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A rich Internet application for automated detection of road blockage in post-disaster scenarios

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Abstract. This paper presents the development of a rich Internet application for automated detection of road blockage in post-disaster scenarios using volunteered geographic information from OpenStreetMap street centerlines and airborne light detection and ranging (LiDAR) data. The architecture of the application on the client-side and server-side was described. The major functionality of the application includes shapefile uploading, Web editing for spatial features, road blockage detection, and blockage points downloading. An example from the 2010 Haiti earthquake was included to demonstrate the effectiveness of the application. The results suggest that the prototype application can effectively detect (1) road blockage caused by earthquakes, and (2) some human errors caused by contributors of volunteered geographic information.

1. Introduction

Current research and practice on post-disaster damage assessment using geospatial technologies are mainly based on comparison of pre-event and post-event optical or radar images supported by data from geographic information systems (GIS) [1,2,3]. Besides the intrinsic limitations of optical and radar images (such as lack of accurate elevation data, difficult for automated detection of disaster damage, etc.), the traditional top-down paradigm for geographic information production in government-driven spatial data infrastructures (SDI) cannot meet the near real-time requirements in many post-disaster scenarios. Volunteered geographic information (VGI) involves potentially billions of people in the world to participate in geographic information production, and has received increased attention in recent years [4,5,6,7]. As part of the user-generated contents (UGC) facilitated by Web 2.0 technologies, VGI has the potential to allow public participation in all phases of disaster management, from mitigation and preparedness to response and recovery, at an unprecedented level. Although some VGI has been produced by worldwide volunteers using OpenStreetMap (OSM) following the 2010 Haiti earthquake, no efforts have been reported on integrated application of VGI and LiDAR data for automated detection of road blockage.

This paper presents the development of a rich Internet application (RIA), a Web application with characteristics of desktop application software, for automated detection of road blockage in post-disaster scenarios based on volunteered geographic information and LiDAR data. An example from the 2010 Haiti earthquake is also presented to show the effectiveness of the application.

2. Data Sources

Three data sources are used in this application: (1) OpenStreetMap. OpenStreetMap is an initiative to create and provide free geographic data to anyone [8]. By using an open source tool called ArcGIS Editor for OpenStreetMap [9], street networks can be selected from the XML-format file in OpenStreetMap and converted into a shapefile. (2) LiDAR. The LiDAR data used in this application

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were collected by Rochester Institute of Technology (RIT). The spatial resolution of the digital surface model (DSM) created from LiDAR point data is 1 m by 1m. (3) Basemap. As a prototype application for worldwide road blockage detection service in post-disaster scenarios, this application requires a basemap that has a range of multiresolution maps which are presented as raster images. There are some existing global Web maps, such as Google Earth, Bing Maps, and a basemap from ArcGIS Online. The basemap from ArcGIS Online is used in this prototype application because it is free and can provide very high levels of detail in worldwide populated areas.

3. Architecture

3.1. Logic components

All logic components in this project were deployed on a single machine with Windows 7 Professional operating system, including an Internet Explorer (IE) 8 browser with Silverlight plug-in, a Web Server, a GIS Server, and a Data Server (Figure 1). The machine was configured with a 1.8 GHZ processor and 2GB RAM.

3.2. Client – Silverlight

Silverlight is a free Web-browser plug-in that runs as a standalone runtime on the client and allows scripts from .Net languages to be run in a browser. By integrating with the ArcGIS API for Silverlight, this project created an interactive and expressive Web application leveraging ArcGIS Server resources. These resources were exposed as services by ArcGIS Server and can be accessed by Representational State Transfer (REST) which refers to an architectural style for distributing resources on the Web.

3.3. Server – Arcgis server site

As shown in Figure 1, the ArcGIS Server site is composed of three parts: Web server, GIS server, and data server. The Web server hosts the Web application created by Silverlight and ArcGIS API for Silverlight. The GIS server hosts services from GIS resources and exposes functionalities through ArcObjects components. It is responsible for handling requests issued from the Web server to the GIS web services and managing GIS services which can access to the resources and data stored in the data server. In this application, the data server contains three map documents and an enterprise ArcSDE geodatabase residing in Oracle 11g. Because the services in the GIS server need a geodatabase with features of concurrency and scalability, ArcSDE was selected to offer these capabilities.

This prototype application has four ArcGIS Server services to support functionalities of the Web application – feature service, geometry service, image service, and geoprocessing service. The feature service and the geometry service are for accessing road data and editing features, the image service is for digital surface model (DSM) display, and the geoprocessing service is for road blockage detection.

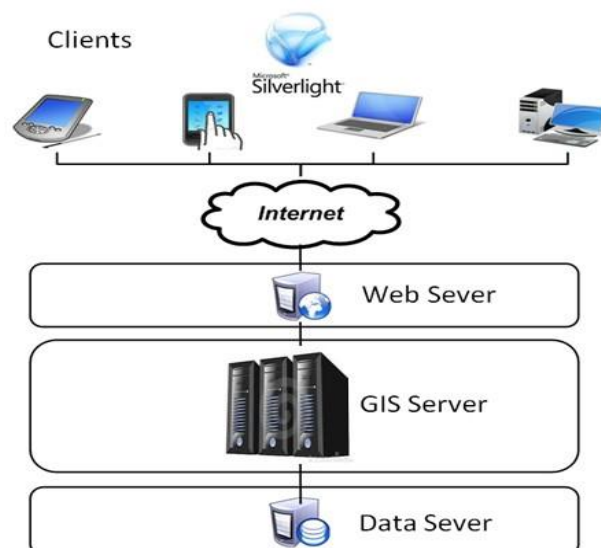


Figure 1. Logic components of the Web application.

4. Functionality

4.1. Shapefile uploading and web editing

At the server-side, a map document containing a polyline layer was set up to be published by the feature service. The source data of the polyline layer is from the ArcSDE geodatabase supporting concurrent editing.

Web editing allows users to modify their uploading data or to create new features to share with others. Based on the feature service and the geometry service, this application uses the Editor Widget which is a set of out-of-the-box controls containing a toolbar and a Template Picker to select the type of feature to add as the default editing interface. Users can add, move, delete, cut, union and reshape features as well as edit street attributes. After that, users can click the Save button to store changes to the geodatabase (Figure 2).

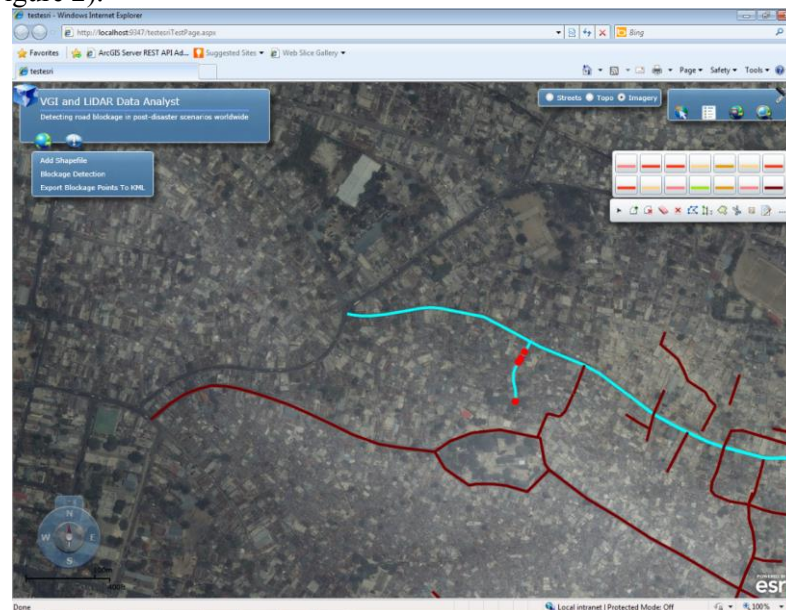


Figure 2. Sample interface the buttons and tools for the prototype application. The basemap (satellite image) is from ArcGIS Online, and a LiDAR digital surface model created by the Rochester Institute of Technology (RIT) is also used as backdrop by setting a transparency level of 50% opacity. Road centerlines are converted from the OpenStreetMap data.

4.2. Road blockage detection

This application has a custom geoprocessing function tool developed using the C# programming language. By embedding specific fine-grained ArcObjects logics within this tool, an algorithm for road blockage detection was implemented. This tool has two input parameters. One is a RasterLayer object for DSM raster data, and the other is a FeatureSet object for street network data. The output parameter of this tool is a FeatureClass object for road blockage points. Figure 3 shows the flowchart for road blockage detection.

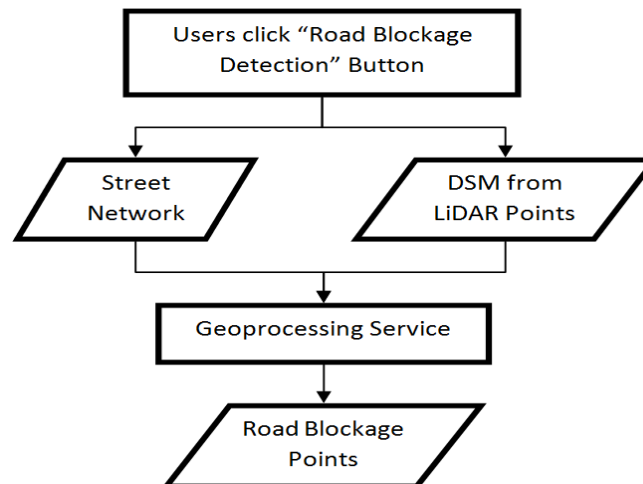


Figure 3. Flowchart for road blockage detection.

Since the details of the algorithm for road blockage detection will be published in a different paper, this section just presents a short overview of this algorithm. Along each street in the DSM, an array of pixel values (elevations) was created by sampling the DSM using 1-meter intervals, which creates a centerline elevation array. At the same time, a baseline elevation array was created along the street as well, which represents the lowest elevation values within a specific buffer of the street centerline. The basic assumption behind this method is that the changes in elevation along a street centerline without any blockage are relatively smooth in normal cases. Based on peak-and-valley analysis along these two arrays, the road blockage points can be detected and false alarms such as vehicles, power lines and bridges can be automatically eliminated in the detection process.

4.3. Blockage points downloading

Detected blockage points can be used to support routing and re-routing in network analysis for disaster response and recovery. By clicking the Export Blockage Points To KML button, the blockage points can be saved as a KML file (packed as KMZ) with geographic WGS84 coordinates. Users can open the KMZ file in Google Earth, or convert the KML file into popular vector formats such as shapefile using existing GIS tools.

5. Application Example

On January 12, 2010, a catastrophic earthquake of magnitude 7.0 Mw hit Haiti. A small area in the capital city Port-au-Prince was used to showcase the prototype application in a post-disaster scenario. The street network data derived from OpenStreetMap were uploaded to the geodatabase and displayed in the Web browser. A digital surface model was created from the LiDAR data collected by the Rochester Institute of Technology (RIT) on January 21, 2012. A high-resolution optical imagery was acquired by RIT, ImageCat Inc, and World Bank on January 20, 2012. Figure 4 shows the road centerlines derived from OpenStreetMap and detected points for road blockage displayed with the LiDAR DSM backdrop. Figure 5 shows the detected points for road blockage on the high-resolution optical image in Google Earth. Based on visual image interpretation using Google Earth and comparison with field data collected by the UNOSAT Program of the United Nations Institute for Teaching and Research [10], the detected points for road blockage are very accurate, although a statistical summary was not produced due to the limited number of samples. Interestingly, the point in the upper-left corner of Figure 4 and Figure 5 is not a road blockage caused by the earthquake, but a point on the wall separating the highway and the community. Contributors of OpenStreetMap data mistakenly connected the street in the community to the highway without noticing the wall. This example suggests that the prototype application is very effective in detecting (1) road blockage caused by earthquakes, and (2) some human errors in volunteered geographic information.

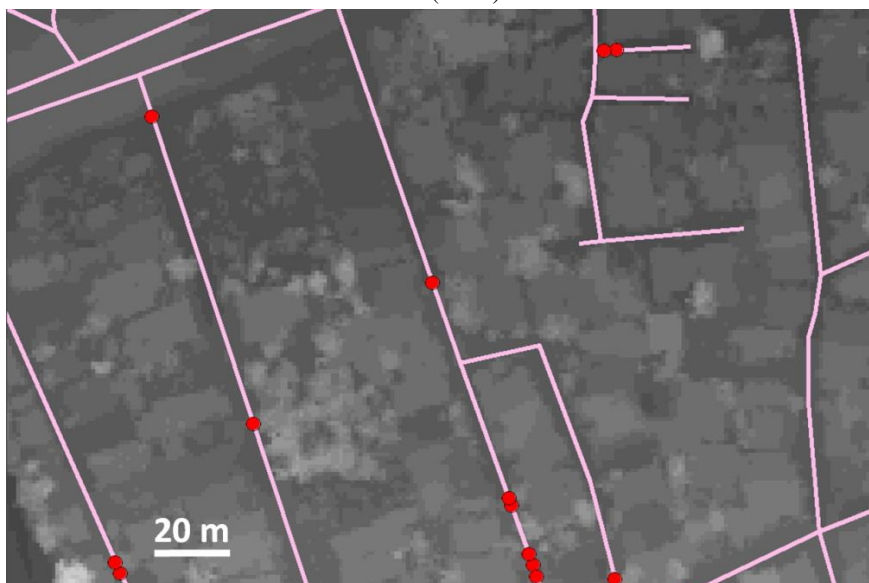


Figure 4. Road centerlines derived from OpenStreetMap and detected points for road blockage displayed with the LiDAR DEM backdrop. The LiDAR data were collected by the Rochester Institute of Technology (RIT) on January 21, 2012.



Figure 5. Detected points for road blockage on the high-resolution optical image in Google Earth. The imagery was acquired by RIT, ImageCat Inc, and World Bank on January 20, 2012.

6. Conclusion

This paper presented a prototype application system for detecting road blockage using volunteered geographic information and LiDAR data. The architecture and functionality of the system were introduced, and an example from the 2010 Haiti earthquake demonstrated. The results suggest that the prototype application can effectively detect (1) road blockage caused by earthquakes, and (2) some human errors caused by contributors of volunteered geographic information. Since rapid routing and re-routing operations over a road network are very important in disaster response and recovery, this prototype application has great potential to support emergency management in post-disaster scenarios.

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