Geo-enabled FOSS Tool supports for immediate flood disaster response planning

Kasun Ramanayake, Dilma Vithanage, Nisansala Hettiarachchi, Givanthika Rathnayake, Samantha Rajapaksha, Nimalika Fernando
Faculty of Computing, Sri Lanka Institute of Information Technology
Malabe, Sri Lanka
kasun.ramanayake@gmail.com, dilvithanage@gmail.com, nmadhuma@gmail.com, givanthikajayamini@gmail.com, samantha.r@sliit.lk, nimalika.f@slit.lk

Abstract—Flood is a major natural hazard occur recurrently in Sri Lanka. Allocating victims to camps and provide medical facilities are two main activities at the immediate response phase of a flood and use of manual methods delayed this process. This project developed a geo-enabled application to support immediate response planning, mainly focusing on allocation victims to IDP camps, provide medical facilities, and supporting access avoiding already blocked roads based on administrative divisions of the affected area. Capacities and facilities in camps and hospitals are matched against the needs of the victims. It identifies the blocked roads, alternative routes to reach resource centers, camps and hospitals and provide navigation guidance. The tool can be used after a flood disaster, assuming basic demographic data and the current flood affected area data are available. The tool is developed as a plug-in for QGIS, a free and open source desktop Geographic Information System software. The tool is verified with sample data related to “Kaluthara” area. It is intended to integrate with InaSAFE disaster response support tool at a later stage.

Keywords—Disaster Response; Flood; FOSS; QGIS; Network Analysis; Health Impact; IDP

I. INTRODUCTION
Flood is one of the most common forms of disaster affecting Sri Lanka and almost half of the population affected by any natural disaster, except Tsunami, is flood victims [1]. The number of people affected by floods reached over 120 000 in June 2014[2]. It is common that cities and populated areas nearby some river basin get affected by recurring floods annually, such as Kalutara, Rathnapura, and Ampara [3].

Floods can results in loss of lives, displacement of people, destruction of infrastructure such as houses, road and telecommunication, affect livelihood and spread of water-borne diseases. Identification of the impact of a flood on different domains is helpful for planning and execution of the recovery process in an organized manner [4]. The recovery process will be handled by a government authority and all planning and the fund allocation will be done based on administrative divisions. Therefore, even though a flood would affect areas covering several administrative divisions, quantifying the impact based on administrative divisions is essential to allocate resources.

Spatial data analysis is useful in impact analysis, considering the flood data and other demographics data as inputs. Such an approach would easily quantify the impact based on administrative divisions of different levels.

The proposed tool, which aims to use by authorities supporting disaster management, integrate the specific requirements of a flood response planning to an already available geographical information system (GIS). It is developed considering the workflow of a main authority responsible for a assisting soon after a flood disaster. It provides facilities to (a) identify possible places for Internally Displace People (IDP)’s camps nearby to flood affected area (b) allocate the IDP to camps based on facilities available on them (c) identify hospitals and other medical establishments nearby the flood affected area with facilities available there (d) identify affected and non-affected roads within the flood affected area and thereby finding alternative routes connecting resource centers (e) calculate medical drug requirements considering water-borne diseases. The tool assumes the basic demographic data such as population, road network and building data are already available. Flood distribution data needs to be input as and when a flood is occurred. It provides the analysis results as digital maps and text reports.

The system is developed as a plug-in for non-proprietary desktop GIS software, Quantum GIS [5]. At a later stage, it is aimed at linking with InaSAFE [6] QGIS plugin, which supports needs assessments after a natural disaster. All analysis will be done for a given geographical area, selected by the user. The tool is tested with the past flood data related to Kaluthara and Rathnapura districts of Sri Lanka, which are affected by floods in “Kalu Ganga” river and data of Jakarta area of Indonesia. Flood prediction or flood area mapping is not considered in this study.

II. BACKGROUND
Disaster management cycle consists of four overlapping stages namely Mitigation, Preparedness, Response and Recovery and the use of ICT is more important in Response
phase than others where main concern is in supporting affected population [7][8]. The proposed tool is useful in the Response and Recovery phases. The geographic information systems are highly useful in disaster management cycle due to their geo-visualization and analyzing capabilities [9]. However, development of geospatial software application requires much time and money in design and development [10]. Use of already available GIS tools and use of adoptive cartography where information needs to be adjusted as per the user requirements in very quick time are possible two approaches to integrate GIS capabilities in disaster management process. In this work, an existing software I used as the basis and required functionality is integrated to it.

Different aspects of the disaster response and recovery phases are supported by many pre-designed location/disaster independent or dependent software tools. Sahana [11] is a key software tool supporting post-disaster response and recovery phases. Its main functionalities include linking different organizations, project tracking, maintaining missing people registry, asset management and message distribution. It aims at rapid deployment soon after a disaster and successfully delayed at different disaster situations. GeoServNet [12] is a simulation and 3D visualization tool aimed at providing emergency response support in an Earthquake situation. Both these systems make use of GIS to enhance their services. The functionalities provided by the proposed tool are not covered by the Sahana or GeoServNet projects.

InaSAFE [6] is a closely relating project with the proposed tool. It is a plugin developed for QGIS software. It is initially developed by the Indonesia's National Disaster Management Agency (BNPB) and the Australian Government with the support of World Bank. As described in the user guide, InaSAFE takes a hazard layer (such as ground shaking, water depth or ash load) and an exposure layer (such as population density) and combine them according to an impact function to produce an impact layer and a report. The exposure layers can be population ( raster data) or structures (point or polygon data) [6]. The analysis model used by InaSAFE is followed by the proposed tool also.

III. Proposed system

Some important areas not covered by InaSAFE are considered in the proposed tool. The three key areas supported by the proposed tool are (1) Identification of medical facilities and possible places for IDP camps, which are nearby to flood affected area with capacities and other information (2) Analyze the impact of flood on road network, which provide the access to villages, IDP camps and nearby hospitals (3) Identification of health impact of the flood such as water-borne diseases with drugs requirements. These areas are not covered by the InaSAFE tool.

By following the InaSAFE, the development of the proposed tool is done based on GIS analysis technique of finding impact of hazard on exposure layers. In the proposed system the hazard is a flood and the exposure layers are population, resource centers, hospitals, administrative divisions of different levels and road network.

A simple GUI is provided to handle these functionalities as the tool is aimed at used by a disaster response officer with entry level GIS knowledge. Instead of designing a full GIS enabled system from the beginning, the required tools are implemented as a plug-in for existing, well accepted Free and Open-Source (FOSS) GIS software, QGIS. Therefore all the common GIS functionalities of the said software can be used by the tool directly. QGIS provides a programming environment to develop plugins based on QT framework and Python as a scripting language and they are used for the development of the tool.

The key functionality of the system is the identification of population centers, which have limited road accessibility due to flood water and finding alternative routes available to reach affected locations. It will help to allocate flood victims to possible IDP camps, which are not affected by the flood and based on available facilities and capacities.

IV. METHODOLOGY

A. Functionality of the proposed system

The major functionalities of the proposed tool are impact calculation process using impact function, finding alternative roots, analysis of health risks and report generation based on the results. Fig.1 shows the in-detail structure of overall workflow of the system. The functionality of input, process and result stages are explained below.

1) Inputs : (a) Exposure layers such as population data, road network data, buildings and (b) Hazard layer, the flood affected area data are the two types of data input to the system. These data is expected to be in .shp file format.

2) Processes :

a) Finding resource centers: This process will identify resource centers affected and non-affected by the flood, possible IDP camps locations with their attributes. User can decide what type of resource centers are to be searched (ex: IDP camps, hospitals, pharmacies), what types of places (ex: schools, temples) can be used as IDP camps and in which distance range the (ex: 10 km from the location selected on the map) the searching should occur.

b) Finding impact on roads : This process will identify roads affected and non-affected by flood and the alternative paths from selected places to required destination avoiding flood. Step by step navigation guide is provided for the selected path. Blocked roads details categorized by Administrative Divisions of examined area is also provided with summary charts.

c) Identification of Health risks : This process finds water sources affected by flood, so that the municipal councils can take immediate actions to reduce the risk of infections of water-borne diseases. Since there is a high possibility of rising up the epidemic diseases such as malaria,
leptospirosis, measles, cholera and dengue with flood [13], the plugin estimates approximate amount of medicines needed for these diseases with the budget. As a supporting function for this, affected population under different age groups and families will be also identified by the tool.

3) Outputs: The outputs are generated as digital maps and reports, which can be used for printing and summary reports such as hospitals in non-affected nearby area with capacity and other information. All results can be categorized based on the administrative divisions of the selected area.

B. Software Architecture of the proposed system

The software architecture of the system with link to QGIS is shown in Fig.2. The plug-in consists of four main components, three of them are related to three processes described in section A above and another component handling the report generation.

V. IMPLEMENTATION

A. Technology selection

The software toolkits and platforms used to develop the plugin are as follows. All tools are free and open source and thereby the software purchase cost becomes zero.

- Ubuntu Desktop version 13.10
- QGIS version 2.2 Valmiera
- Plugin Builder version 2.0.3 for QGIS
- Qt Design.

B. Use of QGIS Geo-Processing Tools

To generate the flood-safe layers (non-impact) and impact layers, different functions of ‘QGIS Geo-Processing Tools’ are used. For example, ‘difference’ function is used to generate new shapefiles of non-overlapping areas from the original features (ex: areas, which are not affected). The user can do the new layer generation process in a single click, by identifying the types of layers loaded, and examining the ‘keywords’ file attached with each layer bundle. In the absence of a ‘keywords’ file, the generation process can be done manually in few steps, as guided in the GUI of the plugin.

C. Finding of flood affected roads and safe roads

When finding the best possible path between two selected locations in the alternative route identification component, the ‘Dijkstra’s algorithm’ is used, which is provided by the ‘Network Analysis Library’ of the QGIS. The library creates a graph from geographical data (polyline vector layers) and implements Dijkstra’s algorithm based on basic method of
the graph theory. The sample code segment for best path finding is shown below.

```python
vl=self.canvas.currentLayer()
director = QgsLineVectorLayerDirector( vl, -1, "", ",", 3 )
properter = QgsDistanceArcProperter()
director.addProperter( properter )
crs =
self.canvas.mapRenderer().destinationCrs()
builder = QgsGraphBuilder( crs )
pStart = QgsPoint( x1, y1 )
pStop = QgsPoint( x2, y2 )
tiedPoints = director.makeGraph( builder, [ pStart, pStop ] )
graph = builder.graph()
tStart = tiedPoints[ 0 ]
tStop = tiedPoints[ 1 ]
idStart = graph.findVertex( tStart )
idStop = graph.findVertex( tStop )
( tree, cost ) = QgsGraphAnalyzer.dijkstra( graph, idStart, 0 )
```

The plugin provides the directions for travel in simplified steps, for example ‘Continue on Kalutara-Horana Road 1.5 km’ and ‘Turn left onto Galle Road’ etc. It also provides the direction information before the flood disaster has been occurred. Thereby plugin gives an idea of the extra time and distance user has to travel more.

In order to perform these operations, the distances and lengths between each connected point in the identified shortest path (and add them together to get the total distance) needs to be identified. The Haversine formula is used for this purpose. It is an equation important in navigation, giving great-circle distances between two points on a sphere from their longitudes and latitudes [14]. As a proof of the results generated, the same start and destination locations were given and checked in ‘Google maps’ and compared its results with the plugin results, which was given very close or exactly the same outputs. The sample comparison is shown in Table 1.

<table>
<thead>
<tr>
<th>Start &amp; Stop locations</th>
<th>Distance (km)</th>
<th>&quot;FLOOgin&quot; plug-in</th>
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</thead>
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<tr>
<td></td>
<td>Google Maps</td>
<td></td>
</tr>
<tr>
<td>Start : Molligoda</td>
<td>21.5 km</td>
<td>21.503 km</td>
</tr>
<tr>
<td>Pirivena, Stop :</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Olahoduwa Purana</td>
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TABLE 1: COMPARISON OF DISTANCE CALCULATION WITH GOOGLE MAPS

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VI. RESULTS

Fig 3 shows the interface for generating the flood-safe layer in the developed tool. Fig. 4 and Fig.5 provide sample outputs of the system showing finding of an alternative route with Kaluthara area data and the details of alternative route with direction information respectively. Fig. 6 and Fig.7 provide sample outputs of the system showing finding of an alternative route with Jakarta-Indonesia data and the direction information. Fig.8 provides sample output of the system showing the blocked roads details. Fig. 9 provides a section of a report with the blocked roads details.
Fig. 3. Generating flood-safe layer

Fig. 4. Finding alternative route

Fig. 5. Details of alternative route, direction information

Fig. 6. Alternative route identification with Jakarta dataset

Fig. 7. Direction information – Jakarta dataset

Fig. 8. View blocked roads details
This plug-in provide support to identify impact on road networks after a flood situation, which is an essential information for evacuation planning and delivery of humanitarian aids to victims. Additionally it provides health impact assessment support. The tool can work with spatial data in any coordinate reference system and it would assist in using the system in different geographical regions with available data. The tool makes use of point, polygon and line data in its calculations and provides successful results with acceptable response time. The availability of up-to-date basic demographic data such as population, administrative boundaries and the building locations are important to the successful use of the tool.

Being a FOSS tool is a main advantage of the plug-in. Anyone is freely licensed to use, copy, study and improve it. Since QGIS runs on Linux, UNIX, Mac OSX, Windows and Android operating systems, it is possible to use the proposed tool also in any of the above platforms.

VIII. CONCLUSION AND FUTURE DIRECTIONS

The research developed a fully automated Free and Open Source tool or a plugin for QGIS (Quantum Geographic Information System) software, which helps to response immediately when a flooding disaster strikes and aims to produce a realistic natural hazard impact scenarios for better planning and response activities using hazard and exposure geographic data.

The main improvement to the tool will be to enhance the health risk assessment functionality with prediction of affected population with different diseases with the gender and other available health data of the population. In the long run it is expected to integrate with the InaSAFE plug-in, so that the users who are already familiar with the InaSAFE can easily adopt the additional functions provided by “FLOOgin” tool.

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REFERENCES


