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DEVELOPMENT OF A RISK ASSESSMENT FOR KOREAN HIGH-RISE MIXED-USE BUILDINGS

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ABSTRACT

This study presents the contents of the development of a risk assessment for complex urban disasters, mainly focusing on super high-rise buildings and complex facilities. It is expected that the developed contents will provide an integrated CPS for responding to high-rise and mixed-use building disasters with important analysis information for complex disaster analysis and behavior prediction. This study presents the contents of the development of a Korean-style prediction system for risk damage assessment using Ergo, which is open-source software, and also describes the necessary technologies and basic conditions for achieving this goal. The results of this study will contribute to the development of disaster analysis and damage prediction technology, guidelines for the construction of the integrated disaster response CPS, and the construction of an integrated information system for complex disasters.

Keywords: Risk Assessment; High rise building; ERGO; HPC; Big Data

1. INTRODUCTION

As the 21st century began, the number of high-rise buildings increased rapidly throughout the world. As of 2016, South Korea is fourth on the list of countries with the most high-rise buildings after China, the US, and the UAE. According to its Building Act (Ministry of Land, Infrastructure and Transport, 2016), Act on Fire Prevention and Installation, Maintenance, and Safety Control of Fire-Fighting Systems (Ministry of Land, Infrastructure and Transport, 2016), and Special Act on Management of Disasters in Super High-Rise Buildings and Complex Buildings with Underground Connections the special law on disaster management for high-rise and underground-linked mixed-use buildings, the Korean government defines the high-rise building as a building with ʻnot less than 50 floors or with a height of not less than 200 meters (Ministry of Land, Infrastructure and Transport, 2016).
Currently, various disasters such as earthquakes, fires, and floods are occurring around the world. However, research on disaster response for high-rise complex facilities where many people live has been insufficient and has not been well prepared compared with that for general buildings.
There are many high-rise buildings in Korea, yet there is a relatively low sensitivity of alarm systems against earthquakes and fires. In addition, research on structural health monitoring technologies for high-rise complex facilities is scarce. If disasters such as earthquakes, fires, or floods strike high-rise buildings or underground complex facilities located mainly in metropolitan areas, this can cause significant damage. Therefore, the accurate detection, rapid analysis, and reliable information sharing regarding

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disasters that have occurred are essential conditions for active response when high-rise complex facilities are hit by complex disasters such as earthquakes, fires, and floods. In addition, there is an increasing need for an integrated information analysis system to promptly respond to disasters and to provide reliable information in case of such disasters.

In keeping with this trend, the Korean government launched the Multi Disaster Countermeasure Organization (MDCO) in 2016 with the goal of constructing a Cyber Physical System (CPS) to respond to disasters in high-rise complex facilities. The goals of the MDCO are 1) developing an integrated CPS for high-rise and mixed-use buildings and 2) researching core technologies for various disasters, which are crucial in rapid disaster response and recovery. The integrated CPS will provide beneficial estimated results such as potential causes or effects of disasters.

This study focuses on the contents of the development of a complex disaster risk assessment, which is one of the analytical and predictive study elements of the integrated CPS platform. The CPS platform is a system for disaster response for high-rise complex facilities.

The high-rise building has various purposes and characteristics. It is a huge city itself as many people reside there. Therefore, the development of technology for disaster response in the building itself, as well as the development of technology for predicting disaster damage and responding to the occurrence of disasters in advance in conjunction with the surrounding area, are absolutely essential. The analysis of the vulnerability of buildings includes not only high-rise complex facilities but also buildings in the surrounding area, economic analysis including damage to human life, analysis of shelter, the accessibility of police and hospital functions, and the construction of risk assessment systems against earthquakes

2. PURPOSE OF RESEARCH

This study presents the contents of the development of a risk assessment for complex urban disasters, mainly focusing on high-rise complex facilities. It is expected that the developed contents will provide important analysis information for the construction of an integrated CPS platform. This study presents the contents of the development of a Korean-style prediction system for risk damage assessment using Ergo (Vecere et al. 2017) (Makhoul et al. 2016), which is open-source software, and also describes the necessary technologies and basic conditions for achieving this goal.

Figure 1 shows the entire task process of the proposed system. First, this study needs to collect various related data such as infrastructure and building information in metropolitan areas so as to analyze the disaster damage and loss prediction while examining the complex disasters and developing the behavior prediction method. It is necessary to ensure data integrity for the analysis of various complex disaster behaviors and to standardize the data for quality improvement. In addition, this study requires interoperation technology of standard data for collecting and analyzing data, and a technology and development environment such as a high-performance computing (HPC)-based data simulation analysis environment for the development of analysis and forecasting technology based on big data. In order to satisfy these requirements, it is essential to establish a metadata standard for complex disaster data related to high-rise complex facilities, to construct a big-data analysis platform environment for disaster data management and application analysis, to apply a building test bed and optimize the target systems for disasters, and to develop convergence technologies for Information Communication Technology (ICT) and construction.

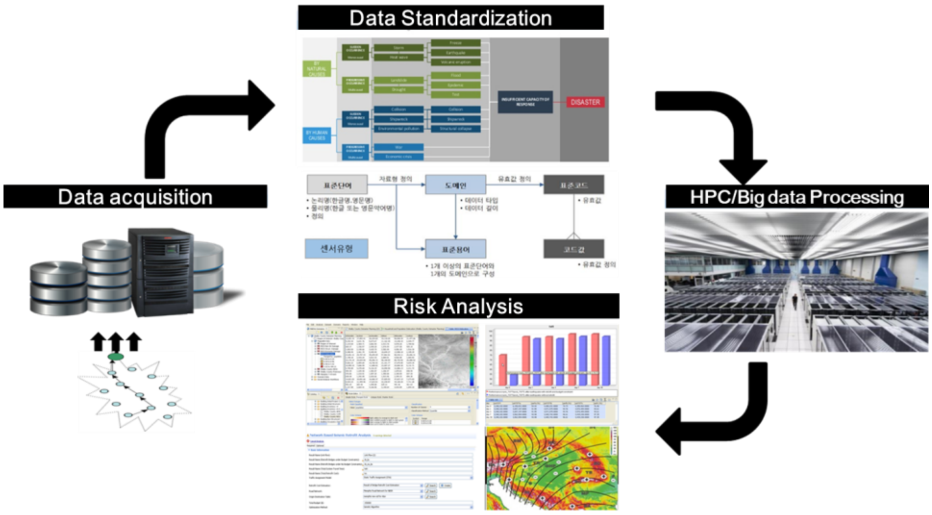

Figure 1. A Whole analysis Process for the Proposed System

3. TECHNOLOGIES

3.1 Data Inventory

First, the task of data inventory involves collecting/building the following datasets: buildings and essential geospatial data for Korean cities from open public data and various institutions. The inventory data will be ingested with specifications that allow it to be used in this system.
Using HAZUS-MH, which is a loss assessment analysis tool, and Ergo, an inventory including buildings, population, and weights was constructed by collecting and refining the data according to local circumstances. The local and international data formats, as well as the geographical and national environments, are different.
In order to construct the building inventory for Korea, we consulted with experts and performed a response process on the use and structure of buildings that reflect the actual circumstances of each country. In addition, we secured the dataset after verifying the accuracy of the collected public data to build a loss assessment dataset that includes the population inventory and the current estimated values of the building.
We suggested the use of the attribute data of the constructed building inventory, and the use of the estimated population per building unit, the period of duration, and insurance data based on the population inventory. It is possible to make a more accurate loss assessment by analyzing the income information per household, revenue information per building unit, and weight information considering the official land value per each region.

3.2 Analysis

The second task of risk analysis enables the estimation of direct physical, social and economic losses regarding high rise and mixed-use buildings, as well as surrounding areas that are expected to be affected by disasters. The analysis of damage in this study reflected the structural damage, direct economics, etc., based on the building analysis module of Ergo. The source code was tailored to fit the local data and environment in Korea.
An earthquake scenario was chosen for this analysis. The damage to buildings and the economy was analyzed based on the earthquake scenario.
We evaluated the earthquake scenario by using a deterministic method. First, we referred to input parameters for calculating the seismic risk of the Korean peninsula, which were presented and analyzed in previous studies about the attenuation equations of the Korean peninsula. By considering a strong earthquake (M = 7.0) and minor earthquake (M = 3.0) depending on the magnitude, distance, frequency, and depth of the earthquake, we predicted an earthquake disaster on the Korean peninsula by applying the attenuation equation derived by assigning Toro, Cho, and No to the ratio of weights 4:4:2 using the

deterministic method. A seismic source was applied to the entire Korean peninsula by setting one unit of the tectonic structure. The soil conditions in the target area might be different depending on the location of the buildings, but all soil conditions were assumed to be deep firm soil (SD) for the simplicity of the analysis.
The damage assessment of buildings was evaluated according to the definitions of HAZUS and Ergo. The seismic fragility function was selected based on the classification of the structure of each building in the building register. A system for estimating the damage to buildings was used to calculate the damage by dividing the degree of the damage into four stages (destruction, nondestruction, partial destruction, and partial loss) by building structure type.

3.3 HPC Workflow

The third task in HPC support requires developing Ergo plug-ins to submit and manage analysis jobs on an HPC. This development has three main components: 1) user interface on Ergo, 2) staging in/out data to HPC, and 3) job management. The user interface on Ergo will allow users to select input data and depict the parameters for the analysis on HPC. Moreover, the status of job will be shown on this user interface and users can control the job (e.g. canceling a job). The staging in/out data to HPC and middleware functionality to support job management will be implemented via NCSA DataWolf[7] which is a scientific workflow management system. The DataWolf has a functionality to support different job scheduler of HPC such as SGE, PBS, LoadLeveler, etc. In this use case, we will use the job scheduler on KISTI's HPC resource.

The Ergo HPC support will be tested with two cases: 1) simple analysis such as building damage analysis, and 2) structural analysis (fragility analysis) using OpenSees/OpenSeeMP (Mazzoni et al. 2006). Especially, the derived fragility curves from OpenSees will be used on loss estimation of high-rise buildings on Ergo.

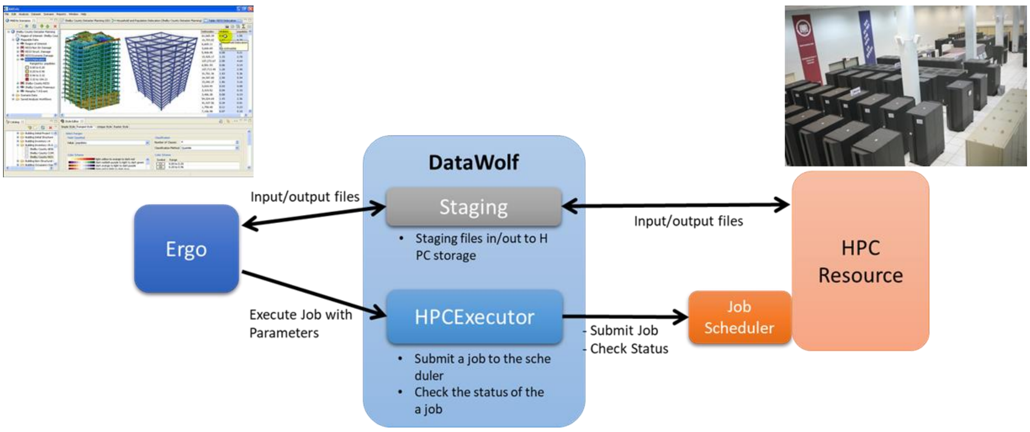

Figure 2. HPC Workflow

3.4 Big-data processing

The machine learning task will allow researchers to analyze many algorithms and revise existing codes to resolve complex tasks on the Apache Spark framework (Apache Spark, 2016).
In this study, we constructed a big-data analysis framework environment based on distributed and parallel processing by considering a big-data processing environment for disasters. Ergo requires long processing times in displaying the data and analyzing the evaluation of large building information in a wide area. We need to develop a function that can be extended to and interoperated with a big-data

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7 http://datawolf.ncsa.illinois.edu

analysis framework for the evaluation of both high-rise buildings and general buildings, for the input processing of quasi-real-time data by seismic monitoring, and for the batch processing of data sets accumulated for a certain period of time.

We also utilized MLlib (Meng et al. 2016), a machine learning library for Apache's Spark and Hadoop, which supports various data formats and algorithms with high speed and scalability so as to support machine learning libraries including deep learning. The Apache Spark API is very friendly to developers compared with MapReduce and other Apache Hadoop components. It supports distributed processing and provides bindings for Java, Scala, and popular languages for data analysis such as Python and R. Therefore, everyone from application developers to data scientists can easily make the best of its scalability and speed.
Therefore, application of the Spark environment will provide high scalability for the platform developed in this study when implementing a machine-learning model for classification and regression analysis. This Spark environment will also benefit a new analysis model based on real-time big data that analyzes by directly reflecting changes in the actual environment based on a large data set or the streaming processing of real-time seismic data acquired from sensors.

4. CONCLUSIONS

The product of this project will be integrated with CPS and can be employed as a decision support system for disaster preparedness and recovery of high-rise and mixed-use buildings by decision-makers at regional/national levels. The product will also assist in making decisions to reduce risk and aid in emergency preparedness.
This study aimed to develop a complex disaster analysis and behavior prediction method for the construction of a CPS to respond to disasters in high-rise complex facilities. We developed a Korean-style prediction system for risk damage assessment using Ergo, which is open-source software.
We developed a technology that can predict and respond to disaster damage in conjunction with the surrounding area, as well as a technology for responding to the disaster in the building itself. Specifically, we developed essential basic technologies for the collection and standardization of data, the construction of inventory, the construction of an analysis algorithm, the development of an HPC support function, distributed processing, and a machine-learning-based analysis module.
In addition, we are considering expansion of this product to a system that can analyze and predict more types of datasets by applying real-time and quasi-real-time Internet of Things (IoT) data processing.
This will provide more types of complex disaster analysis and behavior prediction information to the integrated CPS for high-rise and mixed-use buildings. In addition, it will contribute to the applied analysis of complex disaster data such as the earthquake-related data of high-rise and complex facilities, the development of technology to predict damage, guidelines for the construction of a CPS for integrated disaster response, and an integrated disaster information system.

5. ACKNOWLEDGMENTS

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