THE WATER STORAGE ESTIMATION TECHNIQUE FOR FLOOD MITIGATION PLANNING USING LIDAR TECHNOLOGY

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Abstract: Due to last year flood crisis in central part of Thailand during November to December, 2011, the modeling of water storage capabilities supporting flood mitigation planning becomes major priority in national crisis management. For this reason, the research for applying a high-resolution elevation data which is modeled from Light Detection And Ranging (LiDAR) was established. In this research, we developed the conceptual model that utilizes 2D GIS and LiDAR system to estimate a water volume capacity. This development model is for supporting the utilization of high resolution elevation data from LiDAR project that have been launch in 2012 by four agencies collaboration (Royal Thai Survey Department (RTSD), Geo-Informatics and Space Technology Development Agency (GISTDA), Royal Irrigation Department (RID), and Japan International Cooperation Agency (JICA)). The future works of the project are described in the conclusion of this paper.

INTRODUCTION

Due to last year flood crisis in central part of Thailand during November to December, 2011, the modeling of water storage capabilities supporting flood mitigation planning becomes major priority in national crisis management. The rivers in flood area have become more controlled and river embankments have been heightened. Royal Thai Survey Department (RTSD), Geo-Informatics and Space Technology Development Agency (GISTDA), Royal Irrigation Department (RID), and Japan International Cooperation Agency (JICA) have collaborated on the project of LiDAR production over central basin of Thailand. LiDAR system used for gathering the ultra high resolution elevation data over a basin area. The terrestrial LiDAR point cloud is processed into a DEM by JICA. The applications of applying DEM to support the flood control is required to have researches.

In this paper, RTSD propose a conceptual model of applying DEM from LiDAR system to estimate the water volume (storage). The water storage estimation in a flood area is a major topic in a number of researches that used to simulate a flood risk area. The storage estimation also supports a design and planning of floodway construction. LiDAR project is currently in a progress then conceptual model will be used to implementation in a future.

Figure 1 Flood crisis in Thailand during November to December, 2011.

FLOOD MITICATION PLANNING

Flood impact is one of the most significant disaster in the world. Especially in Asia the heavy rainfall is a major cause of high flood in many countries. The increasing of population and urbanization are also increasing the human factors such as blocking of channels or aggravation of drainage channels, improper land use, deforestation in headwater regions, etc (Tingsanchali T., 2012). Flood hazard depends on flood magnitude e.g., flood depth, velocity and duration. In urban area, the surface area are covered with building, roads, and constructions that flood run-off is only in the drainage system without soil absorption. For the mitigation planning, the simulation of water storage capacities over basin and their surrounding area is required. For example, the designing of floodway that pass to urban area can be studied by a flood simulation.

FLOOD MODELS

Flood models which are mentioned in this paper are numerical equations that represent the capabilities of water discharge from flooded area. Because of the duration of flood is a high impact factor of a flood damage, a number of researches are developed to explain the run-off capability of an area for flood damage assessment, flood management, flood control, and so on.

A number of researchers have developed hydraulic models of flooding based on simplified versions of the full 2D de St. Venant equations (Fewtrell T. J. et al, 2011). The original statement of Saint-Venant's principle was "... the difference between the effects of two different but statically equivalent loads becomes very small at sufficiently large distances from load" (Saint-Venant B., 1855). The shortest form of St. Venant equation is as follows (U.S. Army Corps of Engineers, 1994):

$$I - O = f(S) / f(t)$$

where

I = the average inflow to the reach during time $f(t)$

O = the average outflow form the reach during time $f(t)$

$f(S)$ = storage within the reach

In addition, hydraulic routing model can be alternatively described as the differences between upstream and downstream of water storage where hydrograph has been observed or computed. More demonstration of water routing is as following Figure.

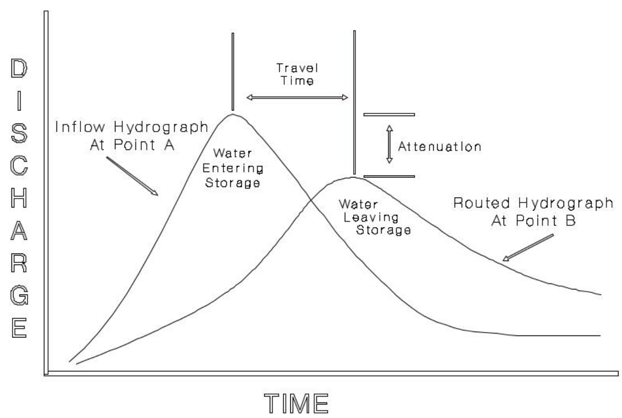

Figure 2 Discharge hydrograph routing effects (U.S. Army Corps of Engineers, 1994).

Time difference between an inflow (point A) and outflow (point B) is a duration of flood in the area. Time interval usually increased in urban area cause of an insufficient outflow.

Thus, a hydraulic model which fits to physical existing can be used to support such; flood management, flood forecasting, flood risk reduction, urban planning, and so on.

LiDAR TECHNOLOGY

LiDAR technology is developed to improve the density of height observations that are used to generate the digital elevation model (DEM). The LiDAR system directly acquires terrain points through a laser scanner which determines the travel time of the laser pulse (Perez J.L. et al, 2011). The density of spot heights can improves an accuracy of DEM (~3 m to ~2.5 m on ground resolution). Urban area which has rich constructions needs the accurate elevation model for improving hydraulic routing equation that are used to evaluate water run-off capability, water storage capacity, etc.

In addition, elevation data from LiDAR related to the ellipsoid WGS84 can be derived to orthometric height (based on a local goid). For example in a research of Peres J. L. et al (2011) the methods to convert LiDAR-derived ellipsoid heights to orthometric heights was demonstrated.

WATER STORAGE ESTIMATION

In heavy rainfall season, water flow can be attenuated by the water storage capacity of wetlands. The study of floodwater mitigation potential in wetlands can reduces the flood damage. A number of researches are developed to evaluate and estimate the water storage capability in wetlands. For example, Huang S., et al (2011) use LiDAR producing high-resolution and high accuracy DEMs for capturing detailed wetland morphology even in areas of extremely low relief. The research modeled the catchment area and spilling point of a wetland. Than the accurate estimation of water storage is allowed. But in urban area that contains houses, roads, buildings, etc an alternative method must be implemented.

In 2D GIS the spatial data such as building polygons, road lines, and another constructions are surveyed by national agency. This kinds of data can be used to improve the storage estimation. The blocking of human factors are causes of such increasing of water high, flood time duration, and also attenuating the water run-off in urban area. Form this idea, we proposed a conceptual model of applying LiDAR and 2D GIS in water storage estimation. The conceptual model will be used to improve hydraulic models which are calculated in an urban area. In Figure 3, polygons of buildings are not included in calculation. Actually, some type of building flooded inside because of the water come from waste pipes. From this reason, buildings and another constructions should be included in the calculation. The multiplication of a constant responding to each type of buildings can also be applied to improve the model. Additionally, through this proposed method a suitable high of a construction of a floodway barrier can be estimated by assigning an additional drainage polygon into a model as shown in Figure 4 (a).

Figure 3 Applying 2D GIS to the water storage estimation models (Fewtrell T. J. et al, 2011).

PROPOSED MODEL

$$V_{flood} = V_{DEM} - V_{obstruction}$$

where

$$V_{obstruction} = \text{2D Polygon} * h_{water} * c_i$$

Or

$$V_{obstruction} = \text{2D Polygon} * c_j$$

V_{flood} is a water volume that is calculated from V_{DEM} (from LiDAR) and $V_{obstruction}$ (from 2D polygon). $V_{obstruction}$ can be calculated from multiplying of 2D polygon, water height (h_{water}), and a constant responding to obstruction type (c_i). The constant of an obstruction type can be a building materials or some types such as monument, football stadium, roads, etc.

The application of the model can also be applied for the period of flood crisis such as a calculation of a barrier height for building a temporal floodway if $V_{obstruction}$, 2D Polygon area, and c_i = 1 (100% of water contain) are known as demonstrated in Figure 4.

(a) (b)

Figture 4 (a) Polygon of the floodway. (b) The barrier height of floodway.

CONCLUSION AND FUTURE WORK

The conceptual model is not only used in a period of planning, but in a flood situation the model also used to support a high estimation of a temporal barrier such as demonstrated in Figure 4 (b). This conceptual model will be developed to an application that supports semi real-time management of flood crisis period due to the utilization of the power of an existing 2D GIS information. The polygon of floodway can be drawn in a period of flood crisis for an estimation of h_{water} which is used to construct a temporal barrier.

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