

A Study on the Flood Risk Index Considering Real-time Information

Eunmi Kim¹, Hyun Suk Hwang², Chang Soo Kim³

¹Pukyong National University, Management of Technology Program,

²Pukyong National University, Interdisciplinary Program of Information Systems,

³Pukyong National University, Department of IT Convergence and Application Engineering,

45, Yongso-ro, Nam-Gu, 608-737, Busan, South Korea

{ kimem01, hhs, cskim }@[pknu.ac.kr](mailto:kimem01@pknu.ac.kr)

Abstract. As the frequency of localized heavy rainfall in urban areas increases due to abnormal climates, flooding from downpours may damage industrial and transportation systems in cities. It is necessary to provide a realistic Flood Risk Index (FMI) for preventing the damage from floods. With the increasing use of smart phones with GPS, real-time information is required in developing a risk index of floods, such as CCTV cameras installed on roads, in addition to SNS posts. This paper focuses on the development of a model to develop a risk index of floods with real-time information. The model consists of social factors, such as information from CCTV and SNS sensors; physical factors such as water levels and rainfall amounts; and stationary factors including elevation and disaster history.

Keywords: Flood Risk Index, Social Factors, Physical Factor, Stationary Factors, Real-time Information

1 Introduction

In recent years, regional torrential downpours caused by abnormal climates have continuously caused irreparable damage to people's lives and property in urban areas. International organizations such as the OECD, the UNDP, the UNCSO and the UNEP also developed the Risk Assessment Index about disasters such as flooding, wave-storm and windstorm, and provide each nation with risk information. The information of the kinds of risk indexes are used to help the Third World countries by assistance from the UN [1].

Many countries including Japan and Germany have also developed risk indexes of inundation level and have been used to establish a strategy of flood prevention. Specifically, as Japan is in a zone which is prone to natural disasters such as earthquakes and tsunamis, a great deal of research has been conducted in responding the natural disasters. The National Institute for Land and Infrastructure Management (NILIM) of Japan developed a Flood Vulnerability Index (FVI) [2].

Many researchers in South Korea have studied the development of the risk index of floods by using a variety of algorithms based on the GIS. Specifically, the Potential Flood Damage (PFD) concept has been introduced at the Water Vision 2020 exposition planned by the Ministry of Land, Transport and Maritime Affairs

³ Corresponding Author

(MLTMN) in South Korea. The Flood Risk Index (FRI) is calculated based on the possibility of damage. The PFD method defines the potential for possibility of damage as variables and calculates a singular index by considering weights of each factor [3].

In light of unpredictable weather, it is difficult to use the risk index to respond to the damage from urgent situations caused by flash floods. Therefore, we develop a risk index of floods with real-time information, not considered in earlier studies

2 Related Research

Lee et al. [4] suggested a method for estimating urban inundation risk using the Fuzzy C-Means algorithm which calculates risk by inducing equally quantified values from five factors. These are: surface elevation, surface slope, pipe density, population and sediment in pipe. Lim et al. [1] presented the factors of pressure, state and response indicators which can measure the risk of damage from regional floods by using the Pressure-State-Response (P-S-R) structure and developed the Flood Risk Index (FRI) to allow a comparative analysis of the flood risk assessment between different sub-basins. Jang et al. [5] suggested a methodology to estimate people's potential damaged property and to calculate the risk of floods using a regional regression analysis.

Connor and Hiroki [6] proposed a method for assessing flood vulnerability caused by climate change in order to help government planners make decisions in regards to structural and non-structural countermeasures to reduce flood vulnerability. Jorn Birkman et al. [7] considered the probability and damage caused by flooding as a degree of risk, assessed the weakness, exposure and response possibility of each region, and finally proposed a strategy to reduce the vulnerability of a region by analyzing factors of environmental, social and economic risk.

In general, the Flood Risk Index has been calculated by using factors, such as records of disaster history, regional characteristics, the areas that have been damaged, and other related factors as reviewed above. The risk index developed in earlier studies may not be accurate in a real situation of a flash flood caused by an abnormal climate. Therefore, the main purpose of this research is to propose a method for developing a risk index of floods considering real-time information extracted from smart phones and equipments such as CCTV and USN sensors.

3 A Flood Risk Index Model 3.1

Factors of the Flood Risk Index

In this study, factors of the flood risk index consist of social factors, physical factors and stationary factors.

Social Factors. The social factors have qualitative values, for example, a dangerous damage level seen in images CCTV and the SNS posts collected by social network services sharing information of current situations.

The CCTV images of disasters will be transferred to a CCTV Control Center and classified into five different categories according to the damage level of flooding as judged by a system or a manager. The SNS posts are collected through smart phones

or the Internet, including locations and related information of floods filtered by a search engine, and classified into five categories consistent with those of the CCTV Control Center. The accuracy of SNS information must be decided by authorized government employees. Therefore, the study focuses on proposing a method for using real-time information to create the flood risk index adaptive in real time situations on the assumption that the SNS posts are mostly accurate.

Physical Factors. The physical factors are defined as variables having a numerical value measured by physical devices. The physical factors include the depth of water and rainfall, which are measured by USN sensors and a number of weather centers [8] respectively. Devices to measure the depth of water are installed in rivers.

Stationary Factors. The stationary factors are defined as having spatial data as well as attributes, such as elevation values and flooding history data [9]. These factors are not dependent on changes in rainfall in real time. The elevation values and records of disaster history are each extracted from DEM or slope data and from a disaster management system respectively.

3.2 FRI Model Description

We propose a model of a Flood Risk Index, which is denoted for each danger area as

$$\begin{aligned}
 \text{Flood Risk Index (FRI)} &= \text{Social Index} \times \text{Physical Index} \times \text{Stationary Index} \\
 &= E_{i=1} [a_i \cdot \text{CCTV} + a_2 \cdot \text{SNS} \times [\cdot \text{USN} + /3_2 \cdot \text{rainfall}] \times [y_i \cdot \\
 &\quad \text{altitude} + y_2 \cdot \text{disaster history}]] \times r_i \cdot C = 1 [Y_k \cdot G_{ik}]
 \end{aligned}$$

$$\text{where } \sum_{i=1}^n d_i = 1, \sum_{i=1}^n ET_{=i} = 1 \text{ and } \sum_{k=1}^n Y_k = 1.$$

The Social Index, the Physical Index and the Stationary Index are calculated by referencing the formula, which was used in HDI (UNDP, 2007), FVI (Connor, 2005) and PFD (MLTM, 2006) [1]. a_i , r_j and Y_k are the weights respectively assigned to factor i , j and k in danger areas.

Each value of USN, rainfalls, elevations and disaster history is standardized by the FRI formula (1) and assigned to each value as defined in Table 2.

The factors of the Flood Risk Index, except for the social factors must be standardized because they have different types of units. Each Z-score of the factors is calculated by formula (1) to standardize the values of the factors.

$$Z_i = \frac{x_i - \mu}{\sigma} \quad (1)$$

The i is an index of the selected area to calculate the Flood Risk Index. The Z_i is the standardized value of each factor for each region i . μ is the mean value, and σ is the standard deviation of each factor for each region i .

4 Simulation

To relatively show risk levels of floods using real-time data, we use the ArcGIS Desktop tool to represent the Flood Risk Index, and five classes is identified by using the Natural Breaks (Jerks) method. The weather information was selected on July 16,

2009 in Busan, South Korea, where the maximum rainfall was about 310 mm per day, and the greatest rainfall intensity was 90 mm per hour caused by unexpected downpours.

We have selected six areas in Busan, where CCTV and the water level sensors are installed in Nak-Dong River and On-Chun Chun River. Two areas entered through SNS were considered for simulation. However, it was not possible to capture CCTV images, values of water level sensors, or SNS texts at that time. Thus, we simulated the model with the assumption that each value of the CCTV, and the water level was assigned to the highest score for flooded areas based on the flooding history. The two locations and these values of dangerous levels transferred from SNS texts are randomly assigned. Fig. 1 shows a model to acquire the Flood Risk Index, and Fig. 2 is the result extracted from ArcGIS Desktop tool.

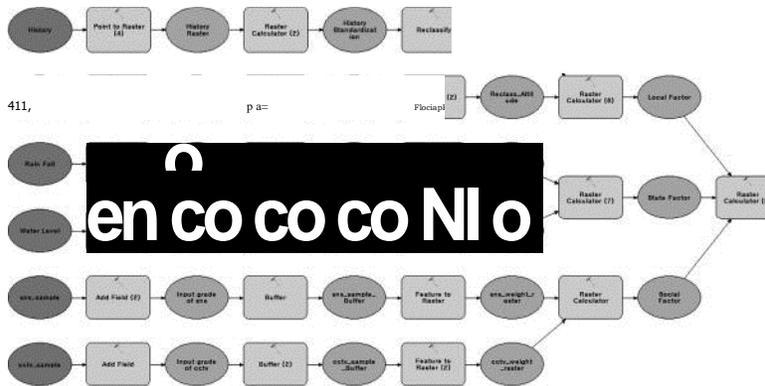
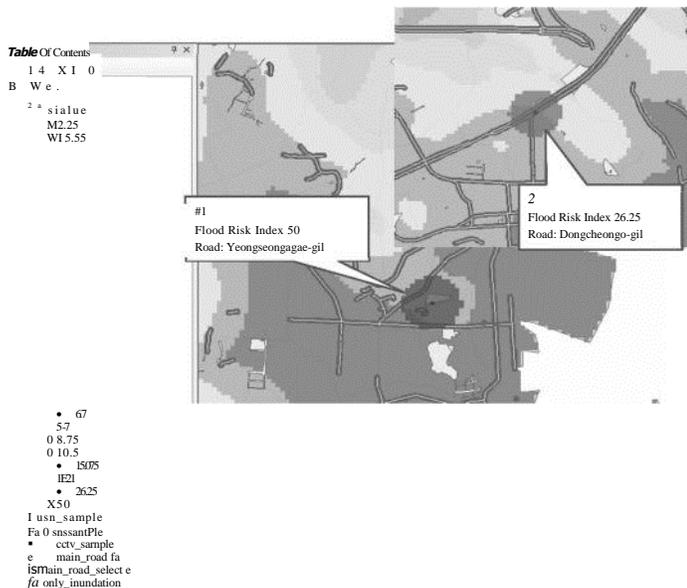


Fig. 1. Diagram of the FRI model

As shown in Fig. 2, the risk index has the highest value of 50 in area #1, where the rainfall is about 78 mm per hour and 266.5 mm per day. In the case of area #2, the rainfall is about 81.5 mm per hour and 283 mm per day. Even though the rainfall is more in area #1 than in area #2, the risk index is lower in area #1 because it is assumed that area #1 includes SNS posts as opposed to none from area #2. Thus, the real-time information from SNS can become an important factor for predicting disasters.



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Fig. 2. Results of the FRI model

5 Conclusion

In this paper, we propose a practical method to develop the Flood Risk Index with social factors in real-time, not considered in previous studies. This model includes three different factors, such as social factors, physical factors and stationary factors with weighted values for each factor.

This Flood Risk Index with real-time factors can predict more accurate dangerous areas, in comparison with predicted areas from previous records of disaster history and topological information. Therefore, related organizations can establish strategies to prevent damage caused by disasters. Evacuation paths can be provided to find the most suitable places according to people's location by connecting the FRI model to Intelligent Transportation Systems (ITS). We will make an advanced model including a variety of factors with proper weights by collecting real-time information based on a test-bed area.

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