GIS Support for Flood Rescue

Gengsheng Liang, Darka Mioc
Department of Geodesy and Geomatics Engineering
University of New Brunswick
Fredericton, Canada
c1g68@unb.ca, dmioc@unb.ca

François Anton
Department of Informatics and Mathematical Modelling
Technical University of Denmark
Lyngby, Denmark
fa@imm.dtu.dk

***Abstract*--Under flood events, the ground traffic is blocked in and around the flooded area due to damages to roads and bridges. The traditional transportation network may not always help people to make a right decision for evacuation. In order to provide dynamic road information needed for flood rescue, we developed an adaptive web-based transportation network application using Oracle technology. Moreover, the geographic relationships between the road network and flood areas are taken into account. The overlay between the road network and flood polygons is computed on the fly. This application allows users to retrieve the shortest and safest route in Fredericton road network during flood event. It enables users to make a timely decision for flood rescue. We are using *Oracle Spatial* to deal with emergency situations that can be applied to other constrained network applications as well.**

Keywords-GIS; flood rescue; Oracle; transportation network

I. INTRODUCTION

Dynamic information on road networks is essential for flood management to make a right decision for rescuing people's lives and properties through transportation networks [1, 2]. Holz [2] states that the information management system includes a wide range of areas. For this project, as shown in Fig. 1, the information on ground rescue focuses on three aspects: *Time, Security, and Distribution*. *Time* is determined by the shortest path, which can be calculated using transportation network. *Security* means that the optimal path can not pass through dangerous areas, such as flooded areas. *Distribution* indicates how quick users obtain information on time and security. These three elements affect each other. If emergency managers or general public can quickly obtain the optimal path, and ensure that this route is safe for vehicles when an emergency occurs, it will enable them to achieve ground rescue. Geographic Information System (GIS) plays an important role in offering information for ground rescue. With the advance of GIS technology, creating transportation networks and performing spatial analyses become available.

However, when a flood disaster comes, it changes the topology of the road network within a GIS, due to damage to roads and bridges by flooding. In spring 1973, the worst flooding occurred along the lower Saint John River in the Fredericton area [3]. At the peak of the flood, basements and ground floors of buildings were flooded, and roads and bridges were damaged (see Fig. 2). Under these conditions, the control of ground traffic in and around flooded areas was a critical problem. In reality, many people know where the refuge shelters are, and how to find the shortest path to their destinations. Nevertheless, under flood situation, they do not know whether their usual path is safe or not since some roads may be flooded. It is dangerous for people to rescue their properties through flooded roads. Therefore, it is important to offer dynamic information on road networks available on the Web and instruction to help people to make the right decision for ground evacuation.

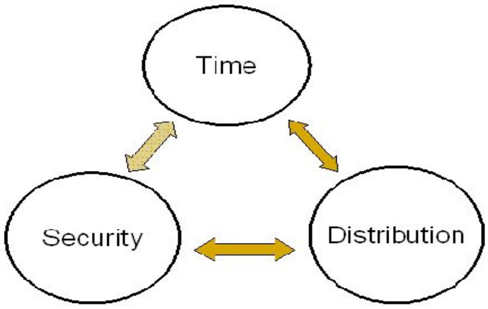

Figure 1. Information on ground rescue.

Figure 2. Roads flooded in Fredericton in 1973.

For dealing with complicated transportation network during flood event, the following aspects should be seriously considered:

- An adaptive road network taking and its relationship with the flood area.
- The Internet connection that allow users to obtain information quickly.

- Availability of the GIS application and the Internet technology.

This project proposes an adaptive Web-based transportation application that enables flood managers and general public to make a right decision for ground rescue during flood events. It is developed using *Oracle Spatial Network Data Model*™ and *Oracle Application Server* 10g (*MapViewer*™*)*. Moreover, the geometry relationships between network and flood areas are considered in this project. By using this application, users not only obtain the optimal path under normal situation through the Internet, but also retrieve the optimal and safest route during flood event. The application can help people make an available and timely decision for ground rescue when a flood comes. Also, the methodology we developed can be applied for other constraint situations.

II. SUPPORT ARCHITECTURE

In order to deal with the information shortcoming on ground rescue during flood events, this research proposes new application architecture (displayed in Fig. 3). It is developed using *Oracle Spatial Network Data Model*, *Oracle MapViewer* as well as spatial analysis between the roads and flood areas. *Oracle Spatial Network Data Model* enables users to build up a topology network in Oracle databases and process a wide range of spatial analyses [4,5,7,10]. *Oracle MapViewer* allows users to deliver and view the spatial data stored in the Oracle database on the Web [4,6,8,9]. Besides these tools, the spatial relationships between road network and flood polygon is taken into account. The overlay between the road network and flood polygons is computed on the fly, and then stored in Oracle database. It allows users to access updated road network during the flood disaster. The flow of application operation is as follows [4]:

- The users construct a Web service request to obtain a map and send request to *MapViewer* Servlet. The request includes choosing a situation, display parameters, and method parameters.
- The *MapViewer* Servlet reads the related map definitions, fetches responding network which have been created in spatial database, processes spatial analyses such as getting the optimal path, generates a map in one format, and constructs an XML response including the URL to the generated map and returns it to the users.
- The users get the response and display it in the browser.

™ *Oracle Spatial Network Data Model and Oracle Application Server 10g (MapViewer)* are registered software products of Oracle Corporation, USA.

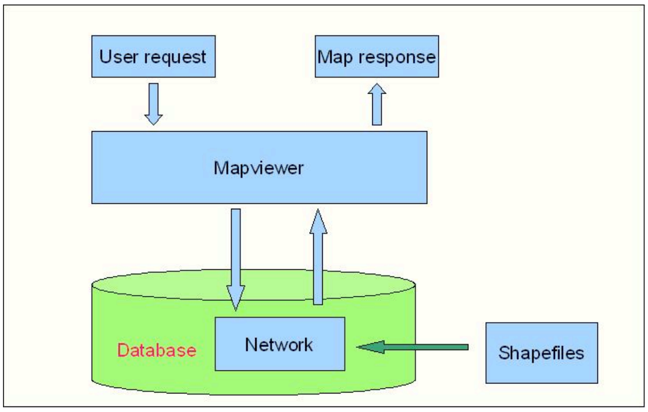

Figure 3. Application architecture.

III. APPLICATION PROCEDURES

This application is implemented using Fredericton datasets of ESRI shapefile format obtained from the City of Fredericton New Brunswick, Canada. It is composed of Fredericton river polygon shapefile, Fredericton road line shapefile, and Fredericton flood polygon shapefile.

The Fredericton flood polygon shapefile is based on the water levels along the Saint John River. The Hydrology Centre in the New Brunswick Department of Environment utilizes a Dynamic Wave Operational Model (DWOPER) to predict water levels for the next 48 hours. We georeference and extend these water levels, and create water surface Triangulated Irregular Network (TIN). Then, we compare the ground surface elevations with water surface TIN in order to obtain the floodplain depth datasets. Calculating the height difference between these datasets, we can automatically obtain the floodplain extent. By using floodplain delineation, the flood polygon can be calculated automatically.

Based on Fredericton datasets and support architecture, we apply the following procedures.

A. Data conversion and validation

First of all, the original data are processed to be used in Oracle database. The processing includes converting data from ESRI shapefile format to Oracle *Spatial* format by using the *shp2sdo* execute file, loading data of the output files into Oracle spatial database by executing Oracle *SQL*Loader*, checking whether data are in valid spatial format by *PL/SQL* functions, and modifying some spatial data by *PL/SQL* functions. All the available data including road, river, and flood shapefiles are converted, validated, and loaded into Oracle database.

B. Road network creation

After data preparation, the second process is to define the network for this project. The road network is based on the road shapefile. According to the requirement of network schema, we use PL/SQL functions to manipulate spatial data in this road table so that both nodes and links tables that are needed by road network can be set up. Then, we define the network metadata, and create the road network (displayed in Fig. 4). Under flood events, the network has to be updated. The node data in the network are not changed, while the values of active attributes in the network links table need to be updated. This is determined by the spatial relationship between links of the network and flood polygons. If links intersect with the flood polygons, the values of the active attribute will be set "N" what means that these links are not active in the network. Otherwise, they are not changed. By applying this procedure, the links table will be updated.

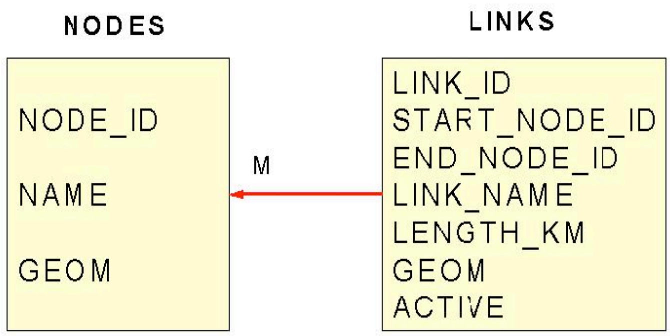

Figure 4. Road Network Model.

C. *Map, theme, and style definition*

Now, the map, themes, and styles about flood and river tables have to be defined. Otherwise, the spatial data of these tables could not be displayed. Each map is associated with a set of themes, while each theme denotes spatial data from a specific table and is associated with a rendering style. By map definition tools, defining map, theme, and style for river and flood the tables become available [4,6] and the network will be defined as dynamic theme.

D. *Application program interface creation*

The most important step of this process is to write JavaServer Page (JSP) programs in order to create a application that allows rich user interactions [4, 5, 6]. In this application, the HTML page consists of the map image, a form that lets users select parameters, and some user actions for zooming and panning. As shown in Fig. 5, the logic processes of this program are listed as below:

- Extract the static and dynamic input parameters from the request object. The static parameters include data source, cx, cy (the coordinates of the centre point), and map size, while dynamic parameters consist of network theme, map, and node label style.
- Process the user actions, such as zoom in, zoom out, and submit.
- Construct a map request according to these parameters and the user actions.
- Send the request to the *MapViewer* Servlet through an HTTP request.
- Process the request, create the response, and extract the URL to the generated map.

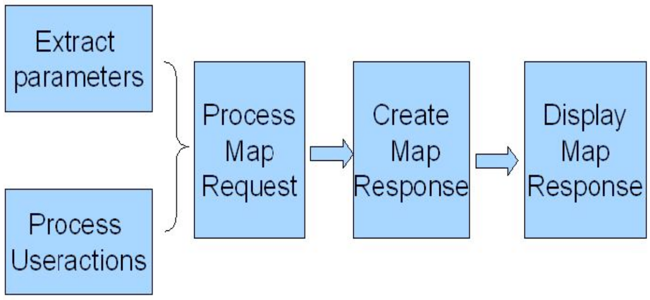

Figure 5. Flow processes of API creation.

IV. RESULTS ANALYSIS

As shown in Fig. 6, users can obtain the base map of Fredericton by this application. The red lines symbolize the road network, and the blue areas represent the Saint John River. Both of them display the geographic information about Fredericton. Moreover, the yellow areas indicate the flood areas. From this map, users can easily find the spatial relationships between road network and flood affected areas. This will help people make a right decision when they want to rescue their properties from flooded areas to safe places.

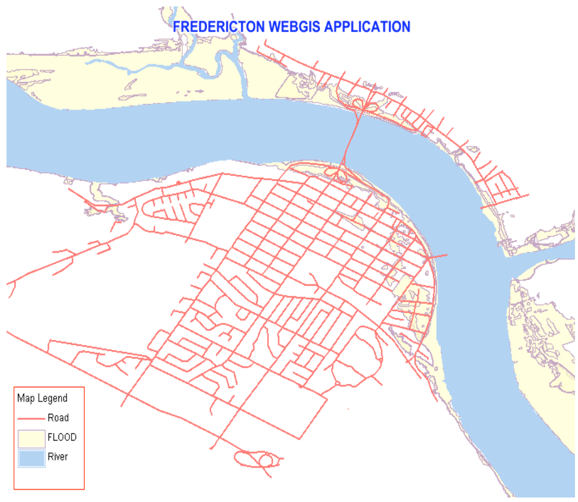

Figure 6. A basic map of this application.

In the application, two different cases were designed and compared. One was to calculate the shortest path under normal situation (see Fig. 7). The second case was to compute the shortest and safe route during flood event (see Fig. 8). Both cases started from the same point A, and ended at the same destination B. Also, users could obtain the results through the web application. As shown in Fig. 7 and Fig. 8, the results displayed that both routes were different although both of them were the shortest paths. The most important aspect was that the route computed during flood event did not pass through the flood areas. If we use the first shortest path for evacuation during flood events, we will find it pass through flood areas F1, F2, and F3. Thus, it indicated that the second path was the safe path for evacuation. With this application, both cases provided timely information for ground rescue under different situations.

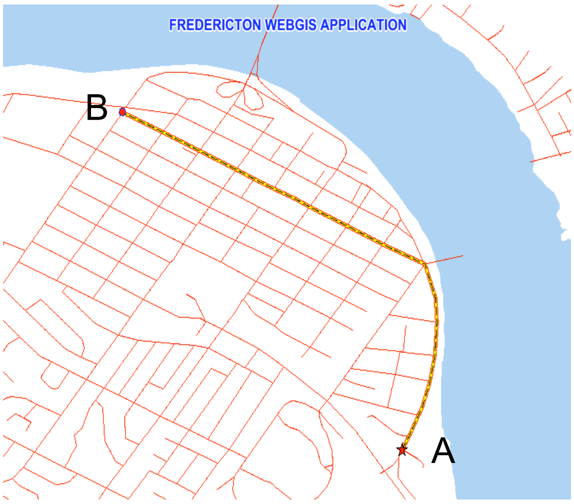

Figure 7. The shortest path under normal situation.

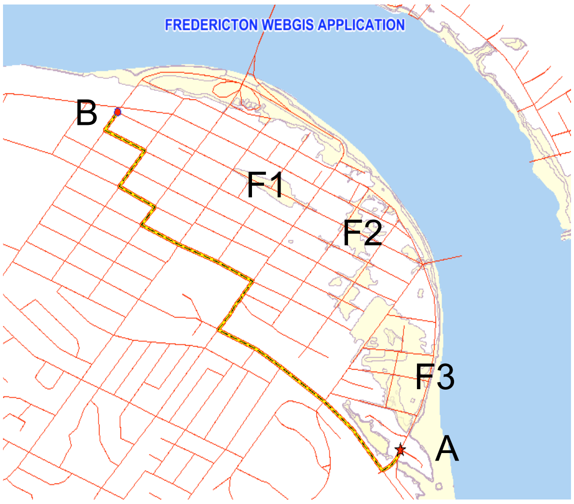

Figure 8. The shortest and safest route under flood event.

V. CONCLUSIONS

During flood events, the topology of transportation networks could be changed since flooding causes damage to roads and bridges. The shortest path that is calculated through normal networks may not be safe due to damage to several roads. Flood managers and general public could not quickly receive the changing information on road networks and flooded area. All of these restrict flood managers and public to quickly process ground rescue. It is necessary for people to obtain the dynamic information on road networks and instructions for ground evacuation during flood events.

In this project, a Web-based application for flood rescue is proposed. The architecture is developed using *Oracle Spatial Network Data Model* with *Oracle application server 10g (MapViewer)*. Moreover, the geographic relationships between the road network and flood areas are considered and integrated in this architecture. The results of our research demonstrate that users retrieve the optimal and safe route via the Website by using this application. This adaptive road network enables users to make an available and timely decision for ground rescue under flood situations.

In the future work, more effort is needed to process other spatial analyses, such as evacuation to emergency shelters and hospitals, allowing users to obtain more benefits from this application. These will help users and emergency planners to make more accurate decisions for evacuation.

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