DEVELOPMENT OF A WEB-BASED GIS AND SIMULATION MODEL FOR THE PREDICTION OF FLOOD AND OTHER DISASTERS

Nguyen Hoa Binh (1), Nguyen Huu Tuat (1), Le The Trung (2),

Hoang Minh Hien (3)

(1) Software Department – PeaceSoft Solution Corporation.

Address: No. 1, 149/3 Khuong Thuong st., Dong Da dist., Ha Noi, VIETNAM

Tel/Fax: (84-4) 563 8927; Email: peace@peacesoft.net

(2) Professional Advisory Council of Disaster Medicine – Ministry of Health.

Address: National Institute of Burn, Thanh Tri dist., Ha Noi, VIETNAM

Tel: (84-4) 688 4778. Email: lthai@fpt.vn

(3) Deputy Director, Disaster Management Center, Department for Dyke Management, Flood and Storm Control – Ministry of Agriculture and Rural Development

Address: No. 2 Ngoc Ha, Ba Dinh, Ha Noi, VIETNAM

Tel: (84-91) 204 1987; Fax: (84-4) 733 6641. Email: hmh@netnam.vn

ABSTRACT

This paper presents a research project between three separate organizations: the Professional Advisory Council of Disaster Medicine, Peacesoft Solution Corp., and the Vietnamese Military Institute of Health. The name of the project is: Flood and Other Disaster Warning and Evacuation System, a case study of Kim Bang district near the Day river basin. The abridged name is: Disaster Map Online.

The objective of the project is to develop a set of IT tools (Disaster Map Online) to support health care activities for people in areas affected by floods. This is done by saving the preventive projects of local health authorities on a digital map that allows easy access via the Internet, and also by predicting potential flood areas and evacuation solutions before floods occur.

The objective of this paper is the study of flood progression mechanisms by using automated tools (namely Flood Simulation) for generating suitable pattern of flooded area, its parameters, its propagation and its consequences in a given region. This tool integrates spatial Geographical Information System (GIS) information (e.g. topographic grid, aqua, inhabitants and traffic layers…) and a Flood Simulation Engine (based on a gradually spreading algorithm). It is also able to publish the results on a Web-based GIS application.

Throughout this research, it became apparent that GIS, combined with techniques of simulation, is a powerful tool for the comprehension of problematical situations like floods. Such functionality of GIS enables modeling of other geographical phenomena of similar nature.

Keywords**: GIS, disaster, flood, web, simulation**

1. INTRODUCTION

In the digital age, the application of Information Technology (IT) brings about significant achievements especially in forecasting thanks to the high calculating speed and archiving capabilities of computer systems.

Natural and man-made calamities such as floods, droughts and forest fires have a big impact on people's lives. Hence, the application of IT in disaster prevention is indispensable.

GIS have become a very useful and important tool to reference and manage natural resources and prevent disasters. In this paper, we would like to introduce a Flood Simulation Engine that can be integrated with a Disaster Map Online System. This engine helps predicting flooded areas and the consequences to people's lives. It is also applicable to similar calamities like forest fires.

2. PROBLEM

Given the information provided by a local vector map showing the topographic grid and other layers: rivers, inhabitants, traffic, plants (Figure 1), the tool will calculate and predict flooded areas as well as damage after the occurrence, with a given amount of discharge and a specified time.

Firure 1. Actual flooded area in Kim Bang district near the Day river basin (drawn manually by local personnel).

3. SOLUTION

3.1. Problem analysis

Let's consider "*v"* as water discharge from the river to land in 1 second, "*t*" as total time of discharge, "*V*" as total water discharged in cubic meters, *H (i, j)* as the topography grid of the local area, so we have: $V = v \cdot t$

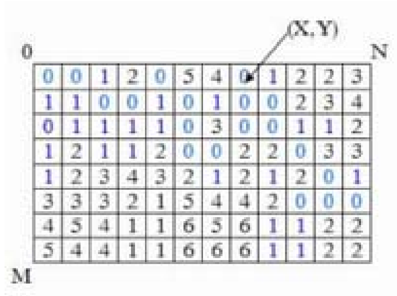

Figure 2. Water spreading trend: water goes to "0 level" cell first, and then higher.

3.2. Problem modeling

Based on the topographic grid, we divide the given area into a rectangle *M* X *N*, each cell represents a small area in real life (ex: 10 X 10 square meters) and contains 2 numbers: its height compared with a standard point (sea level), and its type (river, land or dyke). Consider we are breaking the dyke at position *(X, Y)* with a total discharge volume of *V* cubic meters. So we have two input parameters: *V* and the height grid *H (i, j)*. It is our aim to calculate and output another grid *F (i, j)* representing the water level of the given area.

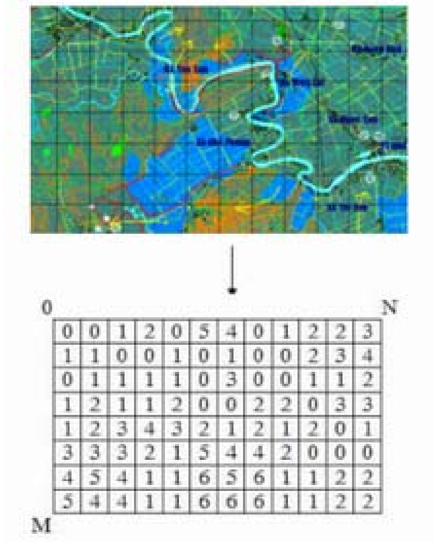

Figure 3. Topographic grid modeling to perform calculations.

3.3. Algorithm idea

To calculate and render the flooded area, we use the spreading technique to mark flooded cells. Depending on the volume of flooded water in each cell, the water will keep trying to spread to 8 other neighboring cells if they are available. The spreading process is stopped only when a balanced state is reached (the absolute height of water in each cell is the same).

A (i, j) = H (I, j) + F (i, j)

Do loop with spreading technique until:

A (1, 1) = A (2, 2) = … = A (M, N) = A0

Where: *(i, j) = a specified cell on the map*

H (i, j) = average height at that cell (compared with Sea level, given as topography grid)

F (i, j) = water level in that cell

A (i, j) = absolute water in that cell (compared with sea level)

A0 = common water level at balanced state

In case of diverging water sperad, because of the high speed and big volume of water over a short period of time, some natural factors of the local area, like: slope and soil absorbency do not affect much the calculation. We do not go into the details of the algorithm in this paper. Please contact the first author for more information.

3.4. Building application

The balanced architecture of the Map Online System is being used, the map server component is Demis Map Server, and the Flood Simulation Engine is integrated inside as a COM component.

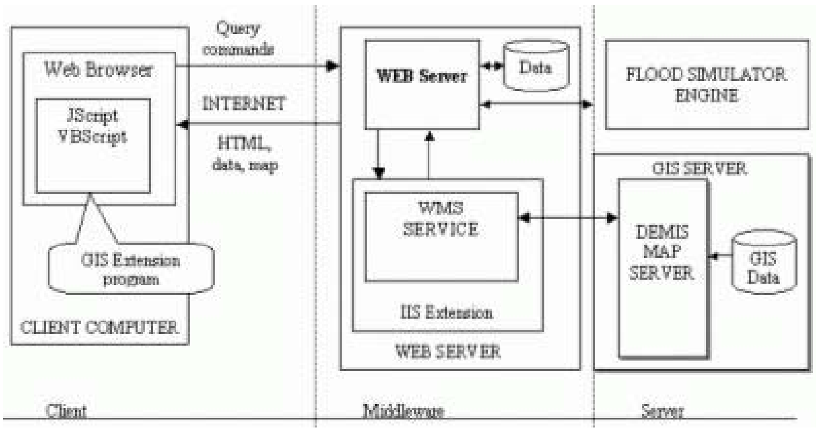

Figure 4. Balanced Architecture of the Map Online System.

The map has 11 layers provided by the Military Institute of Health. Each layer could be switched on and off; the system administrator can add new layers directly on the spot without stopping the map server. Map objects are displayed layer by layer in great detail (even down to each household), each object can belong of one or more layers. This is a useful feature because each object may have different attributes in different locations.

User-friendly features to browse the map are also available: the user can zoom in, zoom out, pin to any point, jump to a specified (longitude/latitude) co-ordinate, and measure the distance between any two points on the map using the tool buttons in the right panel.

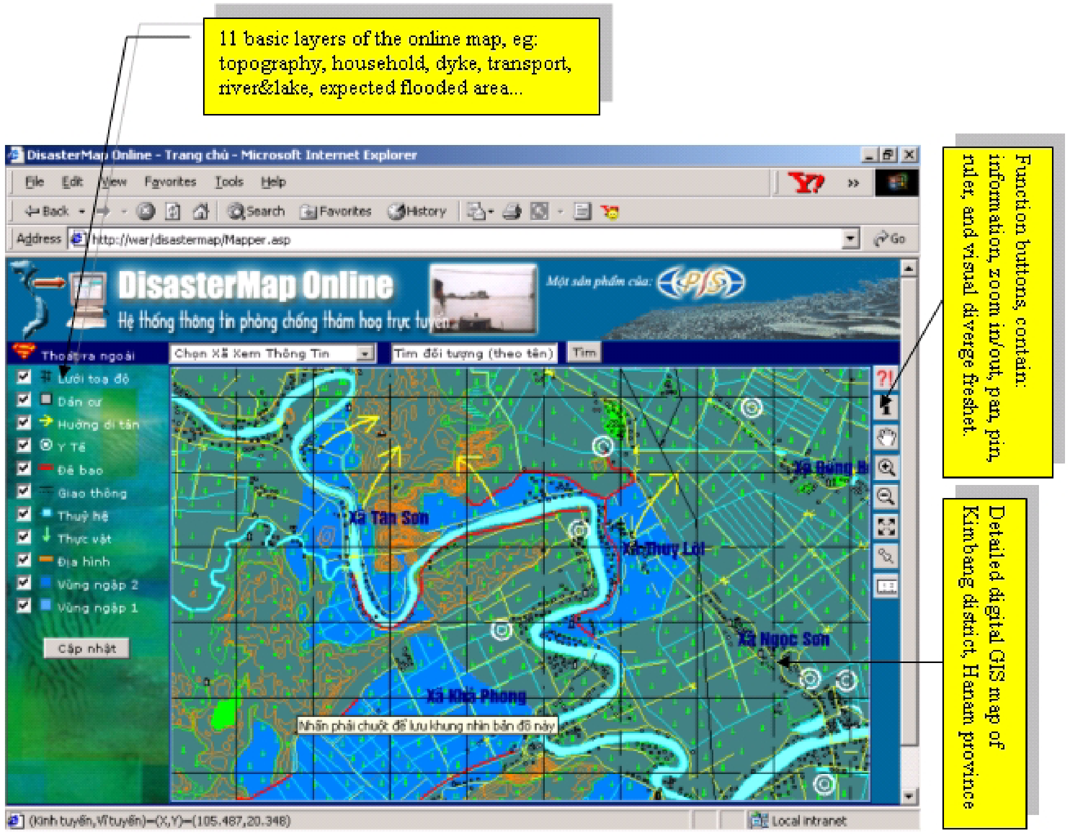

Figure 5. The Disaster Map Online Web-based GIS application presenting the flooded area drawn manually by local personnel.

Users can see and modify information on the Web page or use email to update data remotely using our email-robot technology. The information should be part of the plan of local health authorities, or the characteristic information of a specified location/object that helps in case of flood. The data formats supported are: text/html, pictures, multimedia objects (audio and video). Users can also seek the position of an object visually on the map through a mouse-click.

The searching feature is also very useful in case of calamity. To locate an object (a place, building, household, road, dyke-line, etc.), the user only needs to type its name in the searching function box and then all objects whose names are related to that word will be displayed for selection. The searching keyword tool is available in both English and Vietnamese (Unicode). The advance searching options allow the user to search for additional criteria like: search by location of object, by layer or combination of layers, by object ID, by words in object's information content.

The Flood Simulation Engine was built as a COM application (ActiveX DLL) using the above mentioned idea. This COM object's mission is to receive the height grid and flooding parameters, to calculate, to give out the flooded grid of the area and to recommend the best evacuation direction outside the flooded area following the algorithm mentioned above.

XML is used to exchange data between the host application and the Simulation Engine. The host application does many meaningful things with the results returned. For example, it is able to answer the questions below about a flooded area:

- If Hanoi is in danger, we need to break the dyke at a given position in Kim Bang district for *1.000.000*(m^3) of water to save Hanoi, what is the flooded area and who should be evacuated – show the results visually on the map.
- Where is the safest area to evacuate people?
- How many square meters of crop will be flooded and how many will be lost completely (flooded too deep)? How many houses or kilometers of road will be unusable? This is done by counting the number (in the inhabitant layer) or calculating the total length (in traffic layer) of objects that are covered in the flooded area.

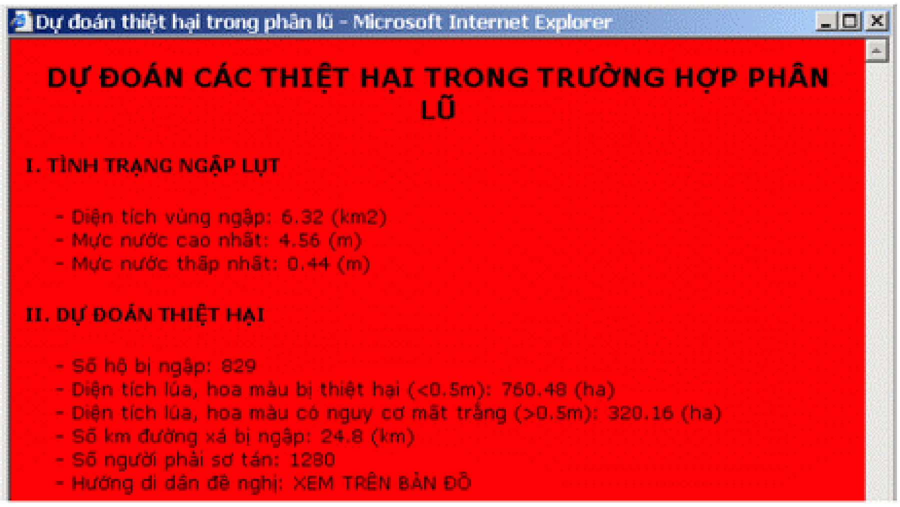

Figure 8: Estimated flood consequences calculated by the integrated system showing the number of houses, length of road, areas of crops…that could be affected.

- If the government orders to release X (m^3) in Kim Bang district, where should I break the dyke so that the above damage is minimized?

Besides, the idea of such a Simulation Engine is applicable to other problems, such as:

- Calculating evacuation routes.
- Modeling areas affected by natural disasters.
- Predicting the spread direction of forest fires.

Currently, our Disaster Map Online has reached its first successes by showing flood information visually on a Web application using Map Server technology. Once this application is completed and applied, its meaning in disaster prevention would be more evident.

4. CONCLUSION

No doubt, flood simulation and modeling is a big and complicated problem. It depends on many different factors with a wide range of possible effects, and the performance is very important to people's lives. Any mistake may lead to unpredictable consequences.

Viet Nam is one of the countries most affected by disaster in the region. Disaster Map Online type of IT application is very useful in helping people to deal with disaster. It does not only assist government personnel in making decisions but also helps citizens in preparing for disaster.

In light of the first successful results of Disaster Map Online, we consider that this important problem has its solution but there is still a long way to go - we need your comments, help and support.

5. REFERENCES

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