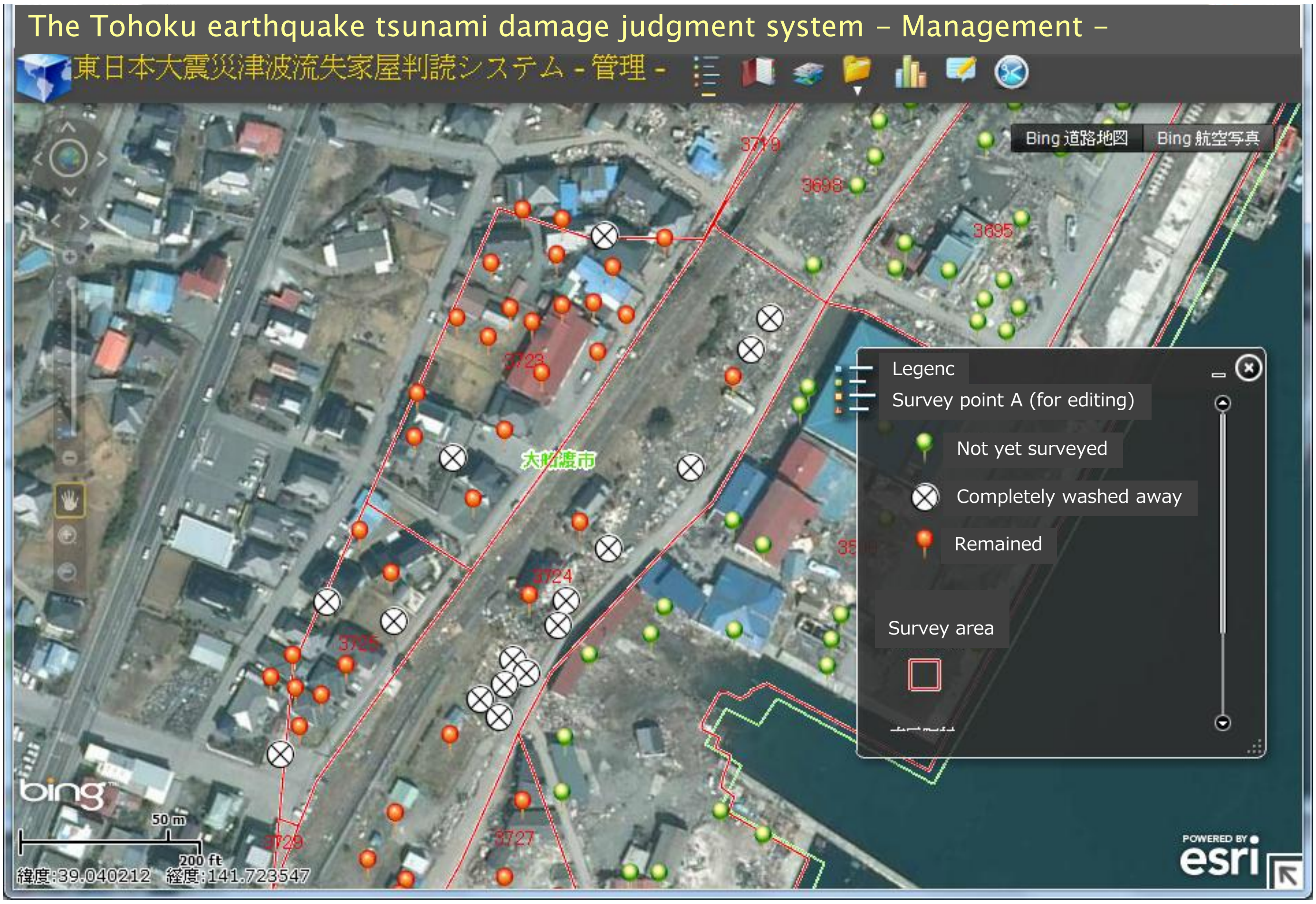


Figure 2. Screen design concept for the washed-away building judgment system using a Web-GIS

Under ideal circumstances we would have conducted a field survey to verify the results of our estimate. However, immediately after the earthquake, access to the disaster area was limited and the survey would have taken a very long time. These conditions necessitated the development of an efficient survey method that did not require visits to the fields.

II. Mechanisms to Determine Washed Away Buildings Using WEB-GIS

The aim was to build a system to enable participation from anywhere in Japan. This requires a good network environment in order to secure a stable supply of human resources for the quick and efficient execution of the survey. Specifically, we designed a system to determine whether a building was washed away or not using the WEB-GIS by superimposing building data before the earthquake (building data) and aerial views after the earthquake (Figure 2).

A. Basic Design Concept

1) To determine the judgment patterns for washed-away buildings

Two categories were created for buildings that were washed away, either completely washed away or partially washed away. The purpose of this was to make it easy for an investigator to intuitively make a judgment (Figure 3).

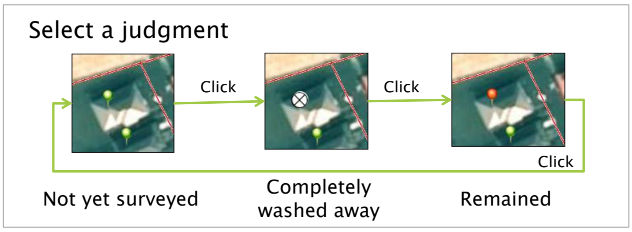


Figure 3. Judgment selection for building damage only by clicking

2) To identify survey areas by roads

We intersected areas by roads, and each area was assigned a 13-digit ID number for each survey area (Figure 4). The 13-digit ID number was composed of a city, ward, or "cho" district code (5 digits), flood area code (4 digits), and survey area code for city, ward, and "cho" (4 digits). This made it easy to visually identify survey areas, and tally the results according to governmental jurisdictions.

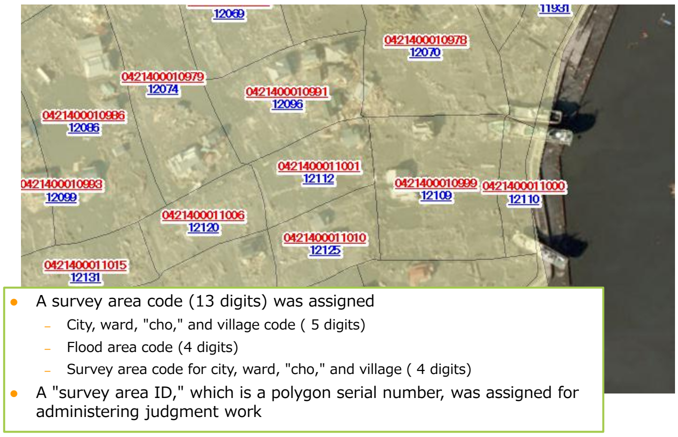
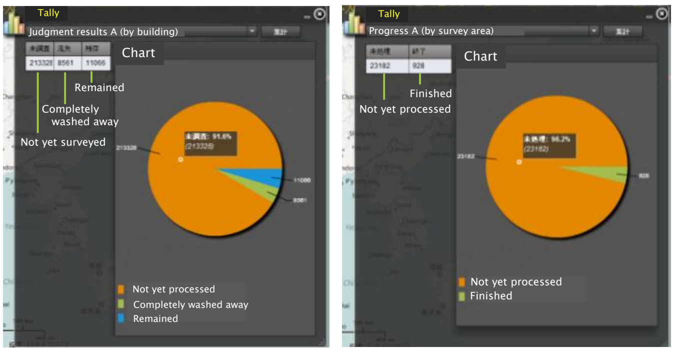


Figure 4. Code system for surveyed areas

3) To construct a system that allowed the progress of the survey to be viewed

Multiple investigators simultaneously conducted a survey using the WEB-GIS. We installed a feature to visualize the overall progress of the survey, which we hoped would motivate the investigators to conduct the survey (Figure 5).



Based on the number of buildings (232,955) Based on the number of areas (24,110)

Figure 5. Tallying function to grasp progress of survey work

B. *System Configuration (Figure 6)*

Configuration of the web application distribution environment involved five components.

1) Cloud infrastructure:

We selected a cloud infrastructure because it offered flexibility for changing the basic specifications, the ease of installation of the environment, and the potential for multiple accesses.

2) Middleware:

We selected a middleware so that many people could simultaneously access, edit, and process the data over the spatial GIS system.

3) Application:

We selected an application that allows the user to bidirectionally interact with the spatial GIS using a web browser.

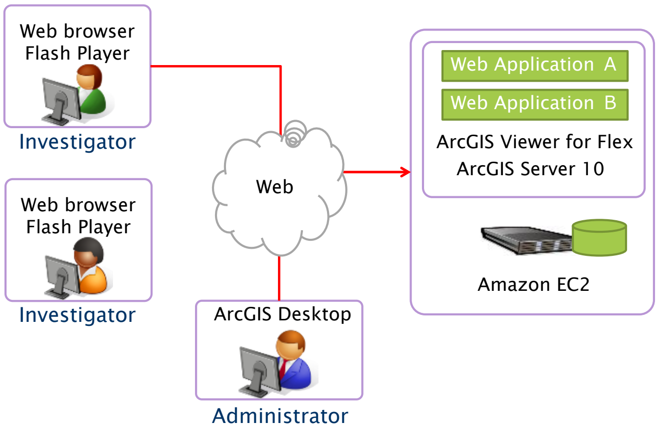


Figure 6. System Configuration

4) Administrator of the web application: The administrator should be able to manage the progress of the survey and conduct a spatial analysis from their local environment, as well as exchange data with the cloud environment.

5) Investigator: Each investigator should have Flash Player, which is typically installed on most new personal computers. This serves as the operating environment for the personal computer, network environment, and web application.

III. System Verification: Washed Away Building Mapping Project

A. *An overview of the project to verify the system*

1) Purpose: To clarify issues that may arise while conducting the survey, in addition to considering an environment to efficiently and effectively tackle future disasters.

2) Overview: To conduct a survey to identify buildings that were washed away in the three afflicted prefectures of Iwate, Miyagi, and Fukushima (excluding areas affected by a nuclear power plant accident because no aerial views were available for those areas). Moreover, to verify the effectiveness of this mechanism to identify buildings that were washed away using the WEB-GIS.

3) Investigators: Undergraduate students, graduate students, and researchers from five research groups in different universities were selected to conduct a study related to disaster prevention and disasters. Two independent investigators conducted a survey of the same area to verify an agreement between two survey results.

4) Instructions: As instruction manual was prepared and is available online at all times.

5) The number of survey points: 232,906

Table 1. Result of experimentation by two investigators (A and B)

		Result: Investigator "B"		Total
		Completely washed away	Remained	
Result: Investigator "A"	Completely washed away	75,032 (46.0%)	6,027 (3.7%)	81,059 (49.7%)
	Remained	8,836 (5.4%)	73,310 (44.9%)	82,146 (50.3%)
Total		83,868 (51.4%)	79,337 (48.6%)	163,205 (100.0%)

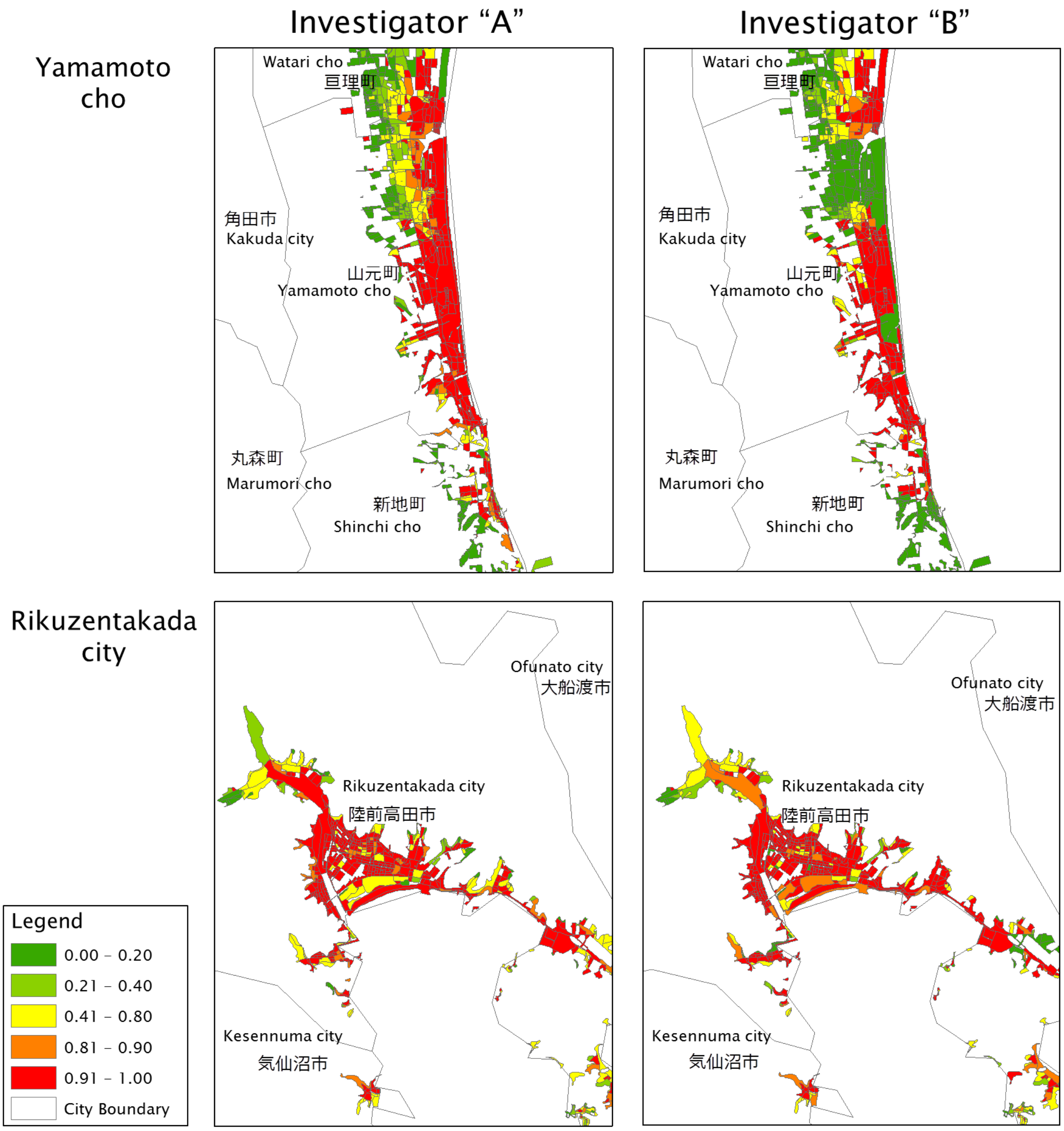


Figure 7. An example of area where there was a discrepancy in judgment

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B. *Results of the system verification project*

1) Verification results 1: The percentage of concordant survey results

The overall percentage for concordant surveys conducted by different investigators was 90.9%. This percentage was highly statistically significant ($X^2(1) = 109305.7$, $p < .001$) (Table 1).

2) Verification results 2: Issues with the data

a) An important issue to keep in mind is that there were no aerial views of the areas near the Fukushima Nuclear Power Plants since airplanes were not allowed to fly over these areas. Therefore, a survey using this method was not possible in these areas.

b) Differences in the precision of the spatial information lead to discrepancies between the building information before the earthquake (building foundation data) and aerial views after the earthquake. In some instances these data discrepancies made it difficult to distinguish between a building that was in fact washed away and a building that appeared to be washed away.

3) Verification results 3: Issues in operation management

a) There were differences among the five research groups in the way the survey was conducted. Some groups followed the instructions, while others did not.

b) Comparison of survey results conducted by different investigators revealed areas with a high degree of agreement and those with a low degree of agreement. This was likely due to personal bias in the criteria used by the investigators to make judgments according to the instructions (Figure 7).

4) Verification results 4: Issues with the system

We realized that it was necessary to develop an interface to minimize human errors in the operation management.

IV. Future Challenges

Multiple people judged the effectiveness and viability of the cloud-based participatory WEB-GIS system to certify building damage due to the tsunamis. Although a web-based system can increase the participation of investigators, it is often difficult to guarantee the quality of investigation conducted. We show that consolidating the judgments of multiple investigators was an effective means to improve the quality of investigation.

While this system was configured to be a judgment system, it is possible to adopt it to a wide variety of surveys depending on how categories are set for judgment and selection; therefore, it has promise as a highly versatile survey system. We aim to build a system with an even higher level of viability by solving the issues that we found in the areas of data, management, and systems.

Acknowledgment

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