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AIWEST-DR 2018

IOP Conf. Series: Earth and Environmental Science **273** (2019) 012051

IOP Publishing

doi:10.1088/1755-1315/273/1/012051

WEBGIS Application for Planning the Tsunami Evacuation Route

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Abstract. The tsunami that occurred on December 26, 2004 has resulted in massive casualties in Banda Aceh City. As one of the steps to avoid the huge casualty if the tsunami repeats itself, a number of Escape Buildings have been built in the city. In spite of the availability of the Tsunami Escape Buildings, the number of casualties can be reduced only if everyone in the tsunami-prone areas knows the nearest Escape Building from his or her position and the best route to reach the building. The purpose of this research was to build a GIS web application that can help determine the nearest Escape Building from a user-selected location and the best route to reach it. This application utilizes a web service that implements the Dijkstra algorithm to find the closest facility and the best route to the facility. The web GIS application was built using the open source API. The web GIS application developed in this research helps users find the nearest Escape Building and the best route to reach it without the need of any GIS software. The application is easy to use because it provides a user-friendly interface via a web browser.

1. Introduction

The earthquake and tsunami disaster which occurred in Aceh on 26 December 2004 took a large number of casualties, especially in the city of Banda Aceh and surrounding areas. Many people were killed, missing or injured when the tsunami wave hit the city because they had not reached safe places before the wave inundated the city. After this earthquake and tsunami disaster, several countries in the world provided assistance to the Indonesian government to rebuild Aceh. One form of this assistance was the construction of escape buildings by Japanese government. The escape buildings are intended to be places for evacuation whenever the earthquake and tsunami disaster threatens the safety of citizens again. The escape buildings were constructed in 4 villages, namely Ulee Lheue, Lambung, Deah Geulumpang, and Alue Deah Teungoh Village.

Finding the route to an escape building may be easy for people living in each village where the building is located, but that might not be the case for other people. Since the escape buildings are located in separate locations, anyone who happens to be around Ulee Lheue, Lambung, Deah Geulumpang, and Alue Deah Teungoh village when a tsunami alert is issued has to decide to which escape building he or she must go. The person must go to the nearest escape building from his or her current location and use the fastest route to reach the building. This is not easy for someone who is not

familiar with the area, so an application or a tool which can help people find the closest escape building and the route to reach it from their location is necessary.

A web-based Geographic Information System (GIS), or commonly known as Web GIS, can be a solution to the above problem. Web GIS is a system that consists of servers that provide geographic data access to clients or commonly referred to as Web GIS applications [1]. GIS and Dijkstra's shortest path algorithm were used, for example, by Inoguchi *et. al.* who develop a Web-based supporting application for individual evacuation plans [11]. Their application let a user choose a starting location, and then, pick the first and the second evacuation places. The application showed the shortest path to reach the first and the second evacuation places. Another application, which was developed by Schuster and Gomez, allowed a user to calculate an escape route out of a location within a hazard zone at the touch of a button [12]. The web GIS application prototype described in this paper is different from those applications. The user only needs to let the application to detect his or her location, and then it will find the nearest escape building and the shortest route to reach it from the location of the user. The location of user, the closest escape building and the shortest route is displayed on a digital map. The application was developed to help people evacuate to the nearest escape building.

2.   Methods

1.1. Data
The data needed in developing the web-based GIS application were road geospatial data and coordinates of escape building location. The coordinates data were converted into point data which show location of escape buildings on the digital map. The road data were used to generate road vertex point data which define the road network of Banda Aceh. This road network data are the most important data for the application because the nearest escape building and the shortest route to the building data are determined based on the road network data.

1.2. System Architecture
The Web GIS application was built as a client-server application as shown in Figure 1. The system architecture of the developed Web GIS application was a modification of the common Web GIS system architecture. As a distributed information system, a Web GIS commonly consists of a Web Application Server as the server and a Web Browser as the client [4]. The Server-side system of the developed Web GIS has three components, namely a Web Server, a GIS Server, and a DBMS. The Web Server receives a request from clients and sends the response in form of web pages which contains an online map. The web server uses the online map from the OpenStreetMap as the base map for the Web GIS application. The OpenStreetMap, which was launched on 2004, hosts a free editable map database of the world [5]. The local GIS Server retrieves the geospatial data of escape buildings and the shortest route from the Database Management System (DBMS) and publishes them as Web Map Services (WMS), which is the most widely adopted and popular specification for geospatial data exchange. This specification allows a GIS Server to provide compiled map images which may contain both vector and raster data [6]. The images can be in the form of PNG, JPEG, and GIF. Web Server consumes the service and adds the escape buildings along with the route geospatial data to the base map to produce the requested online map.
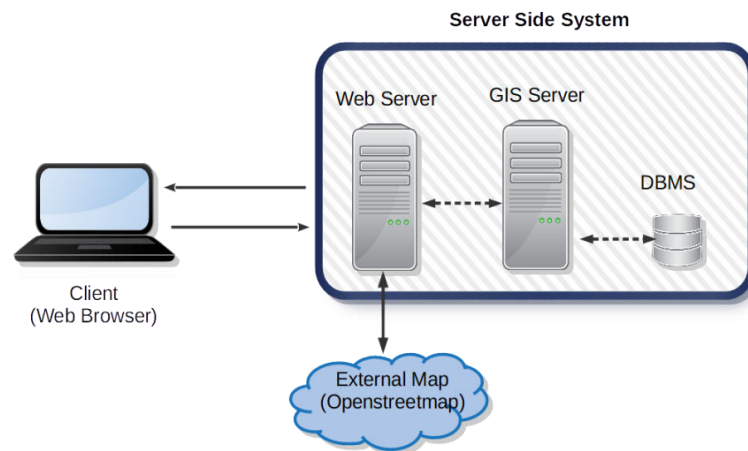
Figure 1. The architecture of the Web application

1.3. Web GIS Development

The online map display of the Web GIS application as created using the OpenLayer API. OpenLayer is a Javascript library for requesting and visualizing geospatial data via the Internet, especially the vector or raster data which have been published as WMS [7]. Every time the client will move to a different area or enlarge an area on the map, the client will give a new request to the web server [8]. The Web GIS application used Geoserver as the GIS Server which published geospatial data for web map applications. The Geoserver uses geospatial data of the type vector and provides Web Map Service (WMS) [9].

The WMS service acts as a media link between the Web Server and the Geoserver which functions as the GIS Server. A web browser sends a pair of location coordinates to the web server, which passes it to the geoserver via the WMS service. The geoserver then executes some previously built functions to calculate the distance to each escape building from the location determined by the coordinate pair and to find the minimum of the calculated distances. Output of these functions are location of the nearest escape building and the shortest route to reach it. These outputs are sent by the Geoserver via the published WMS, and the Web Server consumed the WMS to generate a map which is sent to the client later.

The functions which are used for finding the nearest escape building and the shortest routes were built using the PL/pgSQL script from the PostGIS and pgRouting library, which was installed as an extension of the PostgreSQL Database Management System (DBMS). PostgreSQL is an open source database that is licensed by BSD. This DBMS has a PL/pgSQL procedural language that makes it easy to develop functions for running SQL commands on the database [10]. PostgreSQL can also process spatial data through PostGIS. PostGIS is a geographical extension of the PostgreSQL database, which can store geographic data as tables in the database as well as process the complex geographic data and visually explore them [11]. pgRouting is an additional function library in PostgreSQL/PostGIS which provides some functions for checking the structure of a road network to find the shortest path to the destination [12].

3.   Results and Discussion

The Web GIS application for planning tsunami evacuation routes have a simple Graphical User Interface (GUI) as shown in Figure 2. The GUI consists of a map of Banda Aceh City which shows streets and buildings in the city and three buttons for finding and displaying the shortest route to the nearest escape building. The map also shows several special icon markers which mark the location of 4 escape buildings in the city. Users can zoom in / out by clicking the plus ('+') and minus ('-') near the top left corner of the map to get the detail or broad view of the area.

Each of the three buttons below the map has different function. If a user wants to find the closest escape building from his or her current location, the user has to click the "Locate Me" button to acquire the coordinate pair of his or her current location. After that, the user can click the "Show Route" button. When the "Show Route" button is clicked, the client web browser will send the location coordinate to the server. The server will use the coordinate for finding the closest escape building and its shortest route from the location of the user. The shortest route will be sent by the server to the client as a WMS. The client web browser will overlay the route on the base map and show it in the map. Figure 2 show the shortest route to the nearest escape building as a dark line on the map. The user can clear the point location and the route by clicking the "Clear" button.

The Web GIS application as tested for several user's locations, and the application was able to show the nearest escape building dan the shortest route to the building from the tested user's locations. Since the escape building are concentrated in the Meuraxa District at present, the Web GIS application can only be used within the district. The result will not be logical if the application is used in other area because it will direct the user to an escape building in the Meuraxa District although the building is actually far from the location of the user. Actually, the result is an indication that escape buildings are needed in other parts of Banda Aceh city which are located near the coast.
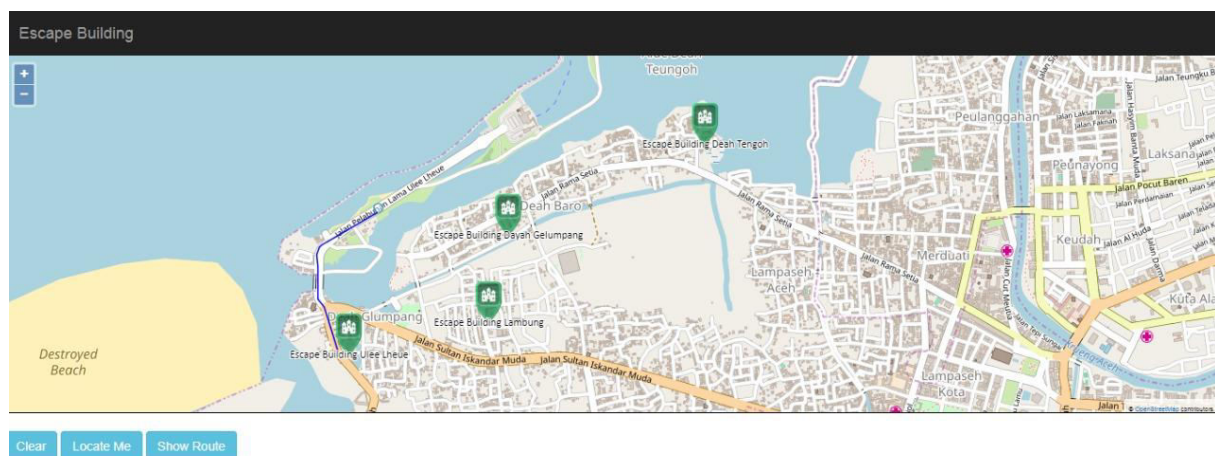

Figure 2. The Graphical User Interface (GUI) of the Web application

4.   Conclusions
Based on the results of research, it can be concluded that a WebGIS application for planning the tsunami evacuation route can be built by using the OpenLayer API to display online map, Geosever as a server to provide Web Map Service (WMS), and PL/pgSQL scripts based on the PostGIS and pgRouting library as functions which were used for finding the nearest escape building and the shortest routes. In order for the WebGIS application to function effectively, information on more places than can be used as a temporary place for tsunami evacuation is needed. The places can be either new escape buildings or other tall buildings which are suitable or the tsunami evacuation.

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