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by Rahmadya Handayanto

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ABSTRACT

Spatial analysis makes Geographic Information System (GIS) more interesting as it supports the user for making a decision not only by seeing the location but also by counting using some algorithms or statistical methods. We have tried to couple Genetic Algorithm with our GIS in searching the best location of Gas Station in Bekasi district, Indonesia. The location must have minimum risk to other important facilities or environment based on their locations. Testing result showed that the system was able to find optimum location and sending it to our database as a Web-GIS data input after converting from local coordinate into latitude and longitude coordinate system.

Key words: Geographic Information System, Genetic Algorithms

INTRODUCTION

Disasters happen when we careless in managing our risk location such as nuclear reactors, oil mills, electrical stations, etc. Some governments have standards for maintaining and their location but others, like our case study, bekasi district Indonesia, only have the general guidance for an important location. Gas station, as our object case, is a dangerous location but it must be placed near the consumers. Therefore we need calculation to find the optimum location based on other important or dangerous facilities like hospitals, electrical substations, government offices, rivers, school buildings, etc.

The best instrument for assessing the optimum location is Geographic Information System (GIS) since it has ability to easily maintains the spatial data. It also has given a big contribution to some areas such as urban planning (Junghoon, 2011), (Abdelfatah et al., 2014), environment study (Masetti et al., 2014), agricultural management (Kubicek et al., 2013), public health (Barjis et al., 2013), and other research areas. At first, GIS use desktop-based application, but it has a drawback in usage since users have to install the application first. Therefore, the Web-based GIS now is being developed by many vendors to solve that problem. Web-GIS is very interesting because by publishing a particular location to internet, it helps everyone by accessing it easily and now as a first choice of every GIS developer, and many researchers have done this kind of GIS (Junghoon, 2011), (Fotheringham et al., 2005), (Urbieta, 2014), (Fustes, 2014), (Fotheringham et al., 2005), (Kulkarni et al., 2014).

Spatial analysis is the important component of GIS, it uses statistical analysis and other methods. The interesting methods now is a soft computing-based methods such as fuzzy, neural network, support vector machine, etc. For optimization, genetic algorithms is still the firs choice because of its robust characteristic. Many research has been done using this method such as for Well Drilling location (Haque., 2002), transportation routing related to dangerous location (Huang et al., 2004), and other optimum locations. They showed the ability of genetic algorithms in finding an optimum location but they did not directly couple it to their GIS system.

Our proposed system uses both desktop-based and Web-based GIS. Desktop-GIS is still in use in this system because it is easier in implementing the genetic algorithms then web-GIS and also we have to consider the security reason when sharing some important objects to our web-GIS. It is very dangerous when terrorists and criminals understand that locations by seeing the free access of Web-GIS event though we add security to our Web-GIS using a password (Longley et al., 2004).

For years, some GIS softwares dominate the GIS user, such as ESRI with its product, ArcGIS, ArcVIEW, etc (Dangermond, 2005). Open source GIS is interesting as well, for instance GRASS, QGIS, and uDig (Sherman, 2008). For analysis, some soft computing algorithm tools, Matlab, the famous one, has been used widely by a lot of researchers (Mathworks, Inc., 2014). For this reason we have created a desktop-GIS using Matlab GUI interface and easily integrating our chosen soft computing algorithms, genetic algorithms, with our GIS. After processing from desktop-GIS component, the result is sent to web-GIS database modul and show it by web server and users can easily access it using their browser from everywhere.

DESCRIPTION OF SYSTEM

Architecture

Figure 1 shows architecture of our proposed system. There is an integration between spatial analysis for finding optimum location and our destktop-GIS. This strongly-coupled strategy is better than loose-coupled since

users will be given the information result from spatial analysis interactively (Fotheringham et al., 2005).

In desktop-GIS we created a genetic algorithms-based engine for calculating the optimum location of gas station using Matlab function. After optimization process finish, the optimum locations which has been converted into latitude and longitude coordinate system are sent to the database system via Open Database Connectivity (ODBC). Web-GIS application was created using Ruby on Rails language and run on WEBrick server in this system or can be run by other compatible ones as well. We embedded google maps (www.maps.google.com) to our web-GIS. By geo-tagging them our system will give the information about optimum location result.
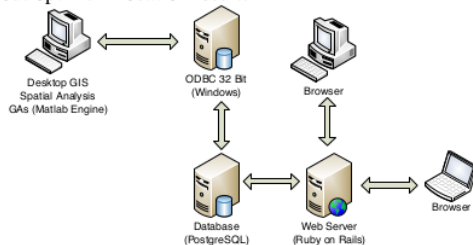

Figure 1. Architecture of Our Proposed System

We need ODBC to bridge our desktop-GIS to database for easiness because they usually run in different operating system platform. ODBC driver for PostgreSQL can be downloaded from PostgreSQL site. ODBC also has advantage when changing our database platform since we do not need to change our desktop-GIS script, but only need to create new ODBC to new database as long as having the similar metadata from the old one.

Spatial Analysis Using Genetic Algorithms

We use genetic algorithms for spatial analysis to obtain optimum location. Some researches has used this soft computing algorithm (Chao et al., 2012), (Huang et al., 2004), but the result could not be easily understand by user because it did not appear interactively on GIS. Instead of separating process between spatial analysis and GIS we integrated them. For more easy access to optimum location, we used web-based GIS.

Genetic algorithms which was proposed by Holland is a robust algorithm for optimization (Holland, 1992). This method mimic the organism which finding the best individual after some biological process such as mutation, breading/cross over, and selection which is adaptive to environment (Sivanandam et al., 2008). We used genetic algorithms function that available in Matlab application.

The specification of Genetic Algorithms are population type = double vector, population size= 20, creation function = use constraint dependent default, initial population and scores = use default, initial range = [0;1], scalling function = Rank, selection function = stochastic uniform, elite count = 2, cross over fraction = 0.8, mutation function = use constraint dependent default, cross over function = scattered, migration direction = forward, migration fraction = 0.2, migration interval = 20, generation

= 100, stall generation = 50, function tolerance = 10^-6, nonlinear and constraint tolerance = 10^-6.

The objective function for this optimum location are the distance from candidate location (in genetic algorithm are called population) to other important objects that must far away from gas station such as hospitals, schools, government, electrical substation, river, etc. These objects also have weight factor, for instance, the hospital maybe more important than school.

Because gas station must be built near the road in order easily accessed by consumers, we have to convert road from raster image into line equations. The candidate of gas station then evaluate based on total distance from important objects using normal Euclidean. This technique has been used in finding optimum location (Longley et al., 2004). For simplicity we use some linear lines instead of interpolated it into high order equation because it will need more computation. Figure 2 shows how to create road equation.

Figure 2. Road equation by Straight Line Approach as Vector Data

The objective function for genetic algorithms are using distance from all point of important location to candidate gas station location from genetic generation using normal Euclidean equation. This is a sample of one region objective function:

```
[1]  for j=1:i;
[2]  p=[x(1) x(2)];
[3]  f=1/(norm(p-data_marunda(j,:)));
[4]  f=f+fold;
[5]  fold=f;
[6]  end
```

The objective function script above uses function norm in Matlab that represent the normal Euclidean distance counting from every point that iterate until all important points are included. Equation (1) shows how normal Euclidean computes the distance between two point (x_1,y_1) and (x_2,y_2) that in objective function using Matlab function "norm". Its calculation iterates until the distance of all important points are counted from the candidate location.

$$\text{Distance} = \sqrt{(x_1 - x_2)^2 + (y_1 - y_2)^2} \qquad (1)$$

The source of data (data_marunda) are from user input. The inversion of function f happens because we follow the default Matlab toolbox that search minimum. Therefore in order to find the maximum total distance where the gas location we have to make an inversion (shown in line 3 of the objective function sample above).

We use multiple objective function according to the need of gas station based on road segment and road capacity. Every objective function then evaluated to get the optimum location (best individual).

2

Both important object and road equation uses local coordinate system. We create a desktop-GIS to depict them for georeferencing process that compare between desktop-GIS to real coordinate in web-GIS. The result then converted into global coordinate system (latitude and longitude) before storing to database because google map use latitude and longitude and height system (XYZt). Below is a sample of a road equation with its function in Matlab language. The script then created using multiple straight line, for example sumberjaya road that have six line segments. The local coordinates are used because latitude and longitude coordinates need more numeric calculation as they contain a lot of decimal fraction.

```
[1]   function y=sumberjaya(x)
[2]   index=find(10<=x & x<=50);
[3]   y(index)=-1.2*(x(index)-10)+500;
[4]   % segmen II
[5]   index=find(50<=x & x<=105);
[6]   y(index)=450
[7]   % segmen III
[8]   index=find(105<=x & x<=135);
[9]   y(index)=-2.6*(x(index)-105)+450;
[10]  % segmen IV
[11]  index=find(135<=x & x<=240);
[12]  y(index)=0.45*(x(index)-135)+375;
[13]  % segmen V
[14]  index=find(240<=x & x<=255);
[15]  y(index)=-3*(x(index)-240)+425;
[16]  % segmen VI
[17]  index=find(255<=x & x<=330);
[18]  y(index)=380;
[19]  index=find(330<=x & x<=330);
[20]  y(index)=(x(index)/x(index))*220;
```

We used raster data from scanning a map of Bekasi district and vector data from road equation and location of important objects.

Database Management System (DBMS)

Database is important to GIS because it stores, manages, processes, and organizes both raster data (images) and vector data (points and lines). We use PostgreSQL as database software because it is relational database and open source.

Every district in desktop-GIS uses a local coordinate. Therefore we must convert every data into global coordinate after the calculation is ended. Figure 3 shows desktop-GIS which contain local coordinates, constraint layer and genetic algorithms calculation for Cibitung district sample.
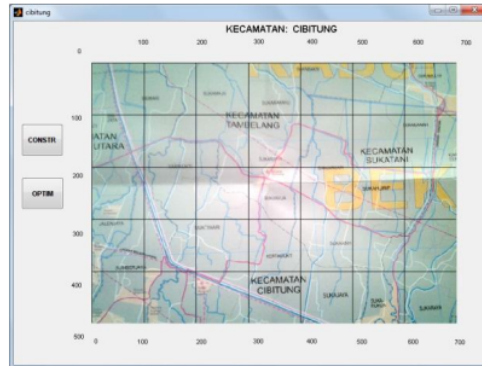

Figure 3. Local Coordinate on Desktop-GIS

The local coordinate then compare to global coordinate of google map and then create conversion function. Because coordinate of image in Matlab is different from Cartesian in its ordinate, we have to make inversion when converting it. As an information, in Matlab, positive ordinate in image presentation is negative in Cartesian.

```
[1]   function z=konversi(y,x)
[2]   latbase=-6.152484;
[3]   longbase=107.068653;
[4]   deltalat=latbase+6.240022;
[5]   deltalong=107.18554-longbase;
[6]   latitude=latbase-((y/500)*deltalat)
[7]   longitude=(x/700)*deltalong+longbase
[8]   end
```

We need a base of latitude and longitude for conversion according to google map standard. In script above we use base of latitude and longitude are -6.152484 and 107.068653 respectively from georeferencing the desktop-GIS to Google map. For example we have a local coordinate x and y are 200 and 400 respectively we will get the global coordinate using conversion function konversi(400,200) and get the result latitude and longitude -6.2225 and 107.1020 consecutively.

The conversion also important because the important location sometimes locates out side the area of desktop-GIS but inside on web-GIS which is dynamic. If we only give important objects inside desktop-GIS, calculation will give an error especially for location at the edge of desktop-GIS.

Web-GIS

To develop a web-GIS we use PostgreSQL as our DBMS (www.postgresql.org). It stored optimum location and constraint for our analysis. The server stored latitude and longitude-based coordinates after conversion from local coordinate of desktop-GIS. The optimum location will be generated in Web-GIS using google map embedded. Google map can be accessed freely and already used by many researchers as Web-GIS support (Wang et al., 2013). Users are able to see the optimum location by accessing the server with their browser. Figure 4 shows a Web-GIS with google map embedded on it and show the location using pin application from Mozilla plug-in (www.mozilla.org).
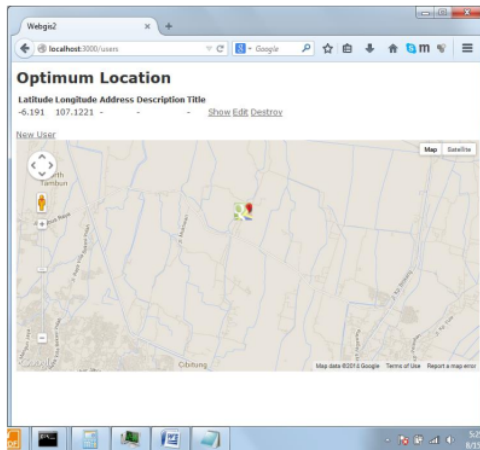
Figure 4. Web-GIS with Google Map Embbeded.

The Ruby on Rails application as an application tier and connect to with PostgreSQL as a database tier in our three-tiers system. In order to get connection to desktop-GIS we need save ODBC which bridges PostgreSQL database with windows.

Discussion

A lot of methods have been implemented to do Spatial analysis from statistical analysis to soft computing. Genetic algorithms is used because its robust characteristic that avoid local minimum problem (Sivanandam, 2008).

The difficult part of genetic algorithms implementation is in generating the road equation as a constraint for gas station location. The irregular line must be converted into equation. If we use interpolation it must be higher degree of order. Therefore we use multiple straight lines to form the road equation. For this case, we use accumulate distance from important object to candidate locations as objective function by Euclidean distance. Every important object must be converted first into local coordinate from its global coordinate. We separated bekasi district into five region for simplicity. Every region has its own function of conversion from local to global coordinate. Figure 5 shows our main menu of desktop-GIS for integrating genetic algorithms with GIS.
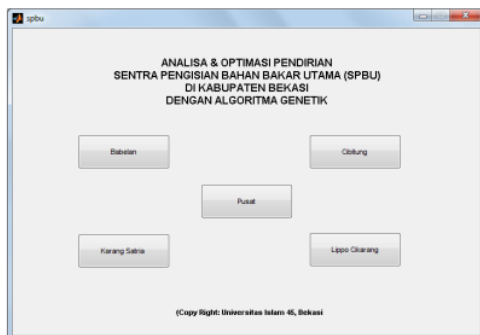

Figure 5. Desktop-GIS Main Menu

The choice of important objects that must far away from gas stations is based on environmental aspects such as rivers, hospitals, social facilities, electrical substations, below high voltage towers, crowd potential locations, flood regions, and so forth. Weighting factor is also used to that important objects, for example, below high voltage towers has weight factor twice against social facilities, and three times against government buildings.

Testing has shown that genetic algorithms could calculate optimum gas station location. The locations are beside the main road according to the rule from national gas and petroleum organization of Indonesia, PERTAMINA.
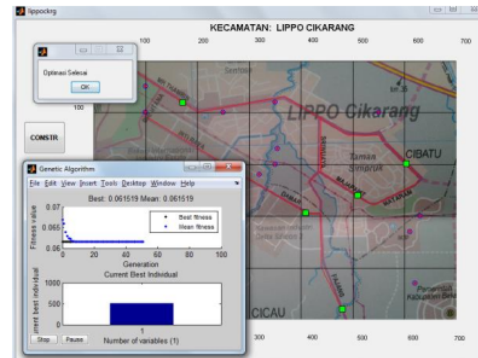

Figure 6. Optimization Result Using GAs

Figure 6 shows the optimization process result using genetic algorithm for one of our region (Lippo Cikarang District). The circles are important objects that must far away from gas station candidates and the boxes are the optimization results. The results are not only stored in database but also shown in desktop-GIS. After conversion to global coordinates, the results then stored in database for web-GIS purpose (figure 7).
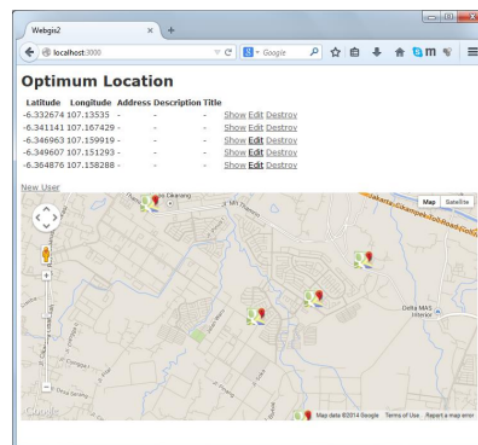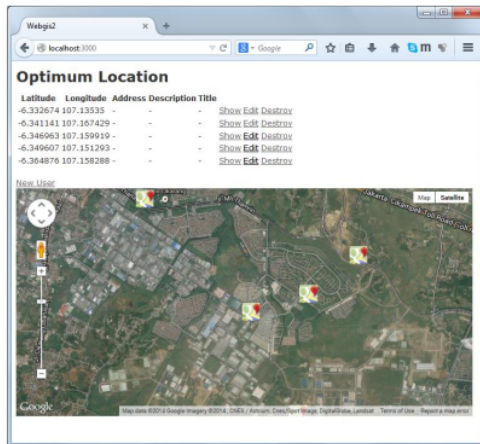

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Figure 7. Optimizing result shown by Web-GIS in Map View (above) and Satellite View (Below).

When we open the web-GIS we will see the optimum location (figure 7). By embedding google map to web-GIS we also able to view the satellite mode in order to get realistic view.

Comparison to other system

This research tries to make strongly-coupled strategy to the GIS both desktop-GIS and web-GIS in order to get user friendly application. The usability of GIS now become main concerns and a lot of researchers try to make the GIS more useful (Brown et al., 2013). The strongly-coupled is a must for creating a GIS (Fotheringham et al., 2005). Therefore this proposed system tries to minimize the drawback of other lossly-coupled strategy which is proposed by other researchers (Haque., 2002), (Huang et al., 2004). Even the biggest commercial GIS developer, ESRI, is still in progress to integrate its software with soft computing methods not only statistical analysis (Dangermond, 2005). The most important point of this system is it can be used by many people using their own machine such as laptop, tablet, and other gadgets to see the optimum location every where using the web-GIS part.

CONCLUSION.

Spatial analysis is an emerging research in GIS. It helps GIS not only in displaying a particular area from spatial database but also in calculating complex problem using some statistical analysis or soft computing methods. Our research has successfully integrated a robust optimization method, genetic algorithms, with web-GIS in optimization analysis. The future research will be more interesting if we integrate some algorithms and statistical tools to our GIS for making some analysis not only optimum location but also other aspects according to our background.

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