Article

Disaster risk and resource management system: Focus on the efficient operation and management

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Abstract: In this study, we developed a system that can operate and manage disaster situations and disaster management resources. Through the development of this system, we tried to prepare a plan to actively respond to single and complex disaster situations that may occur in the city. In addition, it was intended to suggest the direction of effective disaster management through the operation and management of disaster management resources in dangerous situations. In this study, a Python-based database and algorithm were set up to derive complex disaster scenarios. In addition, blockchain technology was applied to improve the transparency of disaster management resource operations and management systems. Through this research, we achieved the result of system design and development by applying the 4th industrial revolution technology. However, at the practical level, when applying the actual blockchain, the process of user authentication is not only the reliable operation of disaster management resources but also the process of utilizing disaster management resource operation and management system prototypes as a whole, as it is linked to government departments and management agencies. The feasibility should be reviewed and applied. In the follow-up study, the prototype developed in this study will be further elaborated to improve performance into a system that can be used in practice.

Keywords: complex disaster; disaster management resources; operation and management system; data analysis technology

1. Introduction

Recently, as the urban structure changes to a hyper-connected society, the city is becoming increasingly diverse and complex [1-3]. Due to such changes in urban structure, the risk of natural disaster damage in a specific point or region of a city spreading to other regions without being limited to that region may increase. In addition, it has a positive and strong influence on deteriorating into a complex disaster by linking and integrating the occurrence of disasters in a specific facility into various sites [3-5].

Complex disasters do not yet have a unified definition, but are generally conceptualized in two ways [6,7]. The first is the concept of spreading disasters. It means that the same disaster occurs secondarily due to social disaster, that is, a single disaster occurs in a chain and spreads to the same kind of disaster. For example, it means that the fire spreads to other areas more due to the fire, and the damage also increases. Even in the case of a building collapse, affecting other buildings to collapse together is included in the spread of the same kind of disaster. The second means that natural disasters lead to heterogeneous disasters. Specifically, natural disasters such as earthquakes and floods cause secondary social disasters such as fires and collapses. At this time, there is a correlation between the disaster that is the cause and the disaster that is the result. As an example, it can be presented that a facility is destroyed due to an earthquake and a fire breaks out in the destroyed facility. In other words, complex disasters refer to disasters in which the range or types of disasters spread, such as natural disasters that can occur in connection

with social disasters, or one single disaster that leads to different types of disasters that occur serially. In order to mitigate the damage caused by these complex disasters, it is essential to predict disasters in advance based on the existing post-response response and establish a disaster management system that considers the entire life cycle of disaster occurrence. In addition, it is key to prepare a plan to reduce disaster damage by utilizing the established disaster management system.

Studies are being conducted to respond to the deterioration of the situation from the spread of disasters and complex disasters and to prepare for various disaster situations. Specifically, various studies are being conducted on the subject of development of case-oriented data and simulation-based integrated disaster management system technology that enables early prediction and proactive response to disasters [4-7]. In addition, in previous studies related to disaster management systems, technical studies were conducted that introduced data analysis-based technologies such as IoT, AI, and big data [5-9]. In these studies, the possibility of development as a next-generation safety management system that meets the purpose of the 4th industrial revolution in relation to the development of a disaster management system was proposed to secure safety in people's living space and reduce continuous disasters. In particular, there is an advantage in that the capacity of disaster management technology can be strengthened by using the driving force of innovative growth applied with data analysis technology in the research field related to disaster safety. Specifically, technology such as correlation and semantic analysis of data and linkage with network technology is being actively applied [9,10].

In this study, we tried to build a system that can manage the entire life cycle of a disaster situation by reflecting the characteristics of each response stage, such as preparedness, mitigation, response, and recovery [9,10]. This is because the city's disaster vulnerability and disaster prevention urban planning system are currently being established and operated, but there are limitations in managing complex disasters and presenting customized measures for the region. In addition, the results of this study are intended to be used as basic data to propose directions for establishing disaster prevention type urban planning that reflects regional characteristics in connection with urban disaster prevention policies.

2. Materials and Methods

2.1. Materials

In this study, a disaster scenario and simulation data-based analysis technology was developed as a method to build a system that manages disaster situations and disaster management resources in an integrated front. The technology to be developed in this study is to build a complex disaster scenario by using simulation results based on a single disaster scenario that can occur in the field as a database. Specifically, a database was built based on the single disaster simulation results. Using the established database, the disaster occurrence situation was specified and the disaster occurrence situation within a certain space was integrated. An integrated disaster situation in a specific space was considered a complex disaster. The category of complex disasters was conceptualized as the sum of single disasters and single disasters, and was organized into the spread to homogenous disasters or the occurrence of heterogeneous disasters. Also, standards were created to automate the generation process. In addition, a prototype design and development of an efficient management system for disaster management resources that can be utilized in complex disaster situations was performed.

The database of the system developed in this study consists of two types of tables. First, the tables related to single disasters are as follows.: A list of single disaster scenarios, a list of simulation results based on a single disaster scenario. The tables related to complex disasters are as follows.: A list of complex disaster scenarios that combine single disaster simulation results, and a list of risk assessment results analyzed based on complex

disaster scenarios. Each table is associated with an algorithm that can generate complex disaster scenarios.

Second, there are tables related to disaster management resources. Specifically, it is a list of disaster types in the region within the test bed, disaster types that should be managed with priority, and priority levels for disaster management resources. In order to utilize the tables divided into two characteristics, the possibility of linking disaster occurrence situations and disaster management resources was considered.

2.2. Methods

In this study, we focused on creating, maintaining, and managing an operating system using life cycle development for system development. Specifically, this study tried to develop software related to network operation and data security.

In order to form the content to be installed in the program to be developed in this study, research was first conducted on disaster occurrence scenario construction, expert evaluation, and disaster definition. First, the types of disasters that are intensively managed within the test bed area are classified. For the classified disasters, occurrence scenarios were established for each single disaster (fire, earthquake, flood). Based on the established disaster scenarios, simulations were performed for each disaster. The derived simulation results were linked by categorizing fire, flood, and earthquake disasters based on the time the disaster occurred within a specific area. At this time, the relationship between homogeneous disasters was defined as the spread of disasters, and the relationship between heterogeneous disasters as complex disasters. The results of the research at this stage were established as databases related to single disasters and complex disasters.

The database for the operation and management of disaster management resources used in this system was established by classifying them into disaster types and disaster management resource grade types. Specifically, natural disasters and social disasters were categorized, and detailed types were composed of sub-factors. On the other hand, the database of the system for operating and managing disaster management resources was established by categorizing each disaster type and disaster management resource level and including details. Specifically, the types of disasters were divided into natural disasters and social disasters. Natural disasters were composed of sub-factors such as floods, typhoons, and earthquakes, and social disasters were composed of sub-factors such as explosions and collapses. Disaster management resources were established by classifying equipment and materials into A, B, and C grades, respectively.

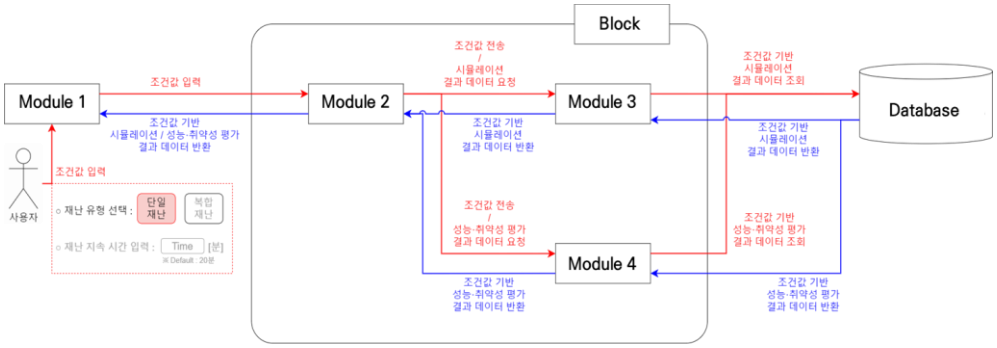
In the case of data for realizing disaster management resources, the amount of support available was used as a reference value to calculate the appropriate stockpile and support amount. Based on the established database, a demand survey and related data for disaster management resources requiring immediacy according to the disaster situation was classified. Finally, the data to be applied to the prototype was analyzed and organized. For differentiation from the existing disaster management resource operation management system, the function was considered to focus on the convenience of the person in charge of resource management. In addition, reference materials and data were provided for easy calculation of the appropriate reserve of disaster resources.

For the operation of disaster management resources, the priority management resource list was activated. In addition, through resource history management, mutual history inquiry was made so that it could be used as a reference value for calculating the appropriate reserve of disaster resources. Blockchain technology was applied to manage the history of resource use within this system. Blockchain technology can transparently record the flow of resources and can store automatically updated transaction records in real-time to create a database [11]. By applying this technology, data was stored and shared in blocks that linked the transaction details of resources within the network.

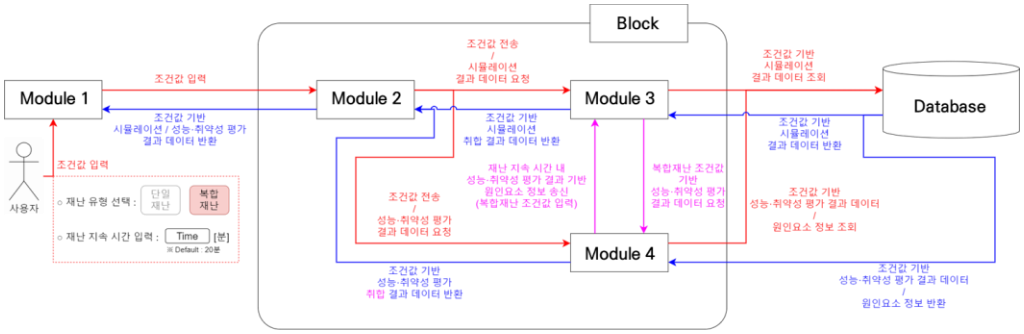
3. Results and Discussion

3.1. Algorithm for Generating Complex Disasters Scenario

Figure 1 shows the principles of the single disaster simulation result derivation and complex disaster generation algorithm developed in this study.



(a) Single Disaster Simulation Result Derivation Process.



(b) Complex Disaster Simulation Result Derivation Process.

Figure 1. Algorithm for Disaster Scenario and Simulation Results Derivation.

In this study, a composite disaster scenario was created based on the single disaster simulation results. First, after selecting a specific area and setting a single disaster that mainly occurs in that area, the standard time for the next disaster to occur after the occurrence of the disaster was set to 20 minutes (taking into account the evacuation time). If a homogeneous or heterogeneous disaster occurred in a specific area before the reference time passed, it was determined as a composite disaster. However, if it occurred after the standard time, it was determined not to be a complex disaster.

In this program, the user can select the disaster type when inputting the condition value. Details on program operation are as follows. First, after selecting a specific area, select either a single disaster or a complex disaster. At this time, the user can select a natural disaster (earthquake, flood) and a social disaster (fire, flood). Disaster occurrence in a specific area is identified through simulation results. If flooding also occurs within 20 minutes after a fire breaks out in a specific area, it is determined as a complex disaster in which flooding due to fire occurs. The simulation results are returned together with the results of estimating the damage in the selected specific area. It is to provide the result of whether or not the function of the facility in a specific area is lost, the location of the facility, and the reference value for the loss of function. Figure 2 presents the detailed functions of the program modules in this system.

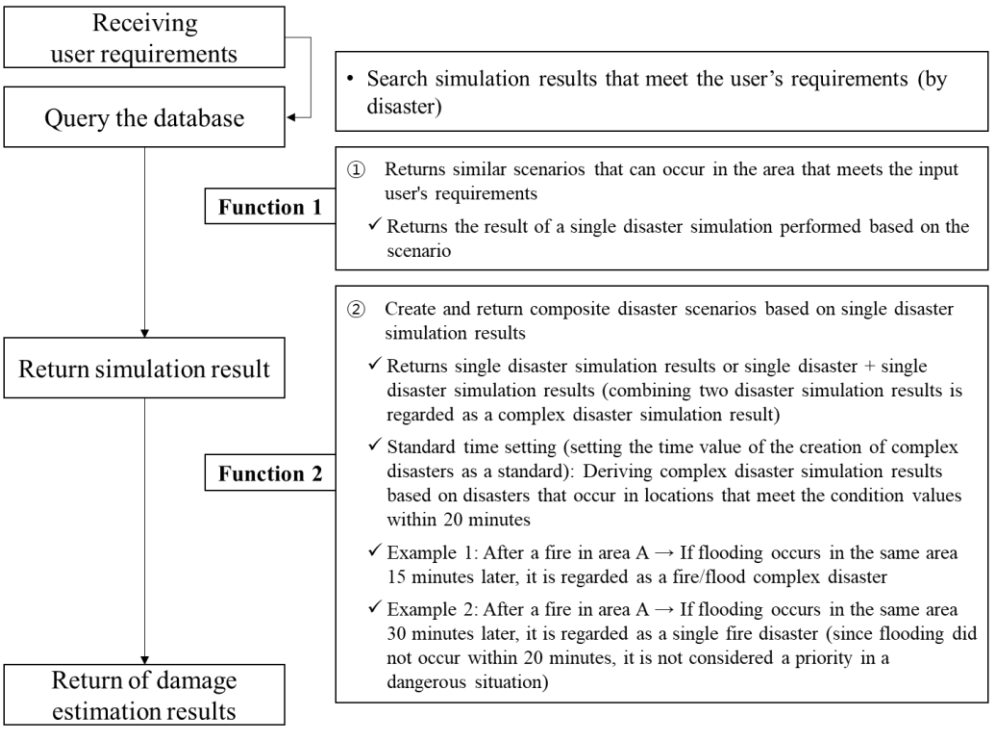


Figure 2. Detailed functions of the system module.

3.2. Disaster Management Resource Operation and Management System

Figure 3 presents the screen design of the system prototype developed in this study. The specialized part of this system is managing disaster management resources through blockchain. In a blockchain system, the improvement effect can be reviewed in the administrator's authentication, authority management, and support/management (inquiry) of disaster resources. In addition, when a user's ID is created using a blockchain and the field name (or address value, etc.) of the data value is transmitted according to the block type, PKI or other encryption methods are applied to store user information. At this time, authentication in the user registration/inquiry process can be verified using the blockchain's hash value of user information. In this case, user authentication can be supported without the support of a reliable third-party authentication authority.

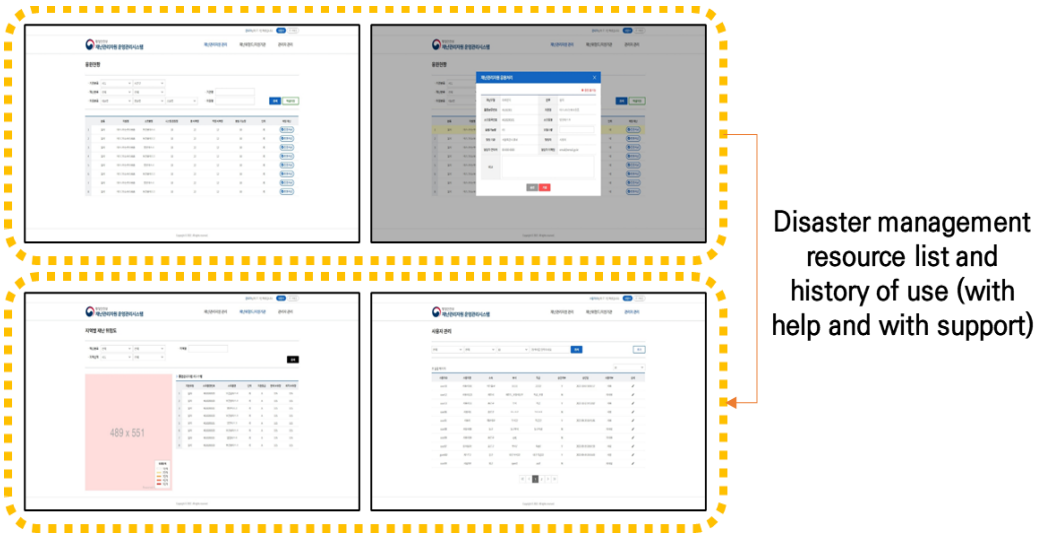


Figure 3. System prototype design.

In the case of disaster management resource support request and management, through the process of executing and verifying transactions through smart contracts (Smart Contract or Chain Code) for transactions that occur in the entire process of registering/supporting request/processing/inquiry of disaster management resources, It is possible to support and manage disaster management resources in real-time without separate transaction authentication and verification procedures. In addition, all agencies can participate in the transaction verification process to support the integrity of disaster management resource information. At this time, it is important to configure a data model suitable for the block size of the blockchain and the smart contract. Figure 4 presents a blockchain operation flow chart.

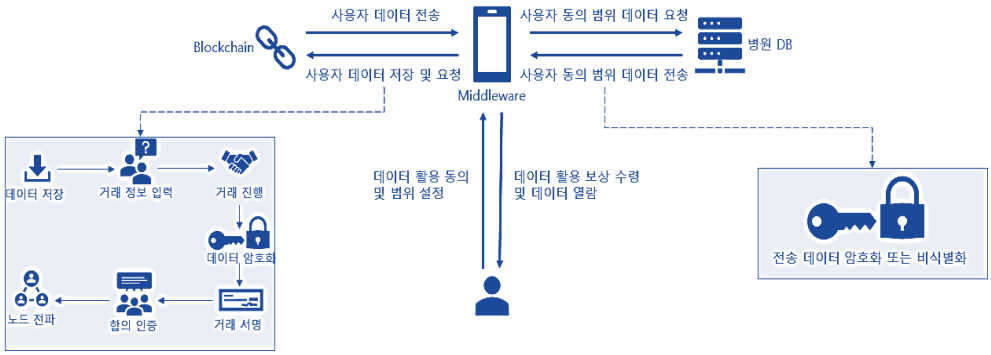


Figure 4. Blockchain Operation Flow Chart.

4. Conclusion and Implications

In this study, a system for operating and managing disaster situations and disaster management resources was developed to develop a plan to actively respond to single and complex disaster situations that may occur in the city. In addition, it was intended to present a direction for continuous disaster management by effectively operating and managing disaster management resources in dangerous situations. In this study, a database and algorithm were set up to derive complex disaster scenarios, and blockchain technology

was applied to improve the transparency of disaster management resource operation and management system. Through this research, we achieved the result of system design and development by applying the 4th industrial revolution technology. However, at the practical level, when applying the actual blockchain, the process of user authentication is not only the reliable operation of disaster management resources but also the process of utilizing disaster management resource operation and management system prototypes as a whole, as it is linked to government departments and management agencies. The feasibility should be reviewed and applied. In the follow-up study, the prototype developed in this study will be further elaborated to improve performance into a system that can be used in practice.

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