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Paper:

Development of Urban Resilience GeoPortal Online for the Better Understanding of Disaster Scenarios

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This paper discusses the development and implementation of the web-based geo-spatial information sharing and integration system that advances the multidisciplinary researches on the processes and impacts of mega-disaster. The mega-disasters predicted in Japan, such as Tokyo Metropolitan Earthquake or Nankai Trough Earthquake Tsunami, bring huge amount of damage and loss in various sectors and various regions, and the scenarios of damage occurrence and loss propagation are very complex. Hence, in order to quantify each problem to create disaster reduction strategies, it is very important to share and integrate data and findings across many disciplines and regions. In this point of view, we are developing the Urban Resilience Geoportal as the sharing site of research findings. In this paper, we discuss the concept of such system focusing on the accumulation and sharing of multidisciplinary data, the integration of damage and loss quantification methods, the collaboration with other disaster information systems, and the utilization of data to create new findings.

Keywords: GeoPortal, mash up, Web GIS, Tokyo Metropolitan Earthquake, Nankai Trough Earthquake and Tsunami

1. Introduction

In this paper, we introduce and discuss GeoPortal we are developing with the aim to prepare for the mega-disaster that will occur in the future by sharing and integrating the spreading geo-spatial information using the Web and to facilitate the smooth execution of the disaster response.

Geo-spatial information plays an important role in the resolution of different issues regarding disaster prevention or disaster response. Ahead of any disaster to occur, geo-special information can be produced in diverse areas and agents starting from making an assumption on the hazard, and from the area of public policies such as anticipation of damage to information such as hazard maps that urge self-help will be utilized. Moreover, it is important to investigate the hazard and damages that have occurred and to understand the circumstance that have drastically changed in handling the subsequent situation.

Considering the mega-disasters occurring in Japan, it is essential that we share, integrate and utilize various Geo-portal information in a positive manner.

The 2011 Great East Japan Earthquake caused by Tohoku Earthquake and Tsunami occurred on March 11, 2011 conduced an enormous amount of damage including over 18,000 persons dead or missing. Damages went way beyond the direct damages caused by the earthquakes and tsunami, stretching to nuclear disaster in and around Fukushima from the catastrophe of the Fukushima Daiichi Nuclear Power Plant, shortage of fuels from the damage of the oil tanks in Sendai or electricity shortage from the shutdown of electric power stations, and then the stalling of commodity distribution such as food or daily essentials caused by the severed roads and the bankrupting of companies caused by severed supply chains or harmful rumor; the aftermath gave great impacts not just to the heavy disaster areas but to broad areas also.

At the same time, Tokyo Metropolitan Earthquake or Nankai Trough Earthquake Tsunami are anticipated as earthquakes we need to be prepared for, and the damages they could cause are projected to be of a vast amount. If Tokyo Metropolitan Earthquake occurred, cities where various commercial and financial functions center and liaise intricately with each other will be hit by earthquakes [2-4] and there exist points where causal correlations with the occurrence of damage are not clarified and are evaluated only qualitatively. There are also possibilities of the damages to spread as a result of unforeknown scenarios arising unexpectedly. In order to investigate measures that are effective and can provide a wide-range of capabilities, it is necessary to quantify various impacts by integrating all perceptions extending into different organizations/disciplines. Earthquakes and tsunami that arise in Nankai Trough will hit a broad area of western Japan [5] and damages occur simultaneously in big cities like Nagoya and Osaka, local cities, and depopulating small towns. The areas that will be afflicted will be broader than those of the 2011 Great East Japan Earthquake, and integrating the knowledge in the entire afflicted area such as how to take preventive measures by utilizing the limited budget and time and how to allocate the limited resources and manpower to take countermeasures against disaster is important in order to avoid immediate chaos.

From such case examples and assumptions, it is necessary for all areas and all regions to work together to take countermeasures as damages or impacts will expand over various fields of expertise and different areas in mega-disasters, and in order that to work it is important to share all in all the knowledge possessed by every field and area in a positive manner and integrate all knowledge on various issues along with quantifying them and to review the way to optimize them altogether.

There have been many researches on the structure of information sharing for disaster using maps. For example, Noda proposes disaster reduction information sharing platform used for disaster response by coordinating simple data and functions using disaster reduction information sharing protocol and building up an ad-hoc system [6]. Nagasaka and colleagues propose disaster risk information sharing platform that shares information on the risks possessed by the nation, local government, research institution, etc. [7]. There are also J-SHIS hazard stations on which information on seismic hazards can be checked on Web maps [8] and consolidated hazard maps. However, these are limited to the development of platforms or what are specialized in certain areas and the research on consolidating information and quantifying the scenario against mega-disaster has only just begun.

The authors take their stand on such perspectives and in order to contribute to the propulsion of researches on disaster mechanisms and countermeasures against disaster, they are trying to build GeoPortal that can share and distribute knowledge possessed by researchers of various fields, especially the knowledge about geo-spatial information. They are also reviewing measures to integrate situation recognition as common operational picture when a disaster strikes by using GeoPortal. In this paper, we outline the geo-spatial information handled by GeoPortal and the integrated manner of utilization of these geo-spatial information.

2. Functional Requirements of Geoportal Seen from the Mega-Disaster Process

Firstly, we would like to define the functional requirements of GeoPortal. Giantism of hazards, complexity of the scenario, enormousness of the damage and the widely spread areas are some of the causes for a disaster to become enormous. In order to cope with mega-disaster, it is important to review the possible hazard and combine all our wisdom to stabilize the scenario, and for that we must first be prepared for as much as possible on both sides, individuals and organizations, and then to optimize as a whole. In this section, we will review from the standpoints of hazard in Section 2.1, scenario in Section 2.2, disaster prevention by individuals and organizations in Section 2.3, and disaster prevention as a whole in Section 2.4 and review these requirements to be considered.

2.1. How to Cope with the Uncertainty of Expected Hazards

After the occurrence of 2011 Great East Japan Earthquake, estimation on Tokyo Metropolitan Earthquake and Nankai Trough Earthquake Tsunami that are of concern to occur in the future is being reexamined.

The tsunami generated by 2011 Tohoku Earthquake has greatly exceeded the expected prior and existing hazards especially in the coastal areas of the three prefectures namely Iwate, Miyagi and Fukushima, and produced spatio-temporal damage spreads and disaster handling that had greatly exceeded the amount expected. Central Disaster Management Council, "Committee for Technical Investigation on Countermeasures for Earthquakes and Tsunamis Based on the Lessons Learned from the 2011 off the Pacific coast of Tohoku Earthquake" has made an announcement that we must investigate more precisely the history of the earthquakes/tsunami that ever occurred tracking back as far as possible after the lessons learnt from the occurrence of the mega-class earthquakes that have never been recognized in the data from the past few centuries and conduct studies of the possible maximum earthquakes/tsunami taking every possibility into consideration [9].

The Cabinet Office "Examination Committee on Nankai Trough Giant Earthquake Model" has made a statement on the estimation to be made for the greatest possible scale earthquakes/tsunami based on the reports made by the aforementioned Technical Investigation Committee. They have taken in the idea to make estimation not on the whole as one case but on various cases and obtain the maximum value of the cases studied in every area and assume that as the mega-scale hazard of the studied area. Taking into account that there is uncertainty in making just one assumption, it is considered effective for preventing the disaster to spread more widely if we made various assumptions in order to be able to cope with a multitude of earthquakes that might occur and make all information lead to real actions for coping with what occurred instead of using them as information for safety.

As for Tokyo Metropolitan Earthquake, not only Assumed Northern Tokyo Bay Earthquake that thought to bring about the major disaster as a whole but also the earthquakes of under magnitude 6.9 that can occur in any area in the shallow part of plate could be seismic shaking to cause disaster for each region. Taking into consideration that each region has its own characteristics, every earthquake has a possibility to cause different phases of disaster and different problems, it is necessary to make multimodal assumptions.

Given the above situation, it is necessary to create an environment where various assumptions can be made. Function capable of calculating base items such as hazards and damages easily even if the accuracy is a little low and judging whether any further detailed investigation is necessary or not is needed. Function capable of teaching the users basic knowledge about natural hazards and at the same time learning the vulnerability of the area by calculating the hazards is needed.

2.2. Functions to Analyze Complex Mechanism of Damages and Problems

The big challenge for mega-damage control is to effectively prevent and mitigate damages and aftermath to spread through networks consisting of multi agents in the society at normal times. As for Tokyo Metropolitan Earthquakes, this will be the countermeasures for the continuation of central function and economic activities in the metropolitan area. Because central functions of multiple fields are assembled in Tokyo, it is required that those multiple fields to participate in order to certainly deter or mitigate the disaster.

As for Tokyo Metropolitan Earthquake and Nankai Trough Earthquake Tsunami, a project research that coordinates disaster management from various angles and fields on a series of processes of disaster such as setting of their earthquake model, assumption on the damage, analysis of the aftermath, investigations on proactive countermeasures and emergency responses, and optimization of restoration handling is being made (e.g., [11]). In order to effectively promote this research where professionals in every discipline participate, it is essential to share more deeply and widely the research findings earned in every discipline. We need to create conditions that can easily take in the data, knowledge or method of other discipline that are necessary to make investigations in each field. And all data obtained in each field be shared and the analytical method used in each field be utilized and a structure that can newly analyze and utilize by combining them is in need of.

A structure that can send the research findings at the earliest possible time and disseminate the latest scientific knowledge is important. And then add a system to feedback demands to the researchers and add a structure that feeds back the demands to the researchers and promote cooperation between those at the scene and the professionals.

When creating a system, it will become obsolete if it does not get updated once it is developed. It is important to promote the system users to input the latest data, and that the system to progress constantly with the latest knowledge or methods put forward by researchers. This will require a system that is not GeoPortal which puts together all data in one place, but something that will consolidate GeoPortal as information infrastructure that put together the decentrally released data and the contents and services are distributed on them.

2.3. Information Service Functions Premised on Vast Amounts of Exposure and Damage

In a massive disaster, it is necessary to look at its vast amount of damages, aftermath on that vast amount of physical objects, and an enormous amount of countermeasures against disaster. The Central Disaster Management Council assumes if Earthquake in South of Central Tokyo (M7.3) occurred, the worst scenario will be 23,000 deaths and 610,000 buildings completely destroyed or burnt, and economic loss of 95 trillion yen [4]. Moreover, a population of 29,000,000 will account for being exposed to above JMA intensity 6 lower and they need to be prepared for. Big numbers including that of 6.5 million people who will have difficulty getting home will present a problem [3].

Elemental countermeasures for such enormous damages will be for every person, every company, and every institution to practice countermeasures to deter those occurrences and prepare for the response to damages which require ample information on the assumption of damage situation to get across to all bodies. It is particularly necessary to make it easier to obtain information on how the situation will be in the relevant areas and relevant organizations at the time of disaster that are needed in order to think about the post-disaster living and the continuation of business.

Everyone needs to utilize the Web to make searches promptly and access easily whenever they felt necessary. Also the system to provide assumption information that can see from both macro perspective that can overview and micro perspective that can probe around a spot where each one is interested in looking by providing information on a mapping system on which enlarging and shrinking can be done easily. As for the information displayed on the map, it is required to devise that not all vast information be displayed together but only the necessary information for users are displayed and easily viewed.

2.4. Functions Capable of Developing Strategies Against Widespread Disaster Expanding Beyond Jurisdiction

The trouble with widespread massive disasters is that the disasters occurring simultaneously in different areas are not of the same kind. For Tokyo Metropolitan Earthquake, scenarios will be different for each of the areas namely metropolitan area of high density and high functionality, downtown area where soft foundation and low ground stretch out, and uptown area where the population is high at night [12]. Disaster area will be wider for Nankai Trough Earthquake Tsunami and because of the difference in geography and location or local industry the problems will become diverse. At the time of 2011 Great East Japan Earthquake, problems to be dealt with differed according to the area; tsunami in Sanriku region, nuclear power plants in Fukushima, sediment disaster in the inland areas, or long-period ground motion in Tokyo and liquefaction in the coastal areas.

Therefore accumulation and distribution of information that can overview become necessary. In these areas habitation and business, produce and consumption work together and therefore the damage in each area will make a great impact on the other areas at the time of great disaster. Hazards will occur irrespective of the jurisdiction and their impacts spread and jump across the jurisdiction and therefore on the assumptions given at present in units of each municipality and each prefectural and city government, it is impossible to minimize the damage by what is best as a whole. A system that can distribute assumption

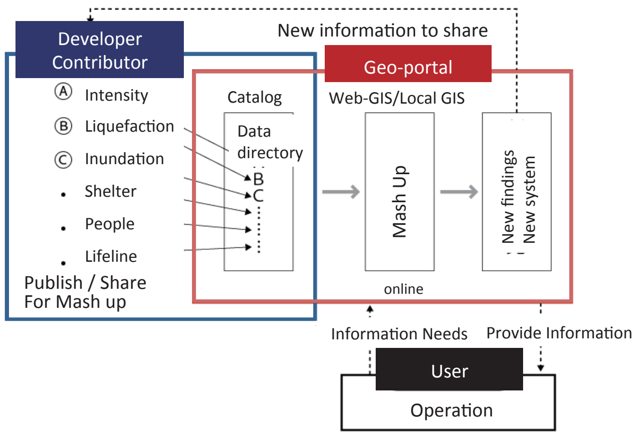

Fig. 1. Concept of GeoPortal.

information to all related disaster municipalities and then mutually investigate the countermeasures is required.

In order to put the above into action, it is essential that all necessary map data be shared online going beyond the frameworks of municipalities or organizations. It is necessary to catalog various dispersed data and make them searchable and consolidate an environment where they can be made use of in a cross-sectional manner without relying on the software or system being used. Moreover, it is also necessary to clarify the copyrights of the data or the directions for use and where the responsibility lies.

3. Concept of GeoPortal

Figure 1 shows the conceptual rendering of GeoPortal based on the review in the previous section.

3.1. Web Service

First component is the method for the implementer (administrator) and the collaborator (author) to provide data and methods. Data means information on a certain matter, and web service is a system that provides those data in the form that is easy to handle on the web.

When hazard data or data such as on emergency evacuation centers are submitted in the original format, it becomes necessary to download these data and convert them into the necessary form. In order to eliminate that bottleneck, we use web service system that enables the application through the web in no time.

Web service can process and return through the web in answer to users' requests. Various data such as seismic intensity, PL-value (Potential of Liquefaction), maximum velocity on the ground level (PGV), building damages and human damages will be provided for by web service. Original data are kept by the server and they are converted into images or features/shapes upon users' request. By doing this the contents offered to users are provided for in the form that is available for reading on a common browser. For instance, assumed distribution of seismic intensity is put in the server as data storing values of assumed instrumental seismic intensity by standard grid. When a user likes to browse, the web service converts those data to images and sends back. If you like to obtain the data to use in damage estimation, web service send the user PGV value, etc.

Because the web service is a system to provide data and processing through the web, the data do not have to be centralized at one place and therefore autonomous-decentralization becomes possible. Data are kept by every implementer and author themselves and transmitted to users as web service. Data are kept under the control of each implementer/author so they can be updated easily and the users can always obtain the latest data. Also compared to distributing data as simple body, it can prevent foul use by those who are not licensed.

However, in order to release web service to the public, it needs dedicated software and therefore highly challenging. In order to easily release data to the public, a system to convert data to web service is required.

3.2. Catalog System

The second component is the "catalog system" which searches the web service that provides the necessary data and introduces the method for utilization whenever there is a demand from a user. This will be a portal site where massive disasters and various map data and mode of analyses that are related to each area are registered and shared among the users. Researchers and collaborators register the URL of the web service to which they provide the data they keep themselves. Or, they send those data and have them converted to web service on the cloud and register that URL. In doing so they write the necessary metadata, information on the copyright, contents of the data and the terms of use. Catalog system will search the data upon request of the users and send them the URL of the web service in return.

Users make a search on the catalog system and obtain the URL, then access to this URL and display the map. They can browse maps on the web browsers or browse and analyze on various GIS software or mobile environment on the local computers. The system is being built to support as many protocols as possible as the application ability will progress by enabling utilization in various scenes.

3.3. Mash Up System

The third component is "Mash Up System" to combine these services.

Means to combine multiple web services as may be necessary and to build up a new web service is called Mash Up. By using this, it is not necessary to create a function needed for building new web service from scratch and we can contribute our energy to the area of specialty in developing web service. We can also reduce work needed for developing and shorten the period of time. In order to promptly respond to mass disasters or widespread disasters, intricate process of the damage in complex disasters and disaster processes, utilization of the Mash Up method is indispensable.

Base map is needed for Mash Up system and information is displayed in various layers on that base map. Base map needs to be something that can be freely enlarged or reduced in size and has no restriction of the government. Users make analyses by superposing the layers they searched as necessary using catalog system.

If analytical calculation function is mashed up instead of layers, simulation execution environment is created. Develop forecast for seismic intensity, damage estimation, impact assessment, and reconstruction analysis, each as an independent function and mash them up, an execution environment that can make simulation of a sequence of disaster from earthquake intensity can be created. Dissemination of research results is expected and strategists will be able to do calculation to a certain point without becoming a researcher by combining flexibly the latest means created by each researcher. Variety of simulation methods that constitute Mash up simulation are offered as geo-processing service. Geo-processing service is a service that performs map information processing for map data. When a variety of map data and conditional variables are input, the GIS server performs the prospectively defined processing (geo-processing) and return the result in the form of a map or data to users. For data required for this work, data that are registered on the catalog system can be utilized. By using this system, a module that will respond to a series of processing can be created by a number of researchers and developers in such way that the earthquake module by seismic researcher, damage module by damage researcher, restoration assumption module by researchers of contingency planning, that is the building of a structure that can perform simulations in no time can be expected. Some people create by dispersing a simulator that has a complex system of disaster processing using the theory of the experts know best.

3.4. Users

Geoportal is targeted for mainly the relevant departments of the government and local public agencies or private sectors and research institutes. There are three utilization forms namely User, Contributor, and Developer.

It is possible for Users (consumers) to only browse the data registered on GeoPortal and execute simulation. They can take actions like printing out after the execution of browsing or simulation but status or result data are not saved.

Contributors (authors) can change data that are registered on the catalog system. Each person registers the data he/she keeps locally and executes various kinds of damage estimations or analyses by Mash Up System using that data, and register the results as data on the catalog system.

Developers can add GeoPortal functions by offering various means of analyses such as damage assumption or releasing the tool on the catalog system to the public.

Fig. 2. Screenshot of urban resilience GeoPortal online.

4. Contents of the GeoPortal

We, the authors, are collecting geo-spatial information connected with researches on urban disaster in accordance with the functional conditions mentioned in Section 2.

4.1. Infrastructure of GeoPortal

We have utilized ArcGIS Online for Organization by the ESRI which is used by organizations including Federal Emergency Management Agency (FEMA) as infrastructure of GeoPortal [13]. **Fig. 2** is the screenshot of Urban Resilience GeoPotal Online we are developing.

The reasons for utilizing this system are that this has almost all aforementioned requirements and that the maintenance of the infrastructure is not up to the users and therefore it enables us to concentrate our work on the development of the contents. Because it is already equipped with a system to mash up the aforementioned catalog system or map layers and users' control system, we need to develop only the data and the web service that make up the contents for the development of GeoPortal that we aim to discuss in this study.

4.2. Static Information

We have gathered and prepared information to be able to access to the necessary information when diverse and a vast amount of manpower and organization mentioned in Section 2.3 are needed. Static information is one component of the contents handled by GeoPortal. Static information is something we can prepare ahead of the disaster to occur such as fundamental information that includes base maps and statistic information, assumption information, and data on research findings.

Fundamental information has been collected based on the ten-layer structure that constitutes society as seen in **Fig. 3**.

There is, (1) natural layer corresponding to ground and terrain information, altitude, etc. as the bottom layer, more specifically, the most fundamental layer where we live on. (2) Structural layer corresponding to roads, river structure, buildings, etc. as artificial hardware comes on top of the natural layer. By adding (3) social/cultural layer

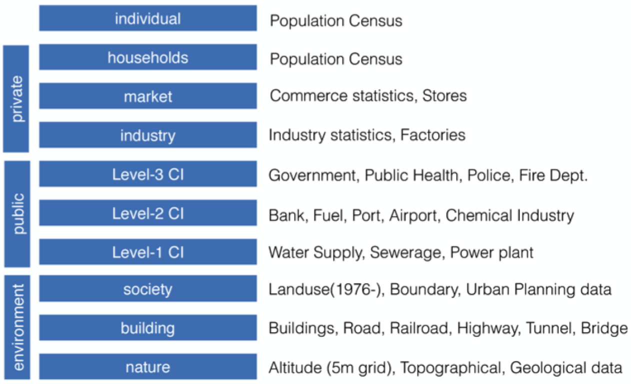

Fig. 3. Layers and samples of fundamental information.

Table 1. Example of gathered research findings.

- Population change after 1995 Kobe Earthquake
- JMA seismic intensity distribution of 2011 Tohoku Earthquake observed by MeSO-net
- Vulnerability index map of water supply
- Survey Result on bridge damage due to 2011 Tohoku Earthquake Tsunami
- Survey result on the damage of offices at 2011 Tohoku Earthquake Tsunami

which is like land utilization, these three layers make up the environmental sector that represents the environment we are surrounded with and this contains mainly what constitutes foundation in general.

Infrastructure sector (public sector) comes next. By invocation of the concept of critical infrastructure protection in the U.S., this sector is made up of the following three layers; (4) level 1 critical infrastructure layer related to utilities such as water, energy, communication, (5) level 2 critical infrastructure related to social and economic flow such finance, transportation or distribution, (6) level 3 critical infrastructure related to administration such as government institutions that provide public services or crisis response institutions. For these, structural data of (2) with attribute information as infrastructure added, or information extracted by function, and statistic information were gathered.

Then there is the nongovernmental activities sector (private sector) where social economic activities that are founded on top of the above-mentioned infrastructure are assembled. As for these, we are trying to set in order the layers founded on various statistics collected from census, such as the data on the information on the number of households. Lastly, we put the population layer including census as (10) individual layer.

In order to be equipped with a function to handle the diverse range of assumptions, we are gathering assumption information as static information. As for information on assumptions, we are gathering data on seismic intensities of Tokyo Metropolitan Earthquake and Nankai Trough Earthquake Tsunami assumed by Central Disaster Management Council, degree of liquefaction risk, hazard information on tsunami, etc. and data on hazard maps announced by prefectural/city governments and municipalities and we try to share them. Those data were difficult to overlap on other maps as they came in PDF and even though they were distributed in paper medium or obtainable on the Web before, they are now made for web service and possible to mash up with the layers requested by the users and made available for use for disaster prevention.

To contribute to the study on large-scale disaster handling strategy expanding beyond the government or organization as mentioned in Section 2.4, we have collected data on research findings to enable the researchers to share their findings among themselves. As for these data on research findings, we are trying to commoditize information based on the idea of starting, from sharing the outcomes among the researchers. Examples on the collected data on research findings are shown in **Table 1**. By gathering various data on research findings, we believe the full picture of disaster becomes clearer and will enable us to study large-scale disaster handling strategy.

First of all, we converted the data kept by each researcher that takes part in the project into GIS data and released them to the public as web service. Because this process requires knowledge on GIS the preparation can become a bottleneck, so we are developing a conversion program from programs used on a routine basis such as creating GIS data from Excel data which use mesh code as a key if they were prepared in mesh data. Then in order to share these data by GeoPortal, users create their own user account and log in by that account. First, users register/save their contents in their own domain. At this point they are not shared by anyone so users can use it as the place to control their own information. Then if they wish to share among the members or open to the public, they set up a title, abstract, sources, terms of use, exclusion of liability, copyright, etc. and share within the necessary extent.

These data will become the input data for quantifying and analyzing the complex damages or issues that are mentioned in Section 2.2.

4.3. Information Sharing

The concept of information sharing becomes important when trying to share static information on GeoPortal. We will discuss this from two aspects in this study.

First, there are things in regard to the manners for sharing the contents, namely Data, Layer, and Map. What it means by sharing as Data is to share all data including attribute data of the contents which makes analyzing possible by using specific letters or numerical numbers. This is to share at the deepest level. Sharing as Layer, it means you cannot access to the data but can share them as presented in symbols in accordance with certain legends. It is not possible to make analyses but mash up to make a new map by overlapping with other layers is possible. Sharing as Map means it is offered only in the form of a set of

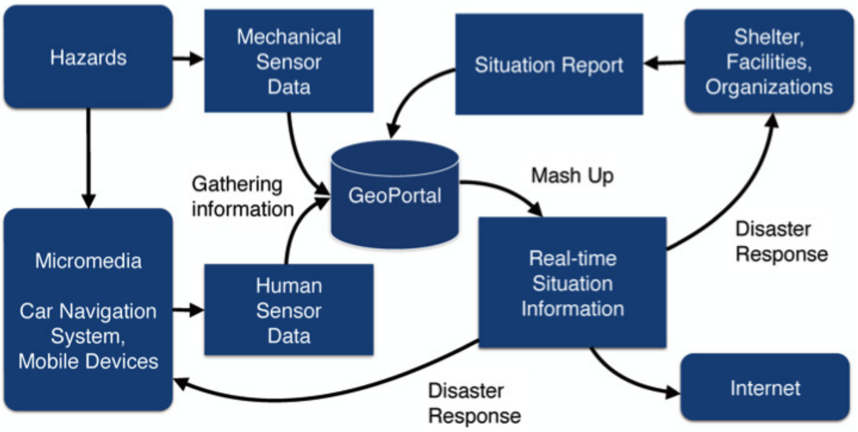

Fig. 4. Concept of dynamic information.

layers restricted by the purveyors and the display method but browsing is possible. You cannot analyze or mash up but sharing of knowledge is possible.

For the other aspect, there are at least four levels of sharing on the point of with whom to share the contents. First is Public which is sharing on the level of releasing to the public including users who do not have an account on GeoPortal. Choose this share if you like to make your research findings widely known. Next is Organization Group as a share on the level of not being able to use without an account. Organization shared among the entire internal members of GeoPortal and any user who has an account on GeoPortal is able to gain access. This is to anticipate the generation of new knowledge by sharing widely among the insiders of GeoPortal. On top of this, Group is narrower and it is of the level for certain users to form a group and share only among its members. By using this, a flexible sharing is possible as you can choose the users you like to share with depending on the contents.

4.4. Dynamic Information

Dynamic information is one of the contents handled by GeoPortal. Dynamic information is not something that is offered in a fixed form prior to the occurrence of disaster but it is obtained dynamically at the time when a disaster strikes and updated as necessary or undergo changes depending on the situation at the time. The concept of dynamic information is shown in **Fig. 4**.

What comes first as dynamic information will be the data on the mechanical sensors that are spread over to monitor hazards or the status of various disaster-prevention facilities such as the intensity in each area on seismic network, rainfall or river observation network released by weather observation network. Presently it is not possible to overlap the data each one keeps using a different system but if the mechanical sensor data is converted as web service using conversion program and put in GeoPortal then mash up with other data will become possible.

And next, image information such as aerial photos or satellite imagery are what most referred to in emergency. It is possible to learn the extent of the damaged area or damage situation each as a simple body but because we can learn the places where disaster struck hard or impassable roads by mashing them up with the building layers or road layers before struck by disaster, it is effective that these information are put in a form that is easy to mash up. Situations on evacuation centers or disaster-related facilities can be circumstance cognition information for handling damage by acquiring information on evacuation centers and disaster prevention related facilities dynamically and plotting them.

The third is human sensor data obtained from micro media such as car navigation system or smart phone. At the time of 2011 Great East Japan Earthquake and Tsunami, travelable road map was made from the probe data gathered on car navigation systems and information was provided to and shared by people who were heading for the afflicted areas to handle the disaster situation. Assessment of the situation at the time of emergency can be obtained by making location data gathered by micro media mash up possible, and providing this situation to each mobile device will lead to information service that supports action.

5. Application of the GeoPortal

In this section, we discuss the method of utilization in terms of how to use GeoPortal after gathering data and modules. There are two major respects; one, that individuals and organizations discuss countermeasure plans for disasters, and two, that they discuss activity policies aiming for the unification of the better situation awareness at the time of emergency.

5.1. Application for Business Impact Analysis

As mentioned in Section 2, it is important for each organization to do business continuity management and be prepared in order to alleviate damages of mega-disaster.

In the study of business continuity management for organizations or disaster prevention of the area, it is important to make assumptions on the possible damages or aftermath on scientific basis and analyze the impacts on business that clarifies what they should secure and prioritize. We can deal with possible damages by using geospatial information. For making assumptions of aftermath it is important that we combine some of the operations, first estimate the hazards and learn what damages they can cause, next learn what would happen to essential utilities, learn what resources can be used to handle the situation, learn the impact of stopping the business. It is especially important to know what other organizations are going to be like and when they will recover. It will become possible to make analyses on business if you utilized GeoPortal that has the function of sharing information on different organizations and combining them.

Here, we created a system that can combine modules such as assumptions on hazard, damage, impact, or recovery simulation by using GeoPortal.

5.1.1. Hazard Simulator

To be equipped with the functions mentioned in Section 2.1, Hazard Simulator is being developed. We plan to be able to discuss not only earthquakes but various hazards also but presently we are developing the part of intensity estimation by mashing up the wide-area earthquake disaster estimation system developed by National Research Institute of Fire and Disaster. Wide-area earthquakes disaster estimation system can presume the three basic damages namely building damage, casualties and fire by inputting earthquake parameter and time of occurrence on the web browser. It is developed as web application by utilizing ArcGIS Server and therefore easy to mash up. Specifically, ask users to access to web application from the catalog system, perform a series of analyses on web application, then save the result in the account of the relevant user of GeoPortal. In this case, web application is already made and it is possible to access to catalog system. Just create the part where URL is registered and the result is conserved in that user's area. **Fig. 5** shows the execution screen being created.

5.1.2. Estimation of Damage

Estimation module for damage will be created by using geo-processing service. For this, ask the researchers to provide us with the method to make damage assumption with necessary data. Then make that method provided for into a program by using the API (Application Programming Interface) that can be executed on ArcGIS Server. Flow of the program is illustrated in **Fig. 6**. Scrape the parameter from the interface and put the program in the model and return as layer. Scrape the data needed for the model from GeoPortal.

The module that assumes damages on water and sewage in the metropolitan area from the assumed intensity was developed by geo-processing service using the method to calculate from PGV constructed by Maruyama et al. based on the data of water pipe damage at the time of the recent earthquake damages by using the standard fragility curve [14] and by a web service that provides

Fig. 5. Screenshot of developing earthquake damage estimation function.

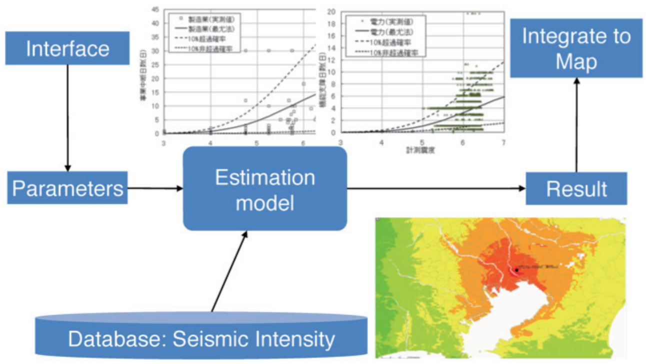

Fig. 6. Typical flow diagram of modules.

water inventory in the capital region that includes Tokyo and three prefectures developed by the method of Nagata and Yamamoto [15].

Make a damage ratio raster by using the calculation of assigning the PGV calculated in Section 5.1.1. and distribution raster of PL-value in the standard fragility curve by using raster operation API, the estimation result raster on water pipe damage can be made by multiplying this by the water inventory raster. Same way, assumption module of water and sewage facility damage have been developed using the fragility curve of Kusaka et al. [16], sewage pipe damage estimation module have been developed using the method of Nagata et al. [17].

5.1.3. Impact Analysis

We have created a module for each of the down time of essential utilities and interruption of business that are necessary in discussing business continuity as impact analysis in the same way as in the previous section using Nagata's method [18]. Also, calculation of the amount of exposure is effective in deciding on the disaster reduction strategies at large by understanding the characteristics by region of the followings: to understand the potentials of the candidate disaster area, specifically how enormous disaster can grow, to understand the operation amount and the size of tasks, and to understand the disaster image by comparing and relativizing with the past disasters, etc. As for the amount of exposure we have

Table 2. Municipalities and population exposed to Nankai Trough Earthquake (Base case).

JMA Intensity	Municipality	Population
>5−	1156	76,010,029
>5+	776	43,742,698
>6−	477	22,213,020
>6+	188	6,904,345
7	70	1,212,509

developed geo-processing service and made it possible to calculate the total amount by the features and the amount of statistics obtained from the web services for each layer exemplified in Section 4.2 for every hazard intensity obtained in Section 5.1.1. The calculation result of the number of exposure municipalities and exposure population at the time of Nankai Trough Earthquakes Tsunami are in **Table 2** as an example. We can see that the population of more than 22 million will be exposed to level 6 lower.

5.2. Utilization of Geo-Spatial Information Sharing at the Time of Emergency

As mentioned in Section 2, when dealing with the enormous and complex issues of mega-disaster it is necessary for specialists on each discipline that composes the issue to exercise their expertise effectively and deal with them. At the time of 2011 Great East Japan Earthquake and Tsunami, various means of tackling with the situation were conducted in various organizations. Making various kinds of approaches for disaster response using GIS was one of them. Specialists in each field starting with disaster management have grasped the situation or made estimations on the situation at different times, did the extraction of tasks and so forth.

Role of the map for creating situation awareness for handling disasters and the collaboration of researchers are becoming more and more important. EMT (Emergency Mapping Team) for making emergency maps for 2011 Tohoku Earthquake has gathered specialists on disaster research to make maps of various disaster situation or response situation and offered them to the Cabinet Office and Iwate Prefecture that will be dealing with the disaster [19]. This was aimed to create common operational picture at the site of disaster response. In addition, the maps completed by the experts on different disciplines that gathered for EMT and the data during the process of making were released to the public to be shared as service to the area and outside, and facilitated the secondary use other than their original goal. Researchers who don't belong to EMT can easily utilize them without making similar data anew and the lowering of creation time for important data in the limited amount of time has been realized.

For the activities of EMT, "mash up" method was used that facilitated introducing new knowledge by combining and utilizing the various information that are distributed and created/developed and not kept by every researcher

Fig. 7. Sample result map of disaster response exercise.

individually, and GeoPortal was utilized as the infrastructure.

EMT created necessary data at the time of emergency and did the mash up but if GeoPortal is equipped and utilized at normal times, preexisting data or services can be accumulated. If this comes in use, we believe that people will be able to use it whenever they wish by making the system sharable and secondary use possible in all at the time of emergency and reduces the labor of creating the data in acute situation and can therefore speed up the assessment of the situation.

To make it possible to use for trainings and such at normal times, and to discuss the concept of maps made for the assessment of the situation, we have created a system that collaborate WebEOC and GeoPortal as a method to mapping disaster response situation.

WebEOC was developed and used in the U.S. as a system to share information in regard to disaster handling on the web. We have created the database where disaster situation data and response situation data are stored. Then we created the system to plot the data in that database on a map as the collaboration system. Collaboration system monitors both WebEOC data and GeoPortal and if a change is made on the either then it syncs the other.

Disaster response exercises were performed in Kashihara City using this program. Disaster response exercises were performed using WebEOC and imparted situation and the responses to that were input on WebEOC. Information input in each of the database for fire-fighting response, evacuation center situation and hospital situation were reflected on the data on GeoPortal by the collaboration system based on the location information. For instance, if the information on a break of fire is input on WebEOC, fire marker is plotted on the point of origin on the map based on the location information. Previously assigned information is plotted for evacuation centers and hospitals but if the status is changed to available or unavailable on WebEOC, then the display on the map will change to green or red and you can see every situation at once. **Fig. 7** shows the map obtained as a result. When you mash up the information on the places handled by different departments and see them on the map, you will be able to understand things you did not before on individual information such as the situation of the evacuation center that is being surrounded by fire. Situation can be better understood when information is shared in each department and the common operational picture can be considered.

Nevertheless, there is no means yet for creating common operational picture and trainings will be needed for the staff to integrate situation awareness using that method. We also believe it is going to be possible to make the imparted situation of the training with the scenario assumed on the latest research findings by using the simulator mentioned in Section 5.1.

6. Conclusion

In this study, we discussed the functional requirements of GeoPortal system that mashes up various map data and analytical methods in order to understand damages and aftermath in enormous widespread disaster in a comprehensive manner by sharing and integrating the scientific research findings. In addition, we have gathered data and constructed a simulator identifying with these functional requirements and developed collaboration with other disaster information systems. Consequently, we have constructed a system to gather and expand both static information and dynamic information as contents to deal with. Also, we have confirmed that we are able to estimate hazards, damages or aftermath with researchers' method using GeoPortal. Further out, we have developed a collaboration system with WebEOC that depicts disaster situation on a map from the actual performance of GeoPortal in 2011 Great East Japan Earthquake and conducted map exercises.

GeoPortal not only deals with just the data specialized in profession like in the past systems but it can also combine and utilize various data and means as necessary. By enabling emergency management officers, private sectors, local communities, citizens starting with researchers to exchange among themselves data or means each has kept by utilizing the Web, it is expected that one's own organization, area, countermeasures in one's own field or investigation that were not being able to carry forward before because of the lack of information on estimation information or information on other organizations, areas and fields.

One of the future tasks is the improvement of interface. GeoPortal can be operated on web browser but you need a technique to operate GIS. GeoPortal will be available to a great number of researchers, officers and citizens, and data will be added, module will be added for availability. Hence, it is necessary to make the operation easier and that will be our future task. It is also necessary to construct a system to release the data to the public and be secondary used. It doesn't have to be the GeoPortal we are constructing at present but if the idea of someone like developer to create data or application and put them on the market on the Web and by transforming them to protocol or data format and flexibly mash up becomes popular, we believe that the foundation to discuss more complex issues will be made.

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