밀집시가지 침수모형의 개발 및 적용

Development and Its Application of Urban Flood Model in Building Aarea

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Abstract

In urban flood model, the features like roads, buildings, and river's banks have great effect on flow dynamics and flood propagation and it must be accounted for model set-up. Two-dimensional hydraulic models in high-density building areas are at the forefront of current research into flood inundation mechanisms, but they are however constrained by inadequate parameters of topography and friction due to insufficient and inaccurate data. This paper describes the development of urban flooding with the extraction of building areas and estimates the its influence on flood inundation extent, and present initial results of flood simulation varying grid size.

Key Words: urban flood model, influence of building, digital elevation models, inundation depth.

도시 침수모형에 있어서 도로, 빌딩, 그리고 제방과 같은 구조물은 홍수전파에 큰 영향을 주므로 모형 구성상 고려되어야 한다. 건물 밀집지역에 대한 침수모형은 현재 주요한 연구과제이지만 불충분한 자료로 인하여 큰 진전을 이루지 못하고 있다. 본 연구는 건물 추출, 격자 크기 등을 고려한 도시 침수모형을 구축하여 그 영향을 검토한다

1. Introduction

Many studies have been carried out in the past to represent the urban inundation depth and velocity in urban areas (Inoue et al. 1999; Kang 2003; Kang 2003). But these models consider only surface and river flows. Compare to rural areas, urban areas are more difficult to simulate flooding due to the presence of small-scale system feature like roads, buildings, and dykes that block and affect flooding inundation. Commonly large DEM grid elements make up the model domain in order to reduce the computation time. This allows quick model calibrations and sensitivity analysis but also, in operational mode, it allows flooding forecasting in real time. A major disadvantage of the use of low-resolution input data is the loss of important small-scale features that affect flood propagation. As such there is a need to quantify on the effects such averaging has on model performance and, more important, the reliability of simulation results. The major issue may be to obtain accurate input data for the model in urban areas. We integrated urban flood model and described data processing procedure to estimate the influence of building and DEM size. GIS is used to perform the pre- and post-processing of large amount of spatial input and output data results efficiently.

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2. Basin description

The social structure of Samcheok city in Kangwon Province is dramatically changing with rapid urbanization. But the natural disaster prevention capacity is declining marginally. In these conditions, Samcheok area was attacked by typhoon Rusa in 2002. The typhoon brought a heavy rain of over 700mm, flooding 3,639 houses, inundating 200ha farmland and claiming lives of 13 persons. To worsen the matter, other typhoon hit the same region in 2002 resulting serious damages.
The successive disasters gave us an unforgettable experience with peoples isolated from other town, the paralyzed public and personal infrastructures, wide-spread destruction of properties and large human casualties.

3. Modeling approach

Neglecting the equation of mountainous and river network, the equation of sallow water surface for urban area can be summarized as follows:

3.1 Urban ar ea

If we neglect convective term, the following equations can be used to calculate urban prone area flooding:

$$\frac{\partial h}{\partial t} + \frac{\partial M}{\partial x} + \frac{\partial M}{\partial y} = r_e - q_{out} \tag{1}$$

$$\frac{\partial M}{\partial t} = -gh\frac{\partial H}{\partial x} - \frac{gn^2 M\sqrt{u^2+v^2}}{h^{4/3}} \tag{2}$$

$$\frac{\partial N}{\partial t} = -gh\frac{\partial H}{\partial y} - \frac{gn^2 N\sqrt{u^2+v^2}}{h^{4/3}} \tag{3}$$

Where, h is water depth, u and v are velocities of flow in x and y direction, M and N are flux of discharge in x and y directions ($M=uh$, $N=vh$). H is water level written as $H=h+z$ (z is elevation). And r_e effective rainfall, q_{out} drainage discharge from urban area to sewer line in each grid.

<Influence of building>

In order to estimate the effect of building, the share of building, λ in each grid and the transmissivity of building, β are applied.

$$M^* = \beta M, \quad N^* = \beta N \tag{4}$$

Where, M^* and N^* are the flux of discharge which is corrected boundary conditions in x and y components per unit width, respectively. If we consider M^*, N^* and λ, the continuity equation can be written as:

$$(1-\lambda)\frac{\partial h}{\partial t} + \frac{\partial M^*}{\partial x} + \frac{\partial N^*}{\partial y} = r_e - q_{out} + q_{over} \tag{5}$$

Where u, v; x, y components of flow velocity, respectively; $M^* = \beta m$, $N^* = \beta N$, x, y components of corrected discharge per unit width; M, N; x, y components per unit width, respectively; q_{out}, drainage discharge per unit area from computational mesh into sewerage system; q_{over}, overtopping discharge flow per unit area of computational grid from the river network.

4. Application and discussions

4.1 Influence of buildings

In order to simulate urban flooding, the influence of buildings should be carefully specified according to the needs of applications. GIS hydrological modeling is applied to delineate the basic hydrological elements from a DEM. One particular feature in the urban flood model is that most of buildings are built with basements. The storage volume in basements is not included in the developed flooding models. In case of basement flooding, the storage of the basements will alleviate the flooding on the surface but cause in these basements. For considering the influence of building, the method of building's share is used as described in Nakagawa et al. (2003). The possible representations of buildings for the model are illustrated in Figure 1. The calculated results of urban flooding with and without including buildings are compared. In our case, the accuracy of grid DEM and the influence of buildings are studied. For extracting building, a minimum filter method by Arc-info was used.

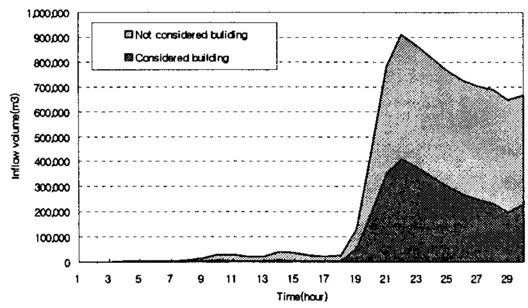

Fig. 1. Influence of building (yellow zone: not considered building, green zone:considered building)

4.2 Influence of DEM size

In the real world topography is one of the critical factors affecting the propagation of a flood wave in a channels and urban areas. Clearly, geometrical properties of topography may obstruct to flow but also could conduct or accelerate the flow of water. In hydraulic modeling, the results of output to a large extent are affected by model input data such as DEM and related properties of slope gradients, slope aspects and drainage density. Often there is a dilemma to select an appropriate DEM size: a small size of DEM results in a larger loss of information while a large size of DEM results in excessive computational time. Thus, the DEM size should be selected in such way that computational time is acceptable while averaging grid size does not generate unacceptable results. Figure 2 and 3 shows the maximum inundation area for 2 patterns of grid sizes that are resolution of 30m and 50m.

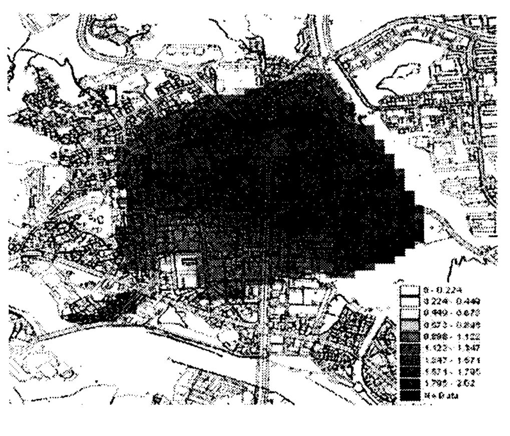

Fig. 2. Maximum inundation depth using 50m grid

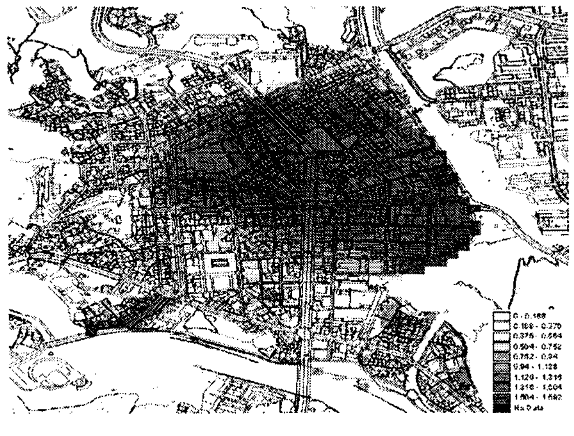

Fig. 3. Maximum inundation depth using 30m grid size

Since the same water level hydrograph is introduced for the boundary condition of broken point on the bank, the equal volumes of water are expected to be stored in the model domain. Even if domain areas increase with increased element size, it is assumed that such effect can be ignored, since inflow and outflow boundary elements are of equal size. This is to satisfy the law of mass conservation: for a certain time period, the inflow minus the outflow must be equal to the change in storage. Thus, a larger flood extent is usually expected to be associated with a smaller flood depth. Following this reasoning, it is surprising that this is not observed in Figure 3, i. e. the simulation results show inconsistencies. For the 50 m resolution DEM as compared to the 30 m DEM, the significant increase in inundation extent and depths were found to be extremely large (see Figure 3). The combined effect of the increase of flood depths and inundation area is unexpected as well the excess in flood extent.

5. Conclusions

Hydraulic models for predicting water surface profiles may be used by local emergency management, public works, planning, flood management, and public safety personal to identify at-risk structures and organizations. The models also provide a basis for predicting the area to be impacted, the water level, and flow extent (corresponding to water surface profiles from selected flows and or high water elevations). The most convenient and user-friendly method to display and query this information is through the use of a GIS. Base map information including an aerial photograph or digital map and point features for critical structures may be used as a backdrop for inundation maps. Each different inundation map may be a separate layer (polygon) in the GIS. In the urban modeling approach the following appreciation can be summarized:

- The advantages of the digital data for building were rapid collection and its accurate digital nature into model. It was demonstrated that urban flood inundation is directly affected by even quite small changes in topography and the model sensitivity was more complex than might have been expected.

- It is concluded that the DEM resolution has significant effect on simulation results. Flood simulation characteristics that are affected are inundation extent, flow depth and flow patterns across the model domain.

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