Tsunami evacuation Geographic Information System (GIS) education as disaster mitigation

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Abstract. Padang City is the largest city on west coast of Sumatra and capital city of West Sumatra, Indonesia where it directly adjacent to Indian Ocean. Because of its position, the people are shadowed by fear and felt threatened when earthquake occurred. If earthquakes and tsunamis ever happened, the people need information of safe zone that in reach to evacuate their families and their own self. If someday the calamity happened, with proper education system the society will be able to anticipate the occurring events. Researcher create a Geographic Information System (GIS) with A-Star algorithm method. A-Star Algorithm using nearest distance available to reach destination and have heuristic value for consideration. In this system include alternative route, total capacity, and distance to the selected shelter. In this research, researcher using descriptive method to collect data, evacuation route, and tsunami shelter around Purus, Padang. With this system the people are expected to have sufficient information about tsunami evacuation route as means to minimalized casualties.

1. Introduction

Padang City is one of the areas that is prone to earthquakes and tsunamis. The Government has made a number of evacuation points or shelter for Padang residents. But there are still some residents of Padang, both native and migrants who still do not know where to escape when the disaster occurred, including the people of Padang Barat sub-district which is the closest area to the coast and has a dense population. Based on data in Kota Padang dalam Angka [1] that the population in the Padang Barat sub-district in 2017 amounted to 46,010 inhabitants. Earthquake followed by a tsunami that engulf a number of coastal areas in Nanggroe Aceh Darussalam (NAD) and North Sumatra, on Sunday morning several years ago (12/26/2004) shows that Indonesia is prone to Tsunamis [2]. Based on the meeting of earthquake and tsunami experts (Team 9) some time ago, there’s a potential megathrust earthquake that might happened Siberut Island, Mentawai, with power up to 8.9 Richter. This earthquake might trigger a devastating tsunami with wave height more than six meters [3]. According to an expert from Earth Observatory of Singapore who has long been researching the Mentawai region with LIPI, Professor Kerry Edward Sieh, from the large earthquake data in Mentawai in 1797 and 1833 they obtained, it turned out that almost all of the megathrust (reverse fault) between South Pagai Island to Batu Island has never been broken since 1797 or even one hundred years before [4]. Author took an interest in this matter and used A-Star Algorithm with web-based GIS. A-Star Algorithm used nearest estimation route to reach goal and have heuristic value that can be used for consideration. GIS also used for Geographical Information Science or Geospatial Information Studies which is the study.
related to Geographic Information System [5]. A-star algorithm examined how to find shortest path finding route with obstacle. [6]. Basic ability of GIS is to integrate various database operations such as queries, analyze them and display them in the form of mapping based on their geographical location. This is what distinguishes GIS from other information systems [7,8]. In this day, GIS Mobile Application has a lot of activities using Global Positioning System (GPS) and GIS software to do mapping in real time [9,10]. Application of A-Star Algorithm has been carried out in previous studies with different kind of variables. Kurniawan (2016) using A-Star Algorithm as a solution to finding the best route of a maze, where the result obtained from Algorithm A* could find the shortest route that might be passed from the start node to the goal node [11]. In this system there are alternative routes and showed the amount of capacity and distance to selected shelter. The system also features emergency contact information such as firefighter, Badan Penanggulangan Bencana Daerah/BPBD (Regional Disaster Management Agency), and police stations as well as the latest earthquake-related information. With this education system, if the disaster occurs, the community is ready to anticipate the situation at that time.

2. Methodology
Researcher used descriptive method to collect data, evacuation route, and tsunami shelter around Purus area, Padang City. Researcher conducted the data collecting by direct observation with the community and related agencies. Analytical tools used is UML (flow chart) to represent the algorithm or other procedure to solve a problem graphically. Application uses PHP programming language with MySQL database by applying A-Star Algorithm. A-Star Algorithm is a path-finding algorithm used to find optimal path that connect two points on the map (graph) from given variables. A-Star Algorithm is suitable for an environment with multiple routes available [12,13].

3. Results and discussions
3.1 Analysis of ongoing system
Stages needed in making a program is analyzing an existing system. Analysis of the running system aims to find out more clearly how a system works and know the problems faced by the system to be used as a basis of a new system design.

3.2 Ongoing system
Lack of information and directions regarding to the tsunami evacuation shelter causes some people in Padang Barat Sub-District do not know the location of the nearest shelter from their location and information about the total capacity of the nearest shelter. Author tries to present a system that displays and show the closest route to the shelter that might help the community in Padang Barat sub-district.

3.3 Implementation of A-Star algorithm
The following is a map of Purus Area of Padang City, as shown in Figure 1 below:
Figure 1. Map of Purus Area, Padang City

The starting point is the Merpati Perdamaian Monument and the goal is Hotel Pangeran Beach. The starting point changed to node S and the end point to node T. To facilitate the search for the nearest route using A-Star Algorithm author changed every route to graph as shown as figure 2 below:

Figure 2. Simple map of the location in graph

Coordinate of each node are shown in Table 1 below:

Table 1. Coordinate list

| No. | Lokasi | Latitude  | Longitude  |
|-----|--------|-----------|------------|
| 1   | S      | -0.928830 | 100.349970 |
| 2   | A      | -0.928150 | 100.350250 |
| 3   | B      | -0.925300 | 100.350000 |
| 4   | C      | -0.928930 | 100.350720 |
| 5   | D      | -0.927230 | 100.350570 |
| 6   | E      | -0.928570 | 100.351890 |
| 7   | F      | -0.924910 | 100.351190 |
| 8   | G      | -0.928570 | 100.351520 |
| 9   | T      | -0.924250 | 100.351060 |

As shown in figure 2, the node on Merpati Perdamaian Monument with coordinate of -0.928830; 100.349970, so the node it passed through is Node A, then Node B, then node C. To determine which node is the shortest it can be calculated by A-Star Algorithm by calculate the distance between nodes using Euclidean equation as follows [14, 15]:
\[ h(n) = \sqrt{(x - x1)^2 + (y - y1)^2} \]  

Where:  
\( x \) : Latitude \( x \) from initial node  
\( y \) : Longitude \( y \) from initial node  
\( x1 \) : Latitude \( x1 \) to end node  
\( y1 \) : Longitude \( y1 \) to end node  

Step 1. Determine coordinate point of \( S \) to \( A \):  
\( x \) : -0.928150  
\( y \) : 100.350250  
\( x1 \) : -0.928830  
\( y1 \) : 100.349970  

Step 2. Convert the degree of coordinate to radians:  
\( x \) : -0.928150 \( = 650244.9876177 \)  
\( y \) : 100.350250 \( = 9897382.5451912 \)  
\( x1 \) : -0.928830 \( = 650212.463167409 \)  
\( y1 \) : 100.349970 \( = 9897307.15450917 \)  

Step 3. Calculate with Euclidean method as follows:  
\[ g(S,A) = \sqrt{(x - x1)^2 + (y - y1)^2} \]  
\[ = \sqrt{(650244.9876177 - 650212.463167409)^2 + (9897382.5451912 - 9897307.15450917)^2} \]  
\[ = \sqrt{3163594361^2 + 75390682183^2} \]  
\[ = \sqrt{\left( \frac{3163594361}{1000000000} \right)^2 + \left( \frac{75390682183}{1000000000} \right)^2} \]  
\[ g(S,A) = 81.75919 \]  

Step 4. With the same method calculate distance of node \( A \) to end node to find the value of \( h(n) \):  
\( x \) : -0.924250  
\( y \) : 100.351060  
\( x1 \) : -0.928150  
\( y1 \) : 100.350250  

Step 5. Convert the degree of coordinate into radians:  
\( x \) : -0.924250 \( = 650334.7429468677 \)  
\( y \) : 100.351060 \( = 9897813.036196975 \)  
\( x1 \) : -0.928150 \( = 650244.09876177 \)  
\( y1 \) : 100.350250 \( = 9897382.5451912 \)  

Step 6. Calculate with Euclidean method as follows:  
\[ h(A,T) = \sqrt{(x - x1)^2 + (y - y1)^2} \]  
\[ = \sqrt{(650334.7429468677 - 650244.09876177)^2 + (9897813.036196975 - 9897382.5451912)^2} \]
\[ = \sqrt{90.6441850977^2 + 430.491005775^2} \]
\[ = \sqrt{\left(\frac{906441850977}{1000000000}\right)^2 + \left(\frac{17219640231}{40000000}\right)^2} \]
\[ h(A,T) = 439.93053 \]

Step 7. Enter the obtained values of \( g(n) \) and \( h(n) \) to find the value of \( f(n) \)

\[ f(S,A) = g(n) + h(n) \]
\[ = g(S,A) + h(A,T) \]
\[ = 81.75919 + 439.93053 \]
\[ f(S,A) = 521.68972 \]

Because in this node there are no comparison, then the next node S is node A. Perform the same calculation for node B and node C using the method as before, and generated as follows:

Node B

Enter the obtained values of \( g(n) \) and \( h(n) \) to find the value of \( f(n) \)

\[ f(A,B) = g(n) + h(n) \]
\[ = g(A,B) + h(B,T) \]
\[ = 316.51658 + 164.8905 \]
\[ f(A,B) = 481.40708 \]

Node C

Enter the obtained values of \( g(n) \) and \( h(n) \) to find the value of \( f(n) \)

\[ f(A,C) = g(n) + h(n) \]
\[ = g(A,C) + h(C,T) \]
\[ = 101.18128 + 518.99272 \]
\[ f(A,C) = 620.174 \]

Because \( f(A,B) \) is smaller than \( f(A,C) \), the next node is B. Perform step 1 again to determine the next step after node B, namely node G.

From node B to node G

Enter the obtained values of \( g(n) \) and \( h(n) \) to find the value of \( f(n) \)

\[ f(B,G) = g(n) + h(n) \]
\[ = g(B,G) + h(G,T) \]
\[ = 138.54592 + 74.06748 \]
\[ f(B,G) = 212.6134 \]

From node G to node T

Because node T is the destination so the heuristic value of it equals to 0. It could be formulated as \( h(G,T) = 0 \). Enter the obtained values of \( g(n) \) and \( h(n) \) to find the value of \( f(n) \)

\[ f(G,T) = g(n) + h(n) \]
\[ = g(G,T) + h(G,T) \]
\[ = 74.06748 + 0 \]
\[ f(G,T) = 74.06748 \]
Table 2 below show the result of calculation of every node using A-Star Algorithm until the destination is found.

| Current Node | Next Node | Score (g)  | Heuristic (h) | Value (f)  | Path  |
|--------------|-----------|------------|---------------|------------|-------|
| S            | A         | 81.75919   | 439.93053     | 521.68972  | S-A   |
| A            | B         | 316.51658  | 1648905       | 481.40708  | S-A-B |
| A            | C         | 101.18128  | 518.99272     | 620.174    | S-A-C |
| B            | G         | 138.54592  | 74.06748      | 212.6134   | S-A-B-G |
| G            | T         | 74.06748   | 0             | 74.06748   | S-A-B-G-T |

Based on the calculation result using A-Star Algorithm found that the path taken from the Merpati Perdamaian Monument (node S) to Hotel Pangeran (node T) is from node S directly to node A, because there are no comparison. From node A to node B by the calculation result show that the result of node B is smaller than node C. then from node B to node G, then node G to node T, as shown in figure below:

![Figure 3. Results](image)

3.4 Implementation and system testing

Implementation and System testing conducted to see whether the system that have been designed is in accordance with the favor. After the testing and implementation is done, the quality of a system will be shown. Below are the implementation of application designing.

a. Shelter Map Page

![Figure 4. Shelter map page](image)

On figure 4 shows the page of shelter map. At this page, the people of Padang Barat Sub-District might see and looking for nearest shelter.
b. Detailed Route Information Page

![Detailed route information page](image1)

**Figure 5.** Detailed route information page

On figure 5 shows detailed information of nearest shelter. At this page the people of Padang Barat Sub-District might see the route to shelter and other information regarding the shelters.

c. Earthquake Information Page

![Earthquake information page](image2)

**Figure 6.** Earthquake information page

On figure 6 shows earthquake information page which contains information of earthquake distribution map that have occurred.

4. Conclusions

After conducting the research and analyzing the problems, the conclusion was drawn that with this education system, if the tsunami happened, the people are ready to anticipate the situation at the given time to determine the nearest evacuation route. Application of A-Star Algorithm designed to view the nearest route to the shelter.

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