Development of remote building damage assessment System during large-scale earthquake disaster

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SUMMARY:
In Japan, several big earthquakes are expected to occur in near future. A lot of structural damages due to these earthquakes will cause enormous needs for building damage assessment. However, there is a limit on the number of specialists with adequate assessment skills who can access the damaged area under bad traffic conditions. Delay in building damage assessment by local governments can disturb rapid reconstruction of the damaged area. Considering these problems during large-scale earthquake disaster, this paper proposed the new system for building damage assessment using photos of damaged houses taken by residents or volunteer fire corps in damaged area. In this paper, the total system for supporting building damage assessment was designed and its prototype system was developed. The system for uploading the photos of damaged houses was developed as mobile communication service. The remote system for specialists to assess the damage level was developed as web service.

Keywords: earthquake disaster, building damage assessment, IT system

1. INTRODUCTION

In Japan, several big earthquakes are expected to occur in the near future. A lot of structural damages due to these earthquakes will cause enormous needs for building damage assessment. Building damage assessment is necessary for governments to issue the Victim Certificates for residents who suffered housing damages. However, current number of human recourses who are trained with the procedure of building damage assessment is not enough. It is necessary to develop the new system which can correspond to next large-scale earthquake disaster. The guidelines of general procedure for inspecting building damage and evaluating loss due to disasters were published by the Cabinet Office in 1968, 2001 and 2009. However, in past disasters, various problems of building damage assessment have been pointed out such as inaccurate inspection, difficulty in quick inspection and lack of human recourses with sufficient skill of assessment.

In this research, new remote system for building damage assessment using IT system was proposed and prototype system was developed. These systems have some features that can solve some problems pointed out by past building damage assessments and execute building damage assessment quickly after a large scale earthquake disaster. This proposed system has two sub-systems. First one is photo uploading system used in damaged area. Second one is assessment system for supporting experts such as registered architects and experienced workers outside the damaged area. Finally, we report that design and functions of developed system.

2. PROBLEMS OF PAST BUILDING DAMAGE ASSESSMENTS AND SOLUTIONS

There are 3 inspection stages in building damage assessment such as “Primary Inspection”, “Secondary Inspection” and “Issue of the Victim Certificates”. Through these stages, damage levels of

Table1. Problems and solutions of building damage assessment after earthquakes

Flow of Inspection		1995 Hyogoken-Nanbu Earthquake	2004 Niigata Chuetsu Earthquake	2007 Niigata Chuetsu-oki Earthquake	Solution of past problems in this research
Ⅰ-Criteria	①Criteria	There is no standard to carry out the building damage assessment. (Murao,1999)	There is no standard to carry out the building damage assessment. Neither examination methods nor the inspection methods are clearly provided. Only guidelines were issued by the Cabinet Office. (Shigekawa, 2005)		-
Ⅱ-Training of Inspector	②Summon of Inspection	Insufficient number of assistant staff (Murao,1999)	Insufficient number of assistant staff (Shigekawa,2005)	Difficulty in assemble of inspectors (Tanaka,2008)	Inspectors who goes in the damaged area becomes unnecessary.
	③Training	-	Because method of assessment is different in each local government, training is difficult. (Horie,2004)	-	Prior training to inspectors can be executed.
	④Organize	Inspector's knowledge was insufficient. (Murao,1999)	Difficulty in gathering enough number of Inspectors and keeping inspection quality (Shigekawa,2005)	-	・The owner of damaged house and the fire fighters can become an investigator. ・Inspection quality can keep by doing prior training and taking a picture using instruction.
Ⅲ-Screening	⑤Screening	-	Limit in on-site inspection for lack of inspectors (Shigekawa,2005)		Because of a lot of support workers exist outside of damaged area. So, a lot of investigations can be executed.
Ⅳ-Inspection	⑥Primary Inspection	-	-	Difference between structural engineer's aspect and the Cabinet Office guideline (Tanaka,2008)	-
		-	Inspector's knowledge was insufficient. (Shigekawa,2005)	-	The assessment result keeps accuracy by a double check.
		Problem concerning inspection accuracy (Murao,1999)	Problem concerning inspection accuracy (Shigekawa,2005)	Problem concerning inspection accuracy (Tanaka,2008)	The assessment result keeps accuracy by a double check.
	⑦Secondary Inspection	Difficulty in responding to residents who have dissatisfaction in inspection results (Murao,1999)	Difficulty in responding to residents who have dissatisfaction in inspection results (Shigekawa,2005)	-	-
		-	-	Difficulty in predicting number of application (Tanaka,2008)	Because of a lot of support workers exist outside of damaged area. So, a lot of investigations can be executed.
		-	-	Needs for assistant staff's for thirdly inspection (Tanaka,2008)	The assessment result keeps accuracy by a double check. So, number of execution of third inspection can be reduced.
	⑧Victim Certificate	-	The efficiency of work was low, because the issue of enormous certificates was the first time for local governments. (Yoshitomi,2005)	-	Because of issue of the victims certificate was automated, the amount of work of administrative office can be greatly reduced.
Use of electronics devices	①Use of GIS	Used by ex post analysis	Used by ex post analysis	Used by ex post analysis	Possible to use GIS by improving the Web environment.
	②Use of GPS	Not used because of technological development	Not used	Not used	Standard equipment in a smart phone.
	③Mobile phone		Used a little.	Used a little.	The usability has improved greatly with a smart phone.
	④Digital camera		Used a little.	・Only used for the record ・Limit in data processing using PC for lack of capacity.	Standard equipment in a smart phone.
	⑤Cloud computing		Not used because of technological development.	Not used because of technological development.	The Cloud computing can be used with a smart phone.

buildings are decided by visual inspection. The primary inspection evaluates the damages appeared on the exterior of a building. The secondary one evaluates not only the exterior damage but also the interior damage. The purpose of the secondary inspection is to provide the second opinion for the evaluation when the owner or resident of a damaged house does not accept the result of the primary one. Therefore, the primary inspection is carried out for all the damaged buildings, while the secondary inspection is usually carried out by request. Finally, Victim Certificates for residents are
Table1: Problems and solutions of building damage assessment after earthquakes
issued from the local governments.

The process of assessment needs accuracy, quickness, objectivity and fairness because the results of the assessments are used as criteria for providing public monetary supports for rebuilding their livelihood. However, various problems have been pointed out for the building damage assessments after past earthquakes. We reviewed literatures regarding past several building damage assessments such as Shigekawa (2005) and classified reported problems as shown in Table 1. As a result, enormous problems in each inspection stage were obtained. Our proposals to solve the problems at each stage were shown in table 1. For example, “primary inspection” stage has the problems with low inspection accuracy and insufficient inspectors’ knowledge. In order to solve these problems, we proposed double check procedures to enhance accuracy of assessments.

3. CONCEPT OF NEW REMOTE SYSTEM FOR BUILDING DAMAGE ASSESSMENT

As a new system for achieving all the solutions for the problems reported at the past building damage assessments as shown in table 1, we proposed a new remote system for supporting building damage assessments during large-scale earthquake disaster. The concept of the system is illustrated in figure 1. The total system consists of two sub-systems. The first one is photo upload system in damaged area.

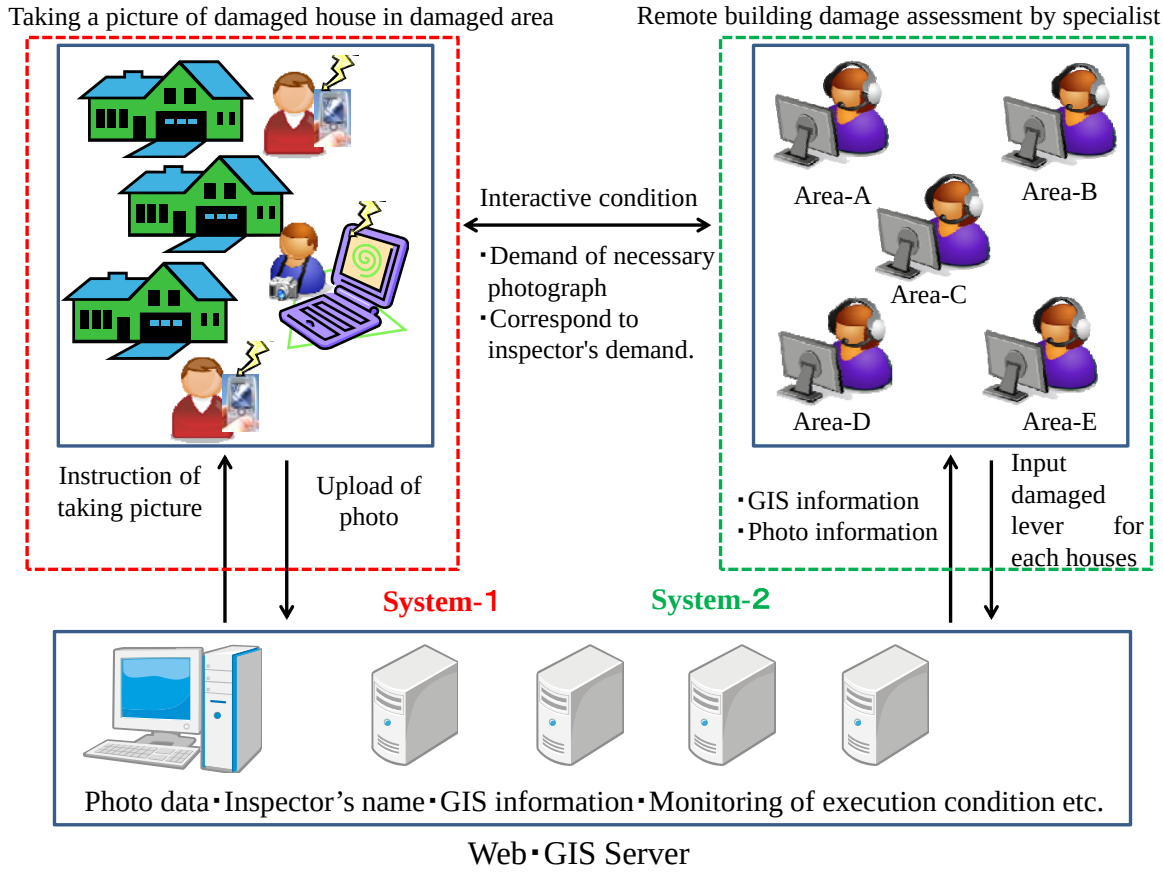

Figure 1. Concept of remote system for building damage assessment

Photos of a damaged house are taken by residents or volunteer fire corps in damaged area and those data is uploaded to the server. The second one is remote assessment system for specialists. Specialists located outside the damaged area confirm these photos through the website, and assess their damage levels and area. All the data used for building damage assessment is managed with GIS database on the management server located outside the damaged area under cloud condition. This kind of digital management system can contribute to enhance the accuracy and efficiency of the procedures for issuing the Victim Certificates for residents.

4. DEVELOPMENT OF PROTOTYPE REMOTE SYSTEM FOR BUILDING DAMAGE ASSESSMENT

4.1 Development of Photo Upload System in Damaged Area

Here, prototype of "Photo upload system in damaged area" was developed. Photos of a damaged house are taken by residents or volunteer fire corps in damaged area and those data is uploaded to the server. This system was developed by Android as the mobile phone operating system which is installed in almost all the smart phones except iPhone. Photo upload application is installed to each Android smart phone by inspectors who are residents or volunteer fire corps in damaged area.

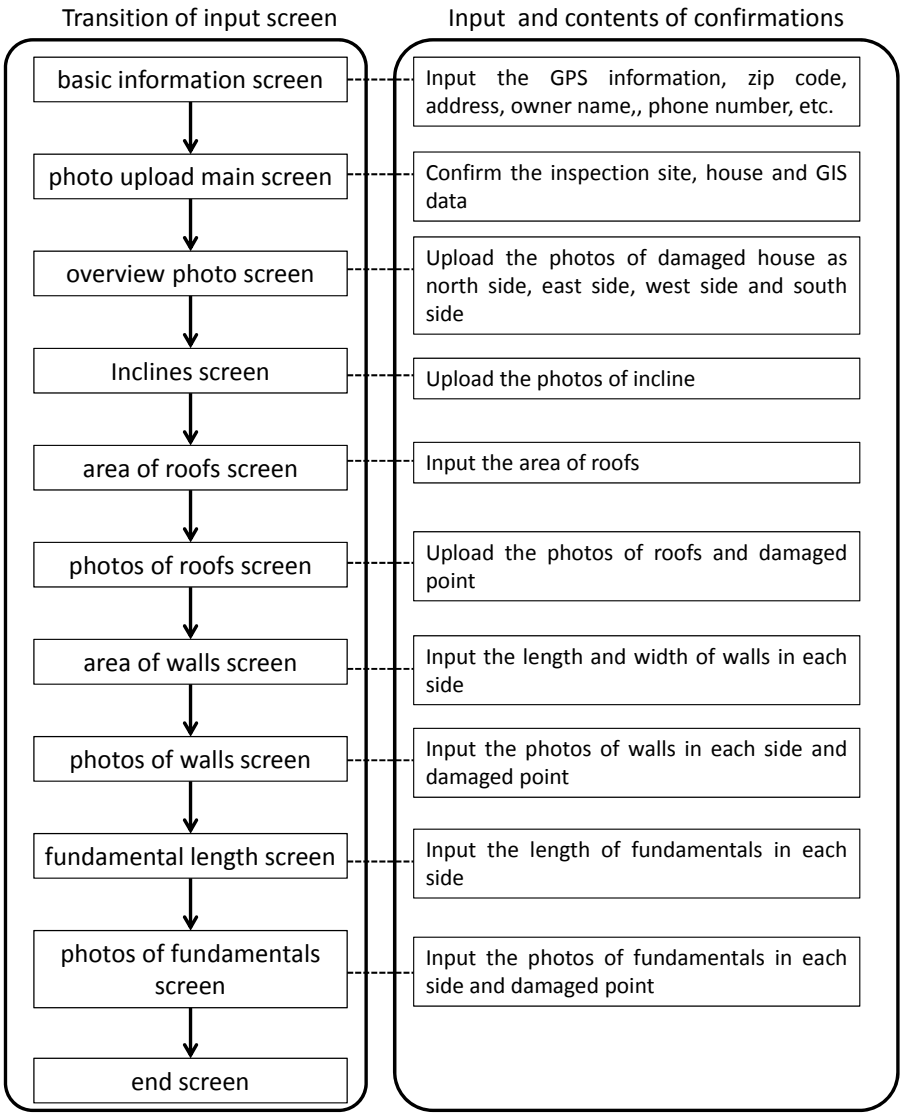

Figure 2. Flow of photo upload system in damaged area

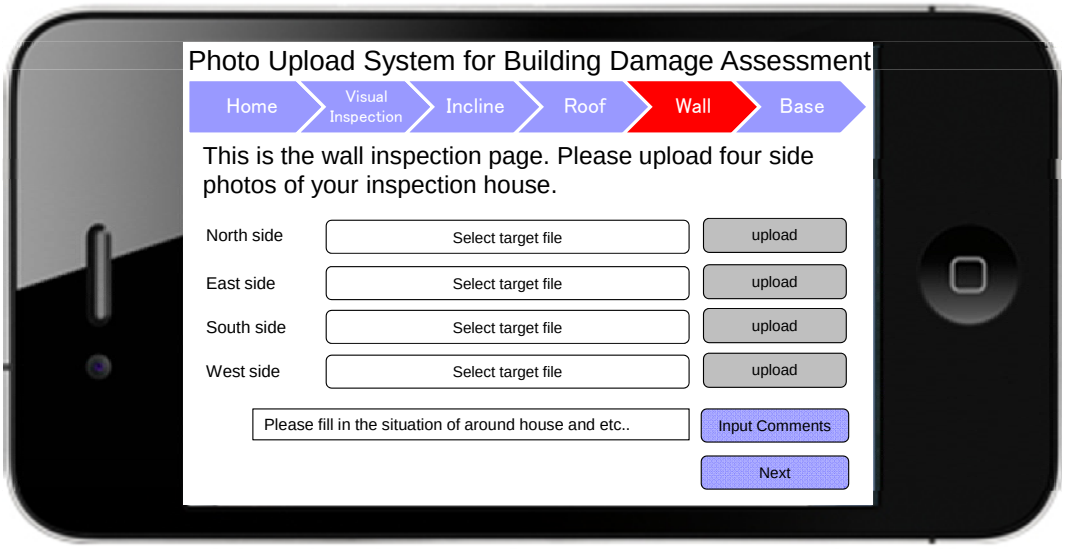

Figure 3. Photo upload system in damaged area (upload page)

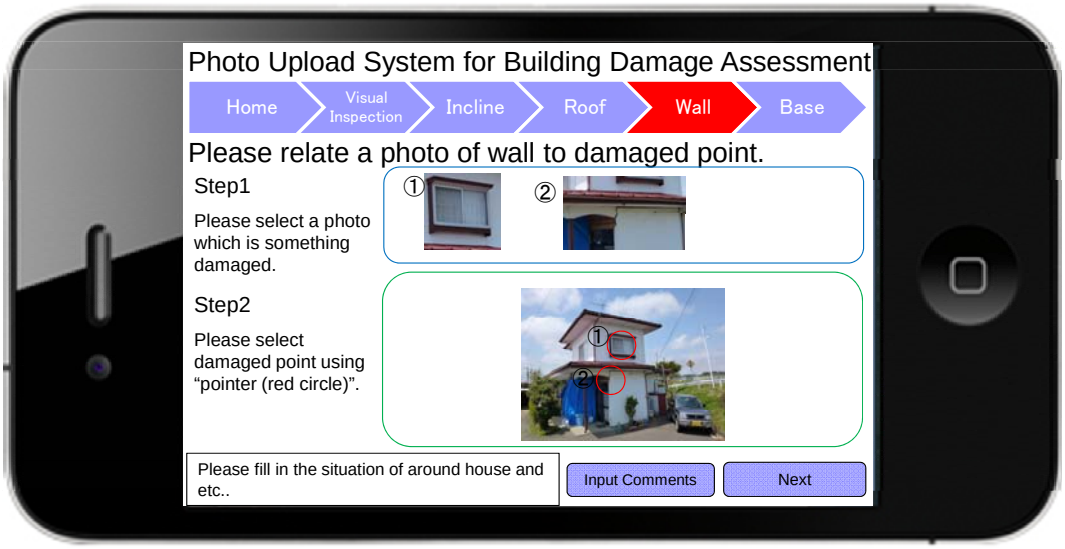

Figure 4. Photo upload system in damaged area (relationship page)

Flow of photo upload system is shown in figure 2. Firstly, residents or volunteer fire corps as inspectors input the basic information such as GPS information, address and owner name. Secondary, they upload some photos such as overview of damaged house, incline of damaged house and damaged point of roofs, walls and fundamentals. Finally, they confirm the input data and some photos.

Method of completing for photo upload in damaged area using upload application is as follows. Inspectors take some damaged house photos which are full views of a damaged house (north side, east side, south side and west side) and closeup views of damaged points.

They select some photos for upload in each factors page, and fill in the comments about damage level and location of a house etc. as shown in figure 3. Inspectors should take pictures of damaged house concerning three factors: externals, inclination and building element (roof, exterior wall and foundation). Furthermore, they have to relate closeup views of damaged points to full views using

touch screen functions as shown in figure 4.Figures 3 and 4 are the prototype images of the system for the primary inspection. The prototype images of photo upload system were developed based on the data of totally damaged houses due to the 2011 off the Pacific coast of Tohoku Earthquake. After taking some pictures, inspectors need to upload them to an exclusive server in cloud condition using upload application. Using this application makes it easier to select and upload photos which are taken by inspector in damaged area. The reason is that smart phone has touch screen functions which are tap, drag, flick and pinch out/in operations.

4.2 Development of Remote Assessment System for Specialists

Here, prototype of "remote assessment system of photos of damaged houses was developed. Specialists outside the damaged area confirm these photos on the website and assess their damage levels. All the data used for building damage assessment is managed with GIS database on the management server located outside the damaged area under cloud condition.

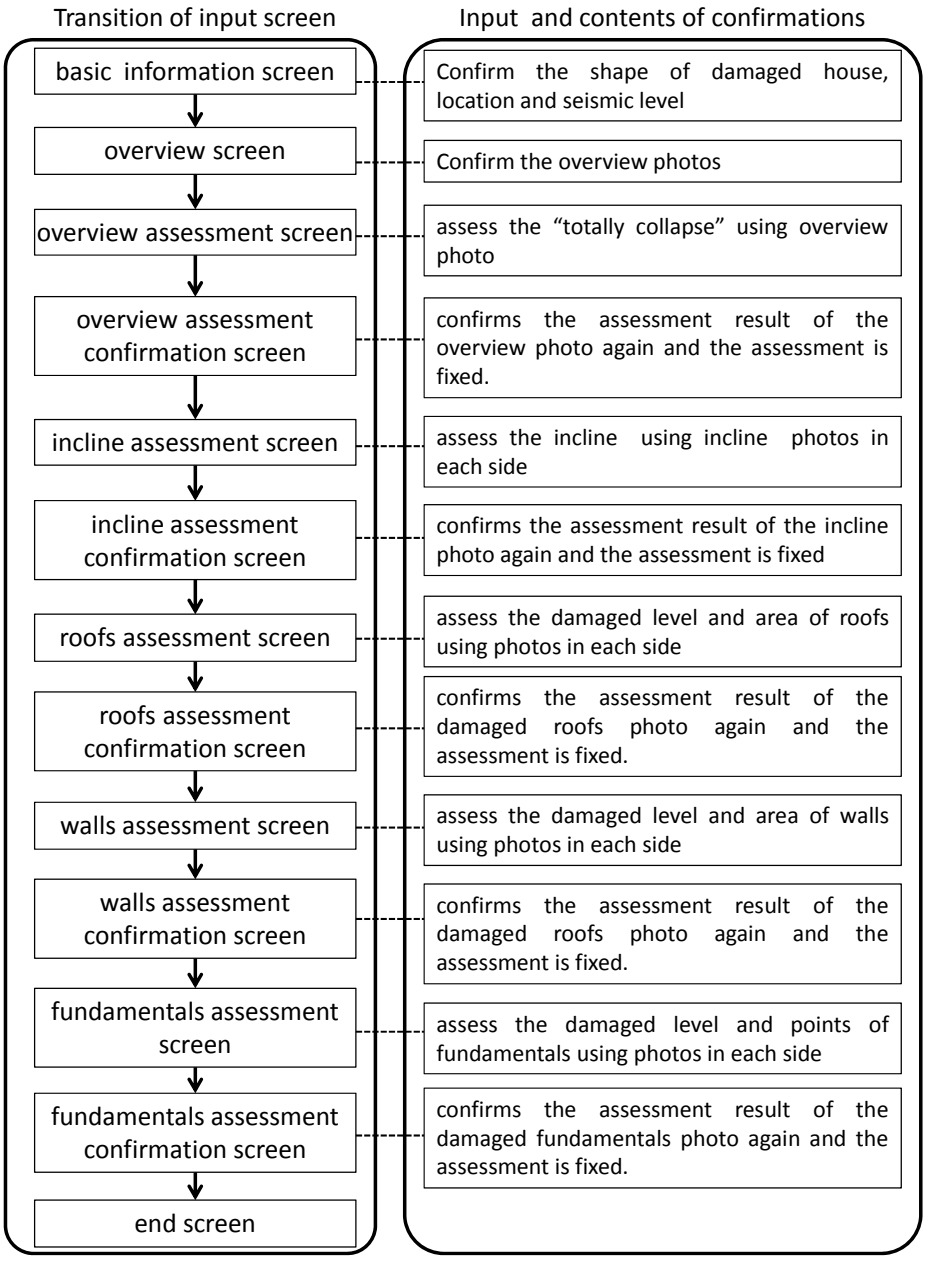

Figure 5. Flow of remote assessment system

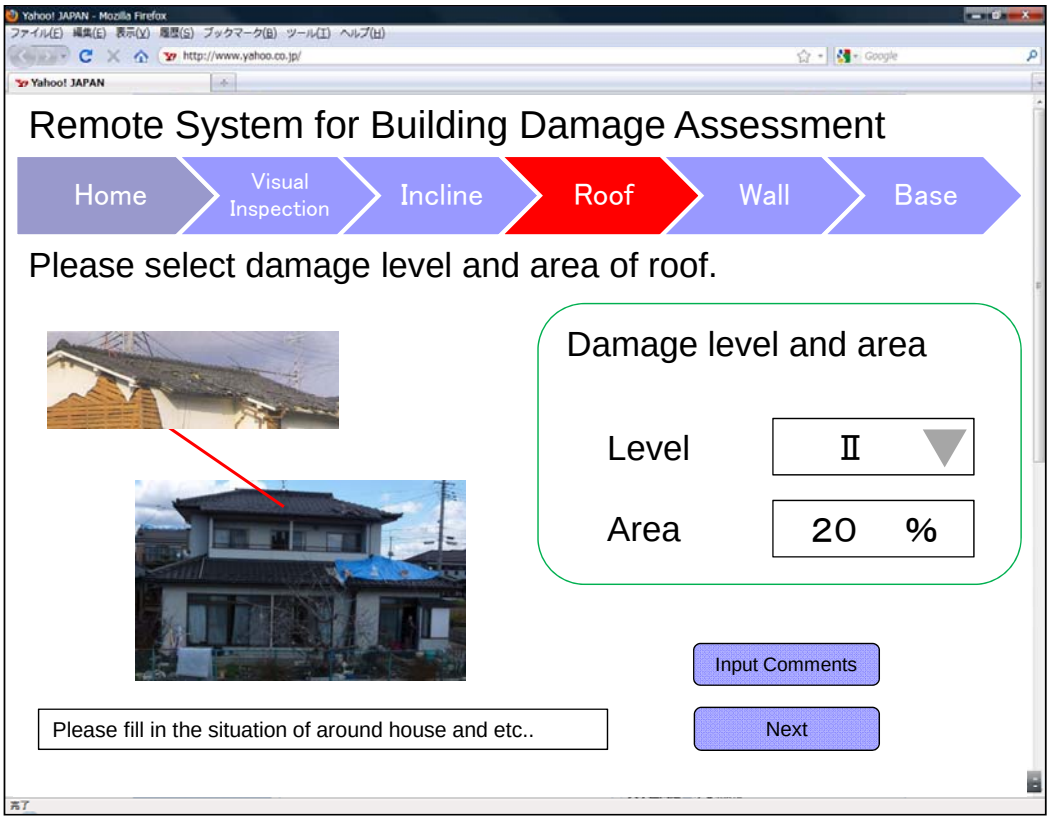

Figure 6. Remote assessment system (roof assessment page)

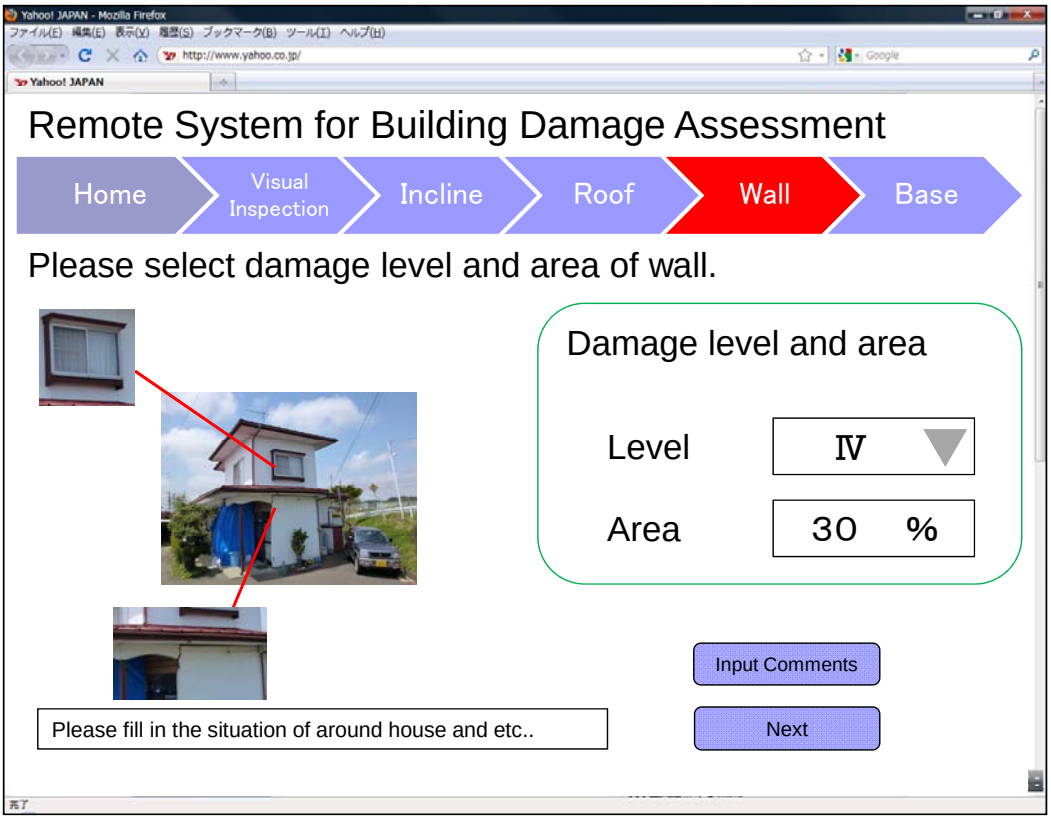

Figure 7. Remote assessment system (wall assessment page)

Flow of remote assessment system is shown in figure 5. Firstly, specialists who are registered architects and experienced workers outside the damaged area confirm the basic information such as shape of damaged house, location and seismic level on the web system and overview all the photos of a damaged house. Secondary, they assess the damage level and area using some photos such as overview of damaged house, incline of damaged house and damaged point of roofs, walls and fundamentals. Finally, specialists confirm the input data and some photos. Then result of first assessment is passed to the next specialist to carry out double check.

Figures 6 and 7 show the prototype images of the system for primary inspection. These images were developed based on the data of totally damaged houses due to the 2011 off the Pacific coast of Tohoku Earthquake. Total damage level of a house is decided based on damage levels of three factors: externals, inclination and building element. Assessment for one damaged house should be conducted by two or three specialists to double-check the result and keep accuracy, fairness and objectivity. They can see close-up photos if necessary. They evaluate the photos and decide its damage level as shown in figures 6 and 7. Specialists select the damage level and area from pull down choice set in each factor page. In addition, they can request additional photos for accurate assessment to inspectors in damaged area through the each assessment page. In final page, fill in the special or caution comments of assessed damaged house and pass to the next specialist. When the assessment ends here, Victim Certificates for resident is issued from local government.

5. CONCLUSIONS

In Japan, several big earthquakes are expected to occur in the near future. It is necessary to develop the new system which can be corresponds to next large-scale earthquake disaster. In this research, new remote assessment system for building damage assessment was proposed.

Some problems of past building damage assessments were analyzed and applicability of new technologies including new electronics devices which are GPS, GIS, digital camera and mobile phone (smart phone) was discussed. Among these problems, this paper focused on “Inspection stage” and “Assessment stage”, and proposed new remote system for building damage assessment using both mobile communication service and web service.

The prototype images of remote building damage assessment system were developed based on the data of totally damaged houses due to the 2011 off the Pacific coast of Tohoku Earthquake. In the future, we plan to improve the functions of the system and examine its effectiveness through experiments for specialists.

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