Information sharing platform to assist rescue activities in huge disasters

— System linkage via data mediation —

Itsuki NODA

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Various “unexpected” situations caused by the Great East Japan Earthquake severely hampered disaster-control systems of Japanese national and local governments. A flexible framework for disaster information systems that is reorganizable depending on circumstances is required to mitigate such serious situations. In this article, I propose the concept of “loose linkages” of information systems based on data mediation and a platform for disaster mitigation information sharing. The platform enables us to link various systems quickly, so that we can reconstruct disaster information systems according to various situations in major disasters. I found that the concept was effective for the Great East Japan Earthquake along with various ad-hoc activities of information volunteers. We should spread this concept and platform to Japanese national and local governments, and support organizations to prepare for future disasters.

Keywords : Information sharing, disaster mitigation, database, system integration

1 Introduction

The off the Pacific Coast of Tohoku Earthquake (The Great East Japan Earthquake) on March 11, 2011 showed us the mercilessness of a natural disaster, the diversity of damages, and the difficulty to make predictions. For the past 15 years, most of the earthquake disaster prevention in Japan was built on the model of the 1995 Hanshin Awaji Earthquake. The Hanshin Awaji Earthquake was an epicentral earthquake where there were many victims of collapsed houses and fire, and the major issues were wide-area firefighting and medical aid, as well as information sharing to support such activities. In order to solve the issues, prior agreements were made among the rescue organizations for the first response to the disaster, and mutual support setup were gradually organized among the local governments. On the other hand, in the 2011 earthquake, most of the victims were of the tsunami, and we were faced with many issues including the information transmission for the tsunamis that occurred with different time lags after the earthquake. Of course, the experience of the Hanshin Awaji Earthquake was utilized, and therefore the initial response and wide-area linkages among the various organizations have improved, and the efforts over the years have steadily fortified the disaster response. However, disaster measure is a kind of endless process, and we were forced to accept the fact that there will always be the *soteigai* (unexpected situations) even if we think we are prepared to the fullest.

In Japan, which is also called the Natural Disaster Archipelago,[1] we must continuously prepare for disasters. All local governments cannot escape from the various natural disasters including earthquakes, volcanic eruptions, tsunamis, typhoons, floods, wind damages, and heavy snow. Also, large cities such as the Tokyo metropolitan area, Keihanshin area, and Chukyo area have high density of buildings and transportations, which may magnify the effects of terrorism or disasters. In fact, major Japanese cities are ranked high as dangerous places susceptible to disasters.[2] Measures to reduce the disaster damage as much as possible are important to protect the lives and properties of the residents, and to help industrial promotion by ensuring a region where people can invest safely.

In disaster measures, establishing frameworks and systems to collect and utilize information is essential along with the preparations of hardware such as earthquake-proof structures. Case-by-case decisions are necessary to deal with disasters including the unexpected, and to do so, it is necessary to gather and share as much accurate information as possible.[3][4] In that sense, there is plenty of room for the development of a disaster prevention information system using the state-of-the-art information technology. However, in practice, during the Great East Japan Earthquake, handwritten memos were posted all over the walls and various pieces of information were scribbled on whiteboards. Communications between the organizations were mainly done by phone and fax, and these were the causes of delay and loss of communication. Of course, the importance of information collection and sharing is widely recognized,

Center for Service Research, AIST Tsukuba Central 2, 1-1-1 Umezono, Tsukuba 305-8568, Japan E-mail: i.noda@aist.go.jp

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and various disaster information systems have been constructed by the central government, prefectures, and local municipalities. However, we rarely hear that such systems functioned as expected during the 2011 earthquake. The reasons why such disaster information systems could not be utilized may be because they were designed as closed and unalterable systems dedicated to disaster prevention. As with other disaster measures, the information system must have case-by-case flexibility.

The viewpoints important in designing the disaster information system that can overcome such difficulties are case-by-case flexibility and lifecycle. Since there are many phenomena that occur during a disaster, it is virtually impossible to predict all events and to incorporate the information processing functions into a system. In fact, in the hearings of the local governments after the Great East Japan Earthquake,[5] it became clear that the prior disaster prevention plan had to be altered in various ways. On the other hand, the activities of information volunteers functioned effectively, as will be explained in chapter 5. The characteristic of the activities by these volunteers was the case-by-case flexibility where the system was built according to the situation and real requirements. Of course, it is not practical to build a disaster information system entirely after an event occurs, but it is necessary to leave room to incorporate such case-by-case flexibility when designing the system. The viewpoint of lifecycle is the way of looking at the timescale difference of the day-to-day advancement of information technology versus the once-in-a-hundred or once-in-a-thousand year disaster. This means that rather than packing as much state-of-the-art technologies into the system as possible, the disaster information system must be designed by paying attention to the fact that technologies will become obsolete with passage of time and will be succeeded by newer technologies.

To establish a method for designing a disaster information system that incorporates the above two viewpoints, a concept of "data-centered ad hoc system building" is adopted in this paper. With this approach, the following three points form the design policy for building the information system.

- **Open system**: the design policy where each information system is built assuming usage of individual functions of the system separately and the system being able to be linked with other systems. This responds to the case-by-case flexibility and the lifecycle viewpoints.

- **Universal data format and protocol standard**: the design policy for simplifying the linkages of the functions and for creating common linkage parts to enable easy replacement and succession of the system. This responds to the case-by-case flexibility and the lifecycle viewpoints.

- **Downward scalability**[Note 1]: the design policy that allows the system to operate on any type of information device or at any sized infrastructure. This responds to the case-by-case flexibility viewpoint.

As the core technologies to realize such a design policy, we introduce the disaster mitigation information platform that is the basic design of the system, the mitigation information sharing protocol (MISP) that is its core, and the database (DaRuMa). The relationships of the viewpoints, design policy, and core technologies are shown in Fig. 1.

The paper will be organized as follows. In chapter 2, the mitigation information sharing platform and its protocol database will be explained. In chapter 3, the design policy of the proposed platform will be discussed from the viewpoints of disaster prevention and mitigation. In chapter 4, the verification system of the proposed platform and examples of actual operating systems will be introduced. In chapter 5, case studies during the Great East Japan Earthquake will be taken up to discuss the effectiveness and the problems of the above design policy.

2 Design philosophy of the mitigation information sharing platform and its implementation

In this chapter, I will explain the design philosophy of the mitigation information sharing platform[6][7] that is the framework for sharing the disaster information proposed in this paper, the mitigation information sharing protocol (MISP) that is the center of its implementation, and the database for rescue utility management (DaRuMa).

2.1 Mitigation information sharing platform by data-centered module linkage

The framework of disaster information sharing is, as shown in Fig. 2, the linkages of the various disaster information systems (these will be called modules) operated by different organizations through the mediation by database. Here, this framework is called the mitigation information sharing platform.

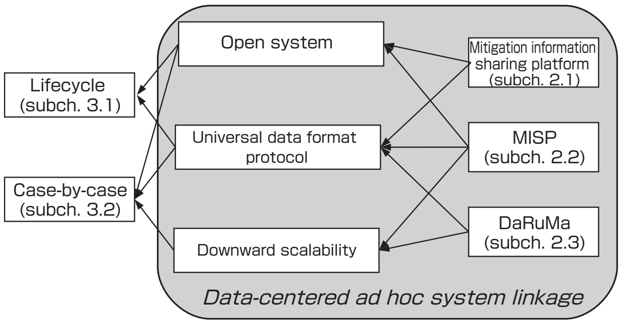

Fig. 1 Relationships of the viewpoints, design policy, and core technology of the disaster information system

As mentioned in the previous chapter, the important concept of this platform is the ad hoc module linkage mediated by data. That is, for each module, information sharing and function linkages are accomplished by retrieving data that were output by other modules to the database, rather than directly calling up the functions of other modules. By limiting to data mediation only, types of linkages are regulated, so that, this will ensure provision of a highly universal framework. The design policy where the modules are linked by a mediating module that acts as a central hub is not new. However, by limiting the linkage format to hub function and data mediation only, continuous and flexible system revision will be possible. Recently, there are many mechanisms where the advanced function linkages are done by the mash-up of web service, but in the framework proposed in this paper, considering the viewpoints of case-by-case flexibility and lifecycles, a simple mechanism is employed. The justification for this choice will be discussed in chapter 3.

2.2 Mitigation information sharing protocol (MISP)

MISP, the mitigation information sharing protocol, is the key of the mitigation information sharing platform.[8] MISP is a database access protocol based on XML, and it determines the basic functions necessary for the database, namely the ways of calling the data search (Query), registration (Insert) and correction (Update·Delete) (upper part of Fig. 3). Instead of preparing high-level functions like the data reconstruction function such as the table join in the structured query language (SQL), we intensively limited the small number of basic functions in order to simplify data expression and to make module linkages easy by data mediation. As a function to help the ad hoc linkages, the meta-function of the database including the data structure definition function (RegisterFeatureType) is provided online (lower part of Fig. 3). This data structure definition function allows additional online registration of the handled data format to the database using the XML Schema. Therefore, it is possible to add a new data format without stopping the system during the operation of the platform, and testing and updating of the new data format can be done in real time as a new module is added. This is an important function in the integration of the disaster prevention information system where it is necessary to link the modules across several organizations. If there is detriment such as stopping the entire system each time a new data format is registered, the module linkage which needs many trials-and-errors will be slowed down. This specification aims to avoid such barriers and to make the system linkage smooth by opening the calling of data feature type online at the module side.

In designing this protocol, emphasis was placed on maintaining the simplicity of the function and ease of description. With a usual Internet protocol design, one tends to consider advanced functions and expandability. For example, XPath and XQuery are being proposed as the retrieval protocol of XML database, but they have become complex to realize highly advanced retrieval and data reconstruction. In the field of information technology that continues to evolve every day, such short-term expandability is important, but as it will be discussed later, considering the fact that the lifecycle of disaster measures is a decade to a hundred years, we need a viewpoint different from the pursuit of advanced functions and expandability. Therefore, simplicity and ease are emphasized in the platform proposed herein. This will be discussed in chapter 3.

The basic function of MISP is based on the web feature service (WFS).[9] Using the various standards including the

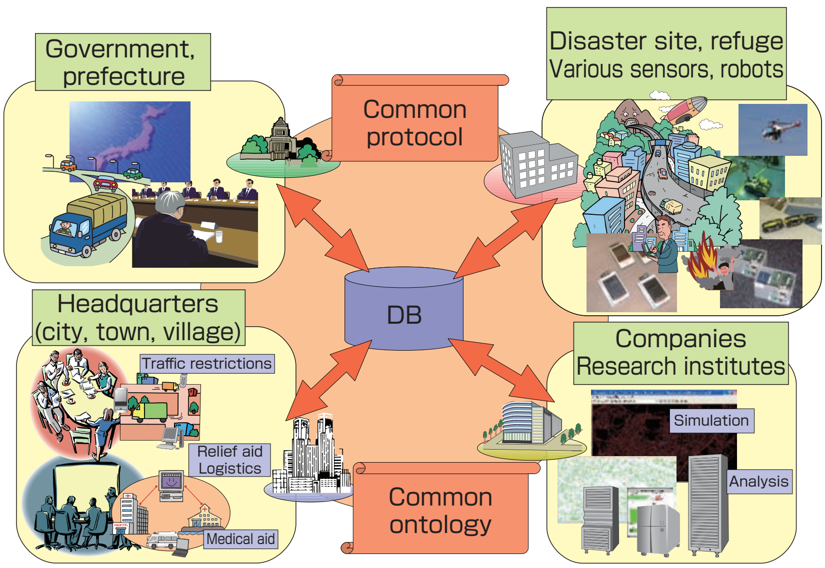

Fig. 2 Mitigation information sharing platform

geography markup language (GML),[10] XML Schema,[11] simple object access protocol (SOAP)[12] that are related to WFS, the areas that may be lacking in sharing the disaster information are defined as additional formats.

These are widely used and standardized by ISO and others, and aim to enhance the compatibility with the existing and future systems. The employment of the standard has the advantage that the existing tools can be used as is, and linkages and application with the systems other than for disaster measures can be done. Downward scalability is achieved by maintaining simplicity that allows handling by systems without large computational ability such as the sensor system.

The reasons for the employment of XML as the expression format are the same as the reasons for being employed in many systems recently, i.e., universality, flexibility and expandability of the data expression. There are four basic data types including numerals (integer, real number) and text, spatial/geographic expression (point, line, and plane defined by GML), and temporal expression necessary in disaster information.[Note 2)] It is possible to handle diverse data structure by defining the arbitrary combination using the XML Schema. That is, any fixed-structured data not limited to disaster information can be handled, and therefore the system can be utilized for normal time routines.

The protocols of MISP are shown in Fig. 4. This example defines a type of feature called ‘RoadLink’. It shows that the feature data are composed of the elements of ‘representativePoint’ described in GML, the list of crossroads (‘nodeList’) and road width (‘roadWidth’), in addition to a structure declared as ‘misp:GeometryFeature’ (defines the information element ‘gml:GeometryProperty’ for position).

2.3 Mitigation information sharing database DaRuMa

DaRuMa is a database developed as the prototype implementation that operates in accordance with MISP explained in subchapter 2.2. It operates as a hub to link the modules in the mitigation information sharing platform. The design and implementation of DaRuMa were conducted under the following policy.

- **Downward scalability and multi-platform**
  The required specification for the operating environment was kept simple as possible, to support a wide range of OS and hardware. Since the information and communication infrastructure may be damaged in a major disaster, high-performance servers and large-scale data centers may not be available. Therefore, one of the requirements was that it would operate in various and restricted computational environments.

- **Utilization of existing software and open sourcing**
  The purpose of the proposed platform was to establish the framework for information sharing during a disaster, and it was not R&D for a new database technology. Therefore, the consideration was to maximize the use of existing software and not to spend much on the development itself. Also, to establish this information sharing framework and to make the diffusion smooth, it was assumed that the results would be provided as open source.

The developed DaRuMa uses MySQL, an existing relational database, or PostGIS[Note 3)] as its backend, as shown in Fig. 5, and has a structure where mediation and conversion of SQL and MISP is done by a middleware written in Java (MISP Processor). Therefore, DaRuMa can be operated on a wide range of OS and hardware that supports Java and MySQL or PostGIS, and it was shown to run on versions of Linux, FreeBSD, Windows, and Mac OS. Moreover, there is a middleware implemented by Ruby, though this is limited in function, and this enables run on portable terminals such as Linux Zaurus, and downward scalability is achieved. The system is light, and in the demonstration experiment that will

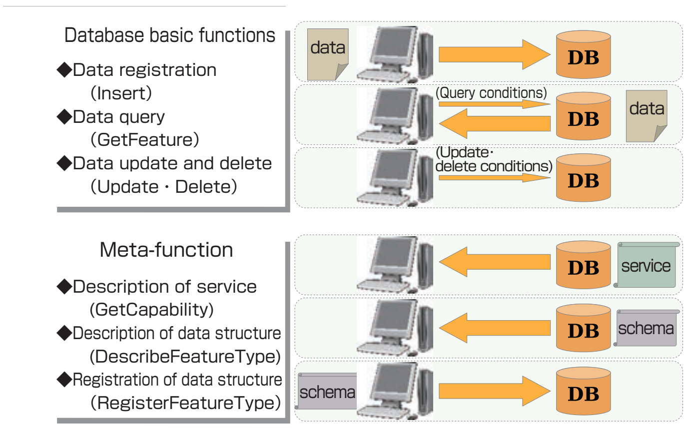

Fig. 3 Basic functions of MISP

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<misp:RegisterFeatureType uri="urn:gfs:ddt:test:Node">
 <xsd:schema misp:id= "urn:gfs:ddt:test:Node" targetNameSpace= "http:..."
                 xmlns= "http:...">
  <xsd:element name="RoadLink" type="RoadLinkType" />
  <xsd:complexType name="RoadLinkType">
   <xsd:complexContent>
    <xsd:extension base="misp:GeometryFeature">
     <xsd:sequence>
      <xsd:element name="representativePoint" type="gml:GeometryPropertyType" />
      <xsd:element name="nodeList" type="nodeListType" />
      <xsd:element name="roadWidth" type="xsd:float" />
      <xsd:element name="nLanes" type="xsd:integer" />
      <xsd:element name="direction" type="xsd:string" />
     </xsd:sequence>
    </xsd:extension>
   </xsd:complexContent>
  </xsd:complexType>
 </xsd:schema>
</misp:RegisterFeatureType>
```

Fig. 4 Example of data structure definition of MISP (RegisterFeatureType)

be explained in subchapter 4.2, we succeeded in receiving over 8,000 reports from residents in 30 minutes and linking them with other information systems and simulations, using an old model laptop PC (Mobile Pentium III 933 MHz, memory 512 MB). This performance is sufficient for disaster information system linkages of a medium sized city, and information systems can be operated on PCs no longer in use in times of emergency. To enable this, we also created the Linux live images where the DaRuMa will run automatically when booted from a USB.

Concurrently with the development of DaRuMa, the development and organization of the tools to connect the DaRuMa and various systems are done. In the mitigation information sharing platform, all modules communicate with DaRuMa by MISP. However it is not realistic to make all the currently existing disaster information system MISP compatible. Rather, it is more practical to achieve partial linkages using the functions of the existing systems and to gradually deepen the linkages when the system is updated, as shown in the right half of Fig. 6. As listed below, the DaRuMa tools are being developed to support such partial linkages.

- **CSV connection tool**
  This is a tool to convert the data output in a comma separated value (CSV) format into XML and to register them to DaRuMa through MISP. It is also a tool to convert the data obtained by MISP into CSV format. Many disaster information systems support the input/output of CSV files that is the universal data format of the spreadsheet software. Partial linkages may become automated by organizing this connection tool. For linkage automation, the functions of regular input/output of the temporal difference data and of setting the condition for data acquisition from DaRuMa are included.

- **GIS viewer linkage tool**
  This is a tool to convert the information (features) stored in DaRuMa linked with the position on the map to KML, and to display them on GIS viewer such as GoogleEarth and GoogleMap. In disaster information where the features will be relevant, it is important to check the information stored in the database on a map as needed to maintain linkages among the modules. The free or low-cost, high-performance GIS viewer such as GoogleEarth is effective as a means to provide information to related organizations, as well as providing linkage support, and the presence of connection tools is important in utilizing the existing software.

- **Log replay tool**
  This is a tool to utilize the log recorded with timestamp of database maneuver and MISP communication to DaRuMa, and to reproduce the flow of situations of shared information according to time steps. When adjusting the linkages of multiple modules, it may be difficult to keep all modules in usable status. Particularly, when conducting linkages across multiple organizations and institutions, they have limited opportunities to connect modules for linkage adjustment. Since the log replay tool will allow pseudo-reconstruction of the recorded receiver module activities, it is possible to simplify the linkage adjustment. This tool can also be used when conducting simulated joint training exercise.

3 Disaster information system linkage based on data mediation

3.1 Lifecycle of a system and continuity of data

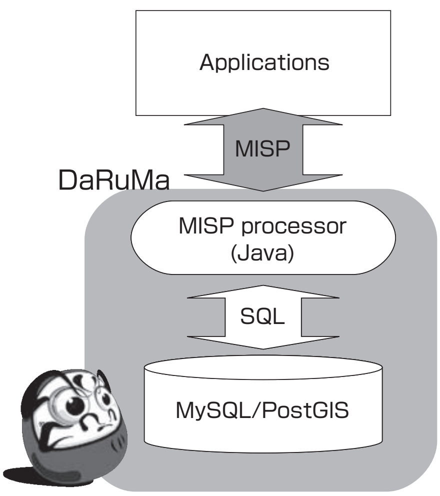


Fig. 5 Structure of DaRuMa

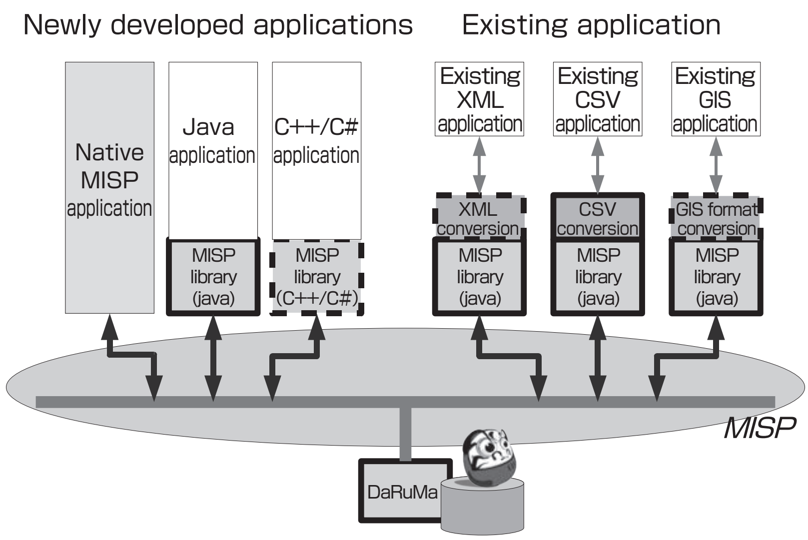


Fig. 6 System linkage by mitigation information sharing protocol (MISP) and DaRuMa

When designing the mechanism for sharing and utilizing the disaster information, particularly in designing the information system, the difference in the lifecycles of disaster and information technology must be carefully considered.

Most disasters occur irregularly and at long time intervals. For example, earthquakes of a scale that incurs societal damages occur at several decades to several hundred years time span, or in some cases in a thousand years for certain regions. The wind and flood damages occur relatively frequently but not regularly every year. Generally speaking, disasters cause unexpectedly large damages because they occur infrequently. In other words, the disaster information system will not operate most of the time, except during disaster drills or during those "infrequent moments." The disaster information system of the local government is updated at five to ten year intervals, and the latest technologies and functions are introduced during the updates. At the same time, old technologies and functions are gradually removed. Therefore, most systems and technologies may be used only a few times or finish their jobs without ever being deployed in actual disasters.

The difference in the time scale of lifecycles is overcome by the continuity of the data. Compared to frequent updates of systems, data is accumulated over a long time, and its lifespan is long. Particularly, value of data recorded in usable format may not become obsolete so quickly. As mentioned earlier, while the information systems of local governments may be updated by five to ten year intervals, it is important how the data is carried over during such updates. Therefore, in designing the disaster information sharing system, it is important to focus on the reusability and accumulation of the data over decades or a hundred years.

3.2 Data-centered case-by-case system linkage

The data-centered concept is important in the viewpoint of case-by-case system linkages. Responses to disasters are done by many organizations, and the disaster information system must be operated across such organizations. Designing and implementing a monolithic information system where multiple organizations are involved is very difficult in reality. The realistic solution will be for each organization to design and construct an information system individually as a subsystem, and to link them. In that case, there are two design policies of linkages: function-centered or data-centered.

One example of the function-centered system linkages is the web service linkage mechanism using the web services description language (WSDL) or universal description, discovery and integration (UDDI). In the web service linkages, individual servers realize and provide various functions, and a high-level service is achieved by combining them. This is excellent in that flexible response to diverse requirements can be realized easily, and is an effective concept for rescue activities where diverse responses are demanded. However, each server must be designed and implemented with consideration of "linkages," and the local governments must prepare the necessary functions.

The data-centered system linkages are represented by the blackboard model. In the blackboard model, each subsystem provides data to the common area (blackboard) or retrieves data from the common area to achieve linkages among the subsystems. In this concept, the subsystem can be operated as long as data are provided to the blackboard, and the "linkages" among the subsystems do not have to be the prime consideration. On the other hand, it is difficult to combine the functions closely or flexibility, and it is not suitable for achieving multiple, high functions.

Considering the fact that the disaster information system is utilized by the local governments throughout Japan, the mechanism of system linkages should be data-centered rather than function-centered. Japan spreads out from south to north, and there are various types of disasters. There are regions that suffer from heavy snow and other regions that must watch out constantly for floods. The functions required vary greatly and the combinations are complex. Also, the disaster prevention system of the local governments and the relevant organizations are not uniform, and the ways of building the subsystem differ. Therefore, the important points are which subsystems have the necessary functions and data and how to supplement the items that are short. While the supplementation of lacking functions is difficult to solve instantly, the lacking data is not too hard to supplement if the deterioration of dynamic property and accuracy can be tolerated.

Moreover, according to the hearings[5] of the local governments of the regions affected by the Great East Japan Earthquake, it has become apparent that many local governments had to alter existing disaster prevention plans because various unexpected conditions occurred. While the disaster prevention plans will certainly be reviewed thoroughly by the local governments after the Great East Japan Earthquake, it is necessary to maintain flexibility in the response, anticipating that the unexpected will happen. The information system must be designed as a system where the functions can be rearranged after an event. The key to allow quick rearrangement after an event is the simple linkage mechanism by data mediation. A case study will be presented with a demonstration system in the next chapter.

The data-centered system linkage concept is similar to the concept of the open source program development. In *The Cathedral and the Bazaar* (http://www.catb.org/%7Eesr/writings/cathedral-bazaar/; Japanese translation available in http://cruel.org/freeware/

cathedral.html), Eric S. Raymond introduces the words of a famous hacker:

> "Smart data structures and dumb code works a lot better than the other way around." (Fred Brooks: *The Mythical Man-Month*, Chapter 11)

> "Show me your flowchart and conceal your tables, and I shall continue to be mystified. Show me your tables, and I won't usually need your flowchart; it'll be obvious."(Fred Brooks: *The Mythical Man-Month*, Chapter 9)

In the open source system development done by numerous people under a relatively loose policy, it is important to reuse the modules created by other people. The above words show that the hand-over of reusable knowledge goes smoothly for data structures that handle modules rather than the functions of the modules. Similarly, many people and organizations will be involved in the design and development of partial modules in the disaster information system. The development span is long, and the transfer of the design philosophy and knowledge of the architecture are important. In that sense, the concept of data-centered module linkages is appropriate as the development method of the disaster information system.

4 Demonstration systems

The mitigation information sharing platform proposed in this paper was developed in the following projects: Special Project for Earthquake Disaster Mitigation in Urban Areas, Special Coordination Funds for Promoting Science and Technology, Science and Technology Project for a Safe and Secure Society, and Special Project for Earthquake Disaster Mitigation in Tokyo Metropolitan Area of the Ministry of Education, Culture, Sports, Science and Technology (MEXT); and Strategic Advanced Robotic Elements Engineering Development Project of the Ministry of Economy, Trade and Industry (METI). Several linkage systems were built through these projects, and demonstration experiments were done. In this chapter, the outline of the demonstration experiments in Mitsuke City and Toyohashi City will be described.

4.1 Demonstration experiment in Mitsuke City

When a disaster hits, the sharing of information reported among various sites and different sections is important. As an attempt in multiple linkages of various disaster information systems based on the proposed architecture, we conducted a demonstration experiment of using the DaRuMa mediation to integrate the various information systems of various institutions that were involved in the disaster prevention and mitigation during flooding, at Mitsuke City Hall, Niigata Prefecture, on October 27, 2006 (Fig. 7). In this experiment, the information from several divisions of the city hall, police and fire departments, and companies of lifelines such as for electricity and gas were integrated by DaRuMa mediation, and attempts were made to share the information among the divisions. At the same time, reports from disaster volunteers using portable terminals and automatic transmissions from water level sensors were integrated. We built an integrated system where the disaster response personnel would not be drowned in the organization of information and therefore could concentrate on disaster response activities.[13]

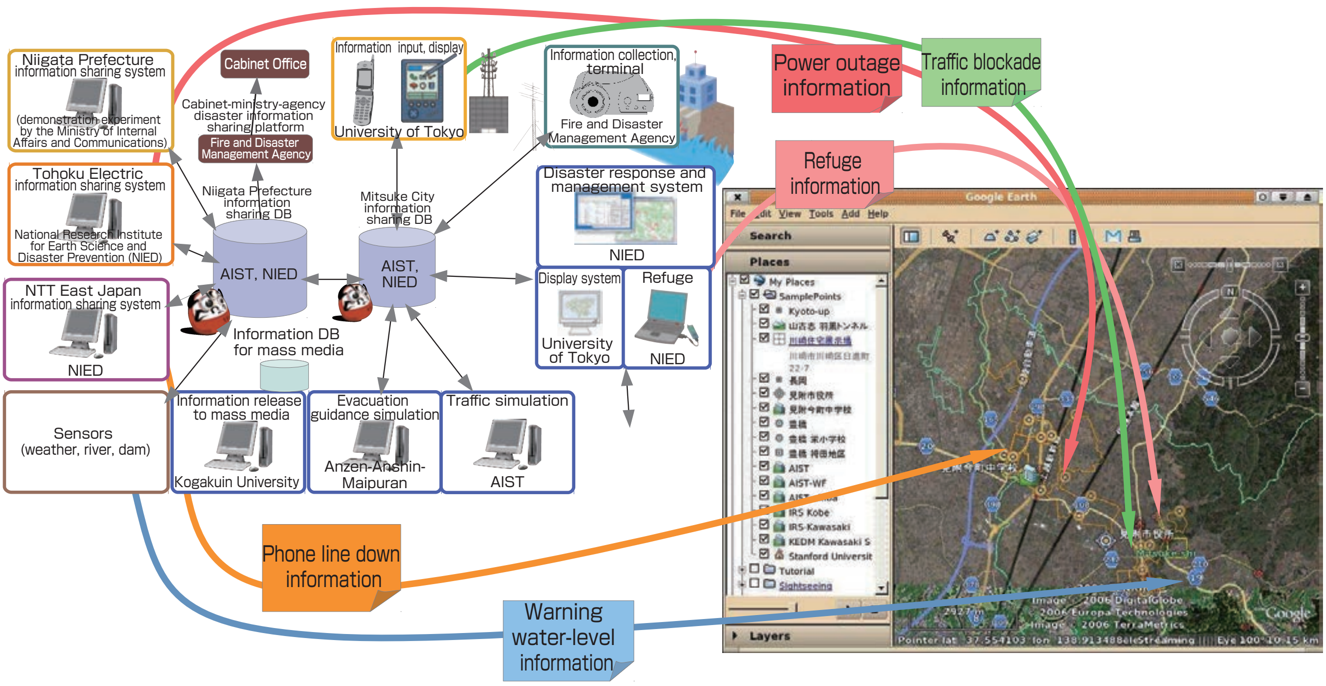


Fig. 7 Overall diagram of the Mitsuke City demonstration experiment

The characteristic of this experiment is that the linkages of over 10 information systems was accomplished in three days, as shown in Fig. 7. In general, time is required for system linkages for matching the functions and adjusting the protocols, and particularly, many steps are required when separately linking designed and implemented systems. On the other hand, in the proposed platform, the linkages were limited to only through the data on DaRuMa, and the protocol was a simple database protocol MISP. The changes to the systems were minimized to the modification to adapt for MISP. As a result, the system integration done in a short time became possible since the connection test between the individual systems and DaRuMa was simple.

This experiment was done as part of the disaster prevention drill of the city hall, and was carried out by the disaster prevention staff of the city using a realistic disaster scenario. Although the evaluation of such systems is difficult, we obtained the evaluation from the personnel who participated in the drill that the disaster response could be done accurately by unifying the information through system linkage.[13] Note 4) From this point and the little time required for system linkage, we can say that the effectiveness of the platform design philosophy was demonstrated.

4.2 Demonstration experiment in Toyohashi City

Several information systems for earthquakes were integrated with DaRuMa mediation at Toyohashi City, Aichi Prefecture on November 12, 2006 (Fig. 8). In this experiment, the voluminous information gathered from the citizens who gathered at the evacuation shelters were organized and integrated using DaRuMa. Based on this information, predictions of fire spread and traffic jams and the search of evacuation routes were done, and attempts were made to provide useful information to ensure smooth disaster response actions.[14][15] The citizens who arrived at the refuges reported the damages they saw when they were evacuating, and the accuracy of damage projections and disaster measures was increased by reflecting such information in the simulations. At the same time, another objective was to raise the citizens' consciousness for disaster prevention and their sense of involvement by visually showing that such citizens' information collection activities help the disaster measures.

The main focus of the proposed platform in this experiment was the simulation linkages (Fig. 9). In multiple simulation linkages, careful adjustment of dependent relations of the boundary conditions was necessary to connect the

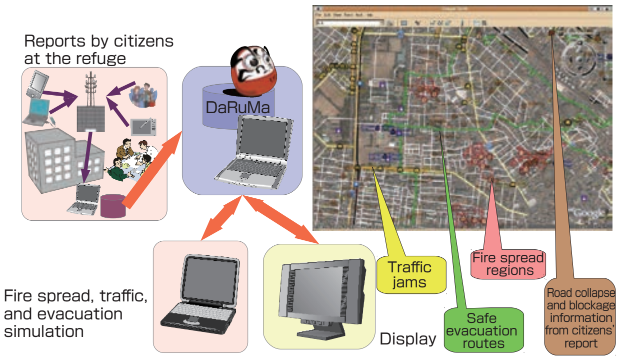


Fig. 8 System configuration for Toyohashi City demonstration experiment

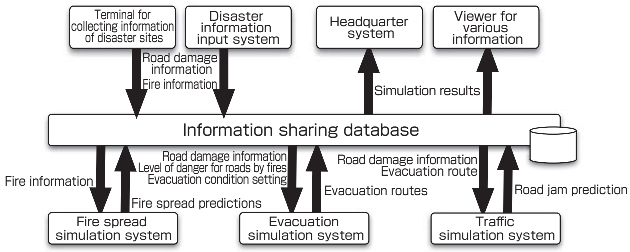
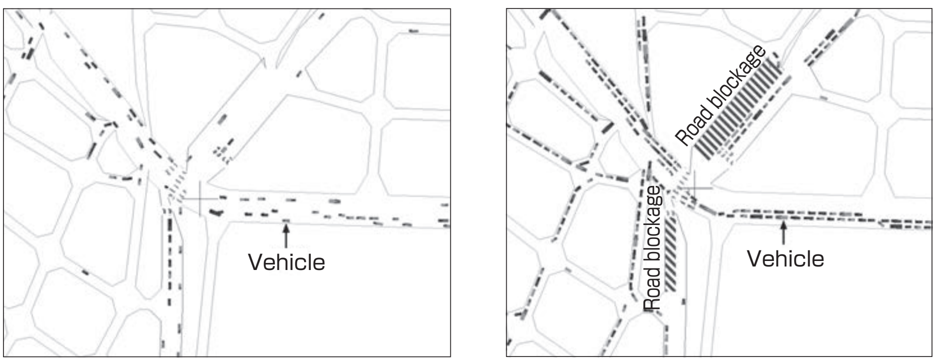


Fig. 9 System configuration for Toyohashi City demonstration experiment



(a) No road damage information (b) With road damage information

Fig. 10 Change in traffic simulation results with absence/presence of road damage information (around Takashiguchi, Toyohashi)

simulations. In this example, we did cut-offs to simplify the dependency relation to one-way, to make the linkages easy. While this cut-off policy is inferior in terms of close simulation linkages, there were many occasions where this worked sufficiently in the context of rescue. Also, since it was by database mediation, the computer environments for running multiple simulations did not have to match exactly, and this is important in realizing the case-by-case simulation linkages with various combinations. The operation of the simulation systems was as follows.

- **Fire spread simulation system**
  The initial setting was fire information reported from the sites, and the spread projections were done from that information.

- **Evacuation simulation system**
  Settings such as road damage information, projection of danger to roads by fire using the fire spread simulator, starting point and destination of evacuation, and others were obtained from the information sharing database, to determine the appropriate evacuation routes.

- **Traffic simulation system**
  The road damage information and evacuation routes were acquired, and simulation was done under a setting that the traffic was restricted on such roads, to predict the roads where traffic jams and congestions would occur.

Figure 10 shows the example of changes in traffic simulation results by the absence/presence of the road damage information. In this example, the difference in the projection of traffic jams is shown when the blocked road information of the main road from upper right to center was reflected in the simulation and when it was not. Each simulation module not only sorts and shifts the conditional information from the information sharing database, but outputs the simulation results to the information sharing database. The results can be checked against the damage information using the system of the disaster management headquarters, and enables use in other simulation modules. The system of this experiment shows that by handling the reports and various simulations as simple data links, the simulations at varying levels could be done easily, including the projections that incorporated the low accuracy information such as the reporting by the general public and simulation projections, as well as the analysis of highly accurate data only.

Interviews were conducted to the Toyohashi City Hall personnel after the experiment, as in the demonstration experiment at Mitsuke City. As a result, we obtained the evaluation that “it is important to handle the damage projection, emergency response demand load, and emergency response items at the onset of the event with shared recognition by all participants of the disaster management headquarters or the disaster management meeting,” and “the mechanism proposed in the experiment may be an effective means along with information gathering done by the government organizations.”

4.3 Toreta Doro (Passable Road) Map

To make the rescue and support activities in massive disasters as smooth as possible, the road information, particularly of passable roads is important for the rescue teams and relief supply carriers. However, most of the road information provided by the local government and police is information of blocked roads or restricted traffic. Moreover, it is not comprehensive information, and it is difficult for the relief

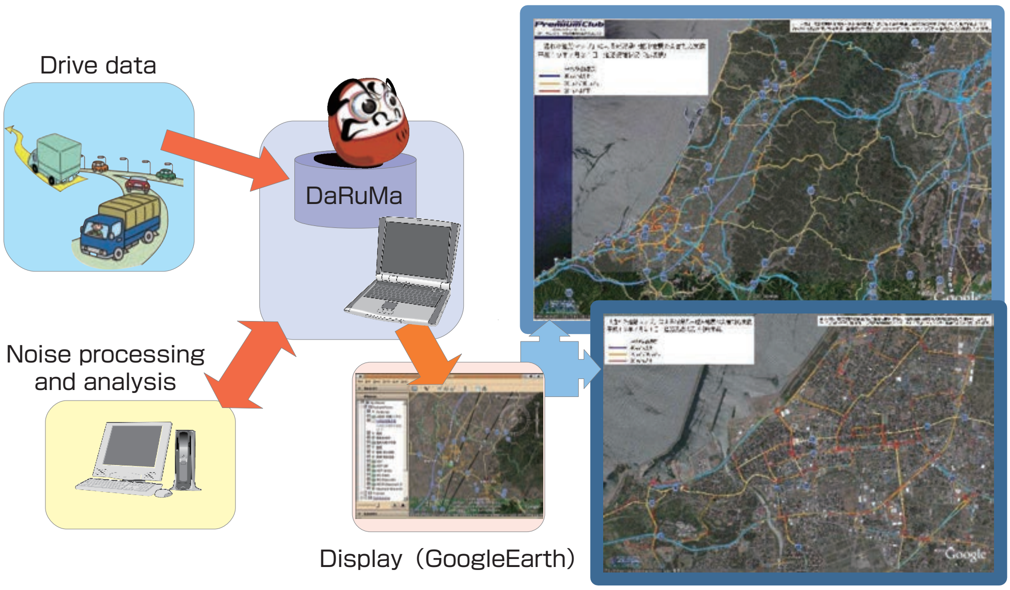


Fig. 11 Toreta Doro Map provided for the Chuetsu-oki Earthquake

teams, particularly those from outside the region, to find the routes to their destinations.

As a method to solve this problem, the passable road information was devised. Based on the driving data of automobiles, the roads that were actually used on a certain day or at a certain time after a disaster were identified and integrated with map data. Since a certain number of cars actually traveled on the roads, it could be expected that the roads were passable to some degree. Because many cars are equipped with car navigations with communication functions recently, it is possible to comprehensively capture the passage data of a specific region. It is also possible to categorize the roads according to the number of passing cars, and to estimate the usability as major roads.

With the cooperation from Honda Motor Co., Ltd. and jointly with Dr. Yasunori Hada of the University of Tokyo (currently at Yamanashi University), AIST organized the passability record information during the Niigata Chuetsu-oki Earthquake that occurred in July 2007. This was organized as the "Toreta Doro (Passable Road) Map" (Fig. 11) and this information was released on the web. For this "Toreta Doro Map," the passability record of each road was processed as follows. First, the drive route data of the vehicles that received Honda's communication car navigation system service were accumulated at the center. Of these data, the areas affected by the earthquake were organized per day, and after securing anonymity of personal information,[Note 5)] removing miss value and errors, and matching with the road data, the average speed for each road was calculated and the passability status was categorized into three levels. The results were overlaid and displayed on the GoogleEarth map, and this was released on the web as image data. The information was updated every day, and the passability of the prior day could be checked.

The production process of the "Toreta Doro Map" was done on the mitigation information sharing platform, and the progress of each process was stored on DaRuMa. Although this process was done by trials-and-errors after the earthquake, due to the data mediation format on DaRuMa, the trials-and-errors could be done quickly and simply, and information provision was commenced three days after the earthquake.

As it will be mentioned later, since this passability record information was established as a processing method, it was directly provided to the public from Honda in the Great East Japan Earthquake. Later, it spread by being provided by Toyota Motor Corporation and ITS Japan. Similar information was provided by ITS Japan during the flooding of the Kii Peninsula due to the typhoon in September 2011, and it has become standard disaster information.

5 Experience from the Great East Japan Earthquake

In the Great East Japan Earthquake of March 11, 2011, many people involved in disaster prevention were overwhelmed with the feeling of helplessness. At the time of writing this paper, there were 19,503 people dead or missing, and the economic damage continued to grow, including the accident at the Fukushima Daiichi Nuclear Power Plant.

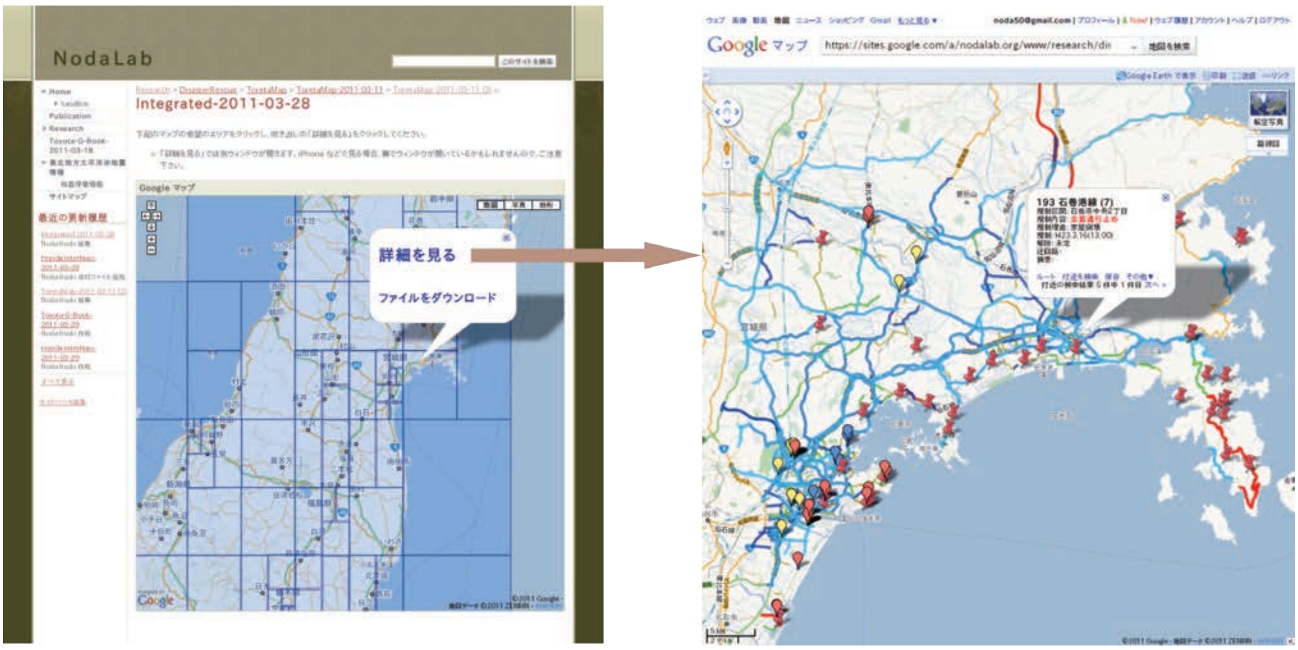


Fig. 12 Toreta Doro Map provided for the Great East Japan Earthquake

Even in such a situation, various forms of trials-and-errors were done to mitigate the damages as much as possible. There are many factors that enabled such mitigations, but it is thought that the design policy of the platform proposed in this paper, including the concept of open system, standard, and downward scalability functioned effectively.

In this earthquake, there was much relief and support by information volunteers on the Internet. For example, in the Person Finder led by Google, photos of the handwritten evacuee lists were shot with a digital camera, and the volunteers at the sites entered this information as text data to create a database. This simple but effective method was certainly supported by advanced technologies such as cloud computing and high-speed Internet, but it was a typical instance where simple functions (photo shooting by digital camera, text reading by people, and database search) were mediated by image and text data. Although there were time delays due to human processing, the linkages were made without problems, most likely due to the fact that it was mediated by data rather than by function.

As mentioned in subchapter 4.3, the "Toreta Doro Map" (road passability report information) was provided by Honda, Toyota, and ITS Japan. This time, detailed data was released using the KML, an international standard format. [Note 6)] Therefore, various attempts were made for information integration using the available data. For example, the author *et al*. lightened the weight of the passability information to create and provide a map that combined the information for gas stations and road blockages (Fig. 12).[17] There were also volunteers that worked to create image files of the passability information that was viewable only on PC so it could be viewed on cell phones. That several attempts can be made concurrently is one solution for responding to diverse needs in times of emergency. There should be more focus on the point that one of the foundations that makes this possible is the build-up of processing by data mediation through a universal format. Such grass-root system development and ad hoc system configuration centered on revisions and linkages are often neglected in disaster measures that are involved in the heavy mission of saving lives. However, considering the case-by-case response to the course of events including the unexpected ones, such loose but supple methods must also be considered. As a preparation, it is necessary to diffuse the system configuration based on the concepts of an open system, a universal format and a protocol standard, and downward scalability.

6 Conclusion

In this paper, the design policy for disaster information system based on the concept of module linkage centered on data mediation and the mitigation information sharing platform that is the implementation of this concept were discussed.

The concept of data mediation aims at rough and simple module linkages. It realizes the case-by-case linkages of simple functions rather than advanced linkages of high functions.

As discussed in chapter 3, whether major or minor, disasters include unexpected events, and the local governments must respond flexibly. Many of the cases in the Great East Japan Earthquake presented the necessity for case-by-case responses and the efficiency of the ad hoc system construction through data mediation to support such flexibility.

Of course, mere data linkages will not take care of all disaster prevention work, and security technology to handle privacy information and the framework for accurate and high-speed processing of massive data will become necessary and possible with the advancement of technology. The concept and the platform proposed in this paper must be developed further by responding to the changes.

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Notes

Note 1) This is a concept where the system is designed so the function is maintained according to the capacity of the device, even if the system is run on a small and poor information processing device. The counter-concept is "upward scalability" where the function is maintained even if the size is increased.

Note 2) For multimedia data, there are several standard formats such as MIME, but some are difficult to handle with XML such as certain streaming formats, and there is the problem of data size. It is necessary to employ a format with emphasis on operation over long periods, and the choice should not be limited to XML.

Note 3) The connection with the backend database is implemented with abstracted API. So, switching to other database is easy.

Note 4) Mitsuke City experienced extensive damage in the 7.13 flood that occurred in July 2004, and many of the city staff experienced difficulties due to the confused information. In this experiment, the drill plan was created and evaluated based on that experience.

Note 5) Since an individual could be identified if there was only one passability report, only the data with multiple passability reports were extracted.

Note 6) In the Chuetsu-oki Earthquake, detailed information could not be released from the perspective of privacy protection, and we provided only the road map images. In the Great East Japan Earthquake, the privacy protection problem was under control, and we were able to provide detailed information.

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Author

Itsuki NODA

Completed studies at the Graduate School of Engineering, Kyoto University in 1992. Joined the Electrotechnical Laboratory, Agency of Industrial Science and Technology, Ministry of International Trade and Industry. Currently, leader of the Service Design Assist Research Team, Center for Service Research, AIST. Also, Professor of Cooperative Graduate Program, Tsukuba University Graduate School and Tokyo Institute of Technology Graduate School. Doctor (Engineering). Working on multi-agent social simulation, disaster information system, and machine learning. Member of the Japanese Society for Artificial Intelligence and the Information Processing Society of Japan. Committee member of the Japanese Society for Artificial Intelligence, RoboCup Federation, and RoboCup Japan. Vice president, Agency for Promoting Disaster Mitigation and Damage Reduction.

Discussions with Reviewers

1 Organization of the main points as a *Synthesiology* paper

Comment (Hideyuki Nakashima, Future University Hakodate)

This is a paper on the disaster information system realized by system linkages through data mediation. Its objective is to link the various and the future information systems, or to synthesize open systems where not everything can be predicted beforehand, and I think it is very appropriate as a *Synthesiology* paper.

As the editorial policy of *Synthesiology*, we expect a clear statement of the basic policy for the construction of such an open system. In fact, such a basic policy is actually written in the text of this paper. However, although I can understand the individual descriptions well, I think you should clarify the overall concept to help readers understand. Particularly, I think you should emphasize the "synthesis method," and provide descriptions with emphasis on the service engineering methods.

In chapter 1, you give the three basic policies of design: "open system, standard, and downward scalability." On the other hand, you also state the concept of data-centered (or data mediated linkages) in subchapter 2.1 and chapter 3. In subchapter 2.3, you give the two points of design and implementation policy: 1) downward scalability and multi-platform, and 2) utilization of existing software and open sourcing. The relationships among these points are not clear. I think you should organize the overall concept and provide descriptions using diagrams or tables.

As a proposal, I think you can give the characteristics that a disaster information system should possess, position the requirements in a top-down manner, and then position the corresponding implemented functions. Is my following understanding correct?

Characteristics of disaster information

- Various organizations (as well as individuals?) operate the disaster information system at varying scales.
- Difference in timescale of the disaster and the information technology
- Disaster measures must be updated frequently, and in some cases, complete makeover is necessary.

The system linkages by data mediation are optimal as the linkage platform that fulfills the above objectives. The requirements to realize such a platform are as follows:

- Simplify the new linkage connections
- Maintain universality: universal input format, universal output format, common structure, etc.
- Simplify the task for new linkages
- No need to consider computational capacity

The functions that came up as issues in implementation were as follows:

- Module linkages mediated by data: to link the various disaster information systems
- Data structure definition function: to test and update the new data format in real time when a new module is added
- Employ standards for the basic function of MISP: to increase compatibility with the existing and future systems. It should be simple, and should be capable of being handled by sensor systems without computational capacity.
- Employ XML: universality, flexibility, expandability
- Low requirement of operating environment: assuming that large servers may be down, it must run on small terminals
- Open sourcing: establish the framework of information sharing and allow smooth diffusion
- Tools to allow linkages, even partially, without limiting to MISP
  - ★ CSV connection tool: system widely supports the universal data format of spreadsheet software
  - ★ GIS viewer linkage tool: tool for displaying data on GIS viewers such as GoogleEarth
  - ★ Log replay tool: tool for reconstructing the changes in shared information of the various modules, including the time axis. Simplifies adjustment of linkages.

I think if you add tables or figures that show the relationships of these functions and the requirements in matrices, it will clarify the synthetic concept (research scenario) toward the research goal, and provide useful information as a *Synthesiology* paper to the readers.

Answer (Itsuki Noda)

Thank you very much for your useful advice. As you indicated, the flow of the entire paper and the relationships of the keywords were difficult to understand. I added some texts to chapter 1 to supplement the explanations. I also added figures to show the relationships of the keywords.

2 Title

Comment (Motoyuki Akamatsu, Human Technology Research Institute, AIST)

Please add a title and subtitle that clarify the above points. For example, "Construction of a platform for disaster information system linkage – Linkage of various information systems that change over a long period via data mediation." Please consider this along with the main points.

Also, please reconsider the subchapter titles of chapter 3 to clarify the main points of the paper.

Answer (Itsuki Noda)

For the title, I added "platform" which is the proposed technology. For the subchapter titles of chapter 3, I used the keywords discussed in subchapter 3.1 to clarify the corresponding relationships. I also added the subchapter numbers to the keyword relationship diagram in Fig. 1.

3 DaRuMa

Question (Motoyuki Akamatsu)

When I look at Fig. 7, it seems that there were two DaRuMas made, one for Niigata and the other for Mitsuke. Did you need two systems for smooth operation? Please explain why you had two DaRuMas.

Answer (Itsuki Noda)

During the experiment at Mitsuke City, there was no access control on DaRuMa, and all systems that could access DaRuMa could see all the information there. Therefore, the information that had to be kept closed within the city hall and offices could not be loaded to DaRuMa, and information sharing in the offices was stopped. To prevent this, we set up the internal DaRuMa and external DaRuMa, installed a mirroring tool with filtering functions, and only the information that can be released publicly was reflected in the external DaRuMa. Later, access control was added to the DaRuMa (and MISP) so such a dual setup is no longer necessary. In this paper, I describe the system configuration used during the experiment. Since access control is not the main subject of this paper, I will not include the explanation.

4 Map

Question (Motoyuki Akamatsu)

In this paper, you present the demonstration at Mitsuke City, demonstration at Toyohashi City, and Honda's Toreta Doro Map. I think it is extremely important to do the demonstrations on site, but what were the backgrounds in which you obtained permission to do the demonstration experiments? What were the motivations of the people on site to participate? Can you describe this to the extent of your knowledge? Were these people members of the MEXT or METI projects, and if so, what were the motivations for the organizations to participate in this project? What are the differences between organizations with and without motivations? I think this should be clarified in terms of synthesiology. Similarly, who initiated the passable road map by ITS Japan during the Great East Japan Earthquake?

Answer (Itsuki Noda)

Speaking of the relationship with the local governments that offered us the sites, it is most important that the relationship is built before and after the experiment, not just during the project. The local governments where the demonstration experiments discussed in this paper were done cooperated via individual relationships with the researchers who participated in the projects. Many of the relationships grew from coincidences, and often a leader of the local government or a person in charge of disaster prevention was very interested. Such coincidental relationships were nurtured carefully by the researchers, and a common consciousness for the disaster issues were identified by visiting the regions and the sites, to obtain understanding of the new technologies, and that led to the execution of the demonstration experiment. The project may last only a few years, but the relationships with the local areas exist from before and extend well after the termination of the projects. I simply received the benefits of the relationships nurtured by the joint researchers of the projects introduced herein, but I am spending effort to maintain as many relationships with various people after the completion of the projects.

For the case of ITS Japan, it started when I was thinking about the idea of Dr. Hada of the Yamanashi University during the Chuetsu-oki Earthquake. I happened to receive cooperation from Honda in the Chuetsu-oki Earthquake, and I was able to provide information, though in a small scale, using an improvised system. Thanks to this success, Honda and Google went into action in the Great East Japan Earthquake, and ultimately, the information was transmitted through the all-Japan system under ITS Japan. In this case, I think the continuity of the relationships from the time of Chuetsu and Chuetsu-oki Earthquakes (and way before that when I started to create various tools) is important, through activities such as the NPO study sessions.