GPS (Global Positioning System) using Dynamic Programming

Reynald Alexander G
Program Studi Teknik Informatika
Sekolah Teknik Elektro dan Informatika
Institut Teknologi Bandung, Jl. Ganesha 10 Bandung 40132, Indonesia
reynald.alexander@gmail.com

***Abstract*—There are a lot of streets in Indonesia. Moreover there are more cars in Indonesia than the amount the street. This paper tells about global positioning system. Instead only giving shortest path, this paper will give recommended solution of best path based on heuristic too. There will be some symbols such as node in dynamic programming that represents intersection on the streets. Another symbols used in this paper is the line between the node. It implies the streets in the GPS. There will be some color that differentiate the density in the street at certain time.**

***Index Terms*— street, dynamic programming, GPS,bottom-up.**

I. INTRODUCTION

GPS (Global Positioning System) is a navigational aid, funded and controlled by the U.S. Department of Defense. This GPS systems utilize 24 satellites that orbit in the earth. Several of satellites able to communicate with any given position on earth on any given time.

There are several benefits of GPS. The benefits are such as travel detection, recreation, maritime GPS, and GPS tracking. In travel detecion, utilizing GPS system will give us quite accurate directions for travelling. In recreation we can find the direction of our camp if we get lost in the woods while we trying to collect any lumber. The same thing occurs to in sea. Of course,we don't want to get lost in sea without knowing any direction that can help us to get back to our city while we are fising or do some kind activity other than like submarine travelling, etc. Besides all of example above, we can use GPS technology in order to able to track our goods that's in delivery to customer or our partners.

Global Positioning Systems nowadays have a lot of features such as real-time traffic reports, predictive data entry and dynamic search, detour feature, reality view, routing options, foreign languages, video player, mp3 player, bluetooth compatibility, etc. Real time traffic report can support the user by alert the user to a problem or slowdown ahead in time so we can avoid it. It can also help us to reroute, change our route to other route. The real-time data is available to subscribers through cell-phone network, FM signal, or satellite radio service. The quality of information like any traffic reporting can vary or be less than current. We can also know information such as rush-hour traffic and so on and so on. Another feature, predictive data entry and dynamic search can help user just like search engine.The feature make entering city name or address fastre. With the feature, when the user type, the screen's keyborad will highligth only letters that help complete a known name. It is example picture of the GPS.

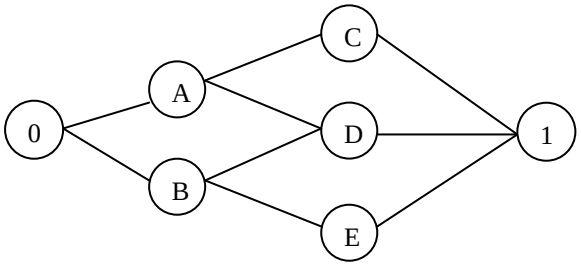
Picture 1 GPS Gadget

II. DYNAMIC PROGRAMMING

Dynamic programming is both a mathematical optimization method and computer programming method. The main idea of dynammic programming is to simplified complicated problem. The way to simplify the problem is just by divide the problem into subproblems in a recursive manner. So the subproblems are divided again until the simplest form of subproblem that can be easily solved. The subproblem that has been solved gives result in optimal subproblem that can affect the problem after that.

There are two key attributes that a problem must have. If the problem have these two attributes, dynamic programming is applicable to this problem. Here are the two attributes. First attribute is optimal substructure. Optimal substructure means that the solution to a given optimization problem can be obtained by the combination

of optimal solutions to its subproblems. In order to devise dynamic programming solutions to the subproblems, check whether the problem has such optimal substructure. The optimal substructures are usually can be detected by recursion. For example we can use shortest path problem such as there are two path a, b, c, d,and e, which c is the node that can only be accessed from a, d is a node that can be accessed both from node a or node b and e is path after node b. Here is the illustrations.



Picture 2.1 Shortest Path Problem

In order to be able to solve the problem by dynamic programming, we separate the problem into subproblems such to a and b paths. Then after that a and b subproblems can be divided again to c, d and e subproblems and then the subproblems are solved and then optimal value are given to problems a and b and so on.

After we understand the first attribute for dynammic programming. It's better for us to have a better understanding on the second attribute. The dynammic programming second atrribute is overlapping subproblems. This attribute means that the space of subproblems must be small. More specifically, the amount of small must be "slightly" kind of smaller. So if the subproblem is just way too small in any multiplication factor compared to the problem, the problem then cannot be classified as dynammic programming solvable problem.

The dynammic programming itself has two ways of problem solving. The first is the top down approach. This approach's main core is memorizing. Hence, in this way of approach, the problem is divided into subproblems until it meet the basis condition. All of the path that created before are memorized. Then the value from the basis are returned to the most little subproblems then the subproblem find the most optimum solutions to the problem above the subproblems and so on. The last result of the problems are undeniably optimum.

The second approach is bottom-up approach. This approach use the main idea of solving the subproblems first. By solve the subproblmes first, we don't even need to memorize the path of division of problem into subproblems. The cause of this advantage is that the subproblems solved and the optimum solution is returned to the parents problem before the subproblems.

This is the example of dynammic programming algorithm to solve checkerboard problem. (http://en.wikipedia.org/wiki/Dynamic_programming)

$$q(i,j) = \begin{cases} \infty & j < 1 \text{ or } j > n \\ c(i,j) & i = 1 \\ \min(q(i-1,j-1), q(i-1,j), q(i-1,j+1)) + c(i,j) & \text{otherwise.} \end{cases}$$

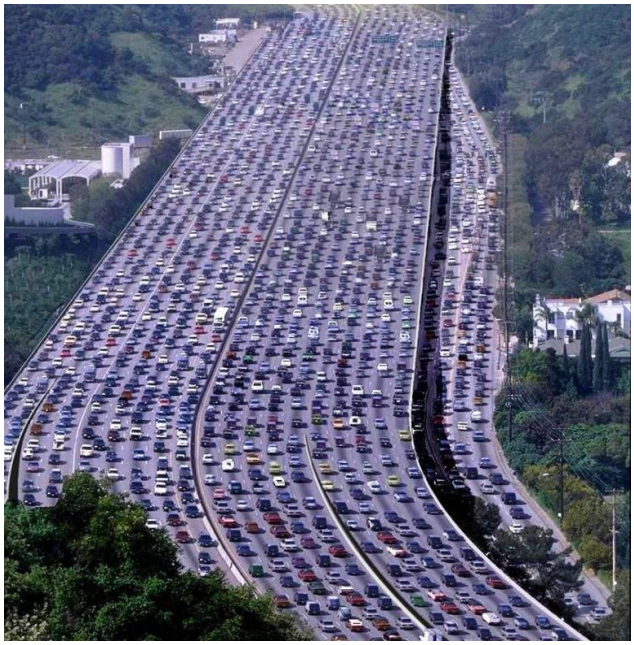
Picture 2.2 Example of Dynammic Programming Algorithm in Checkerboard Problem

III. PROBLEM ANALYSIS

Nowadays, communication is important. One of the important factor is the mobility access to another place. People always wants the easiest way to go to another place. That's why there are lots of street build in order to satisfy human demands to easily go to another places. Especially the amount of streets in Indonesia.

Besides the growth of streets, the growth of the amount of cars is also unavoidably high. This condition may leads people in cars to an unwanted condition. The condition that can annoy people called traffic jam. This traffic jam can causes people getting frustated. Besides that, traffic jam can causes a lot of losses that can lead people even to bankruptcy.

Here is the picture of traffic jam that taken from above.



Picture 3.1 Traffic Jam in Jakarta

Hence, people nowadays need to use Global Positioning Systems. With that kind of tool people in the world, especially in Jakarta, Indonesia can avoid the

traffic jam that happen almost every hours in Jakarta.

But, there's also problem with some GPS. Here are some disadvantage on using some kind of GPS :

1. GPS are sometimes hard to give some commands to the GPS because the GPS has no speech recognition feature.
2. GPS sometimes doesnt't give the best route to the users. Some of GPS just give fake short route and the other give information of the route but some streets in that route are in jam condition.
3. It's often difficult for users to get signal for the GPS, it's often that the GPS must disconnect then reconnect again in order to get signal so it can tell the routes and the condition of them properly.

Picture 3.2 GPS with buttons can endanger people life

IV. GPS USING DYNAMMIC PROGRAMMING

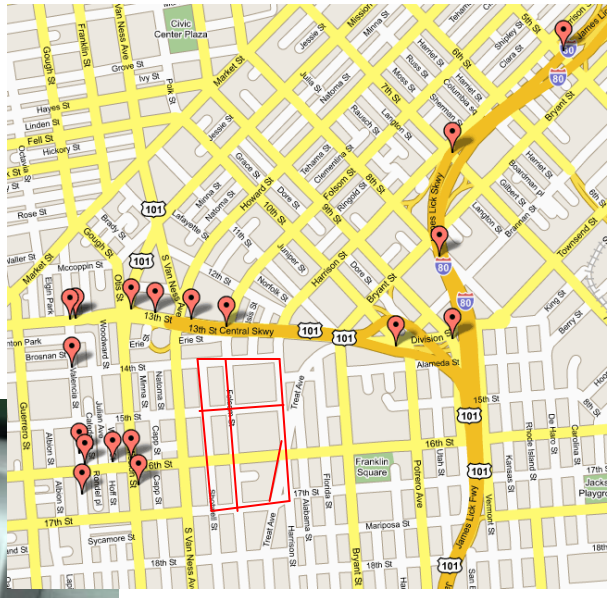
Actually there are a lot of aspect that can affect the decision of the GPS System. The aspects are :

1. Shortest route
2. Density of road
3. The condition of road
4. etc.

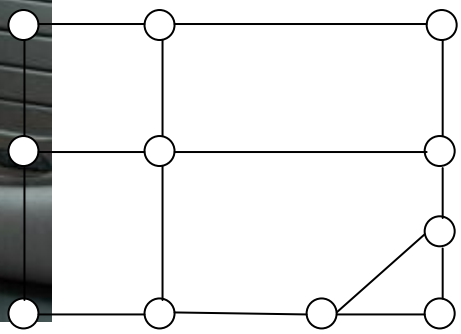
In this paper we're just gonna talk about the shortest route, because the other factors are handled by imaging algorithm via satellite that is not our context of discussion. Because imaging algorithm are using different kind of algorithm than just basic simple algorithm.

The application of dynammic programming in the Global Positioning System is actually in routes decision helper. The concept of the application is quite simple. Consider the intersections of streets as nodes and the streets as the weight of the graph in dynammic programming. The form of the graph can be either direction graph or just simple graph without any direction.

Here is the example of comparison of ordinary map interpretation and weighted graph interpretation.



Picture 3.3 Interpretation using Google Maps



Picture 3.4 Interpretation using Weighted Graph

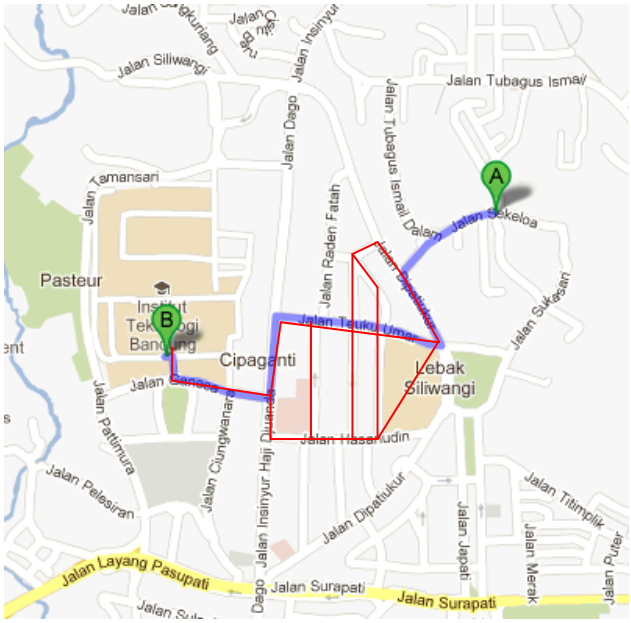
By interpret the map using Weighted Graph, we can measure the shortest path using dynammic programming. Consider the place we press the button as the first node. Then we can also consider the destination as the last node. From the two nodes, first node and last node. The system then can generate the nodes that located between them.(the intersections that can occur) Then the system can also generate the sides of each nodes that has been listed and the weight of each sides.

After we do that interpretation, we can solve it concurrently. Separate the problem into subproblems recursively until we find a basis. Either bottom-up or top-down approach are no problem.

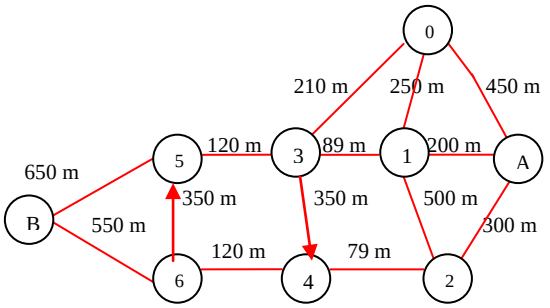
V. CASE STUDY

A. Figures and Tables

In order to get better understanding it's better for us to use simple example.



Picture 4.1 The path from Sekeloa to Institut Teknologi Bandung taken using Google Maps



(data taken using Google Maps)

Picture 4.2 The path from Sekeloa to Institut Teknologi Bandung interpreted using Weighted Graph

Now, we can look at the graph above us. Yes, it's true that it is a weighted graph. The goal of the graph interpretation is to find the shortest path from node A to node B. Now, we will use bottom-up approach to solve this problem. Without further ado, let's separate the problem into subproblem. After separating the problem using bottom up, we get first table.

s	Optimum Solution	
	f1(s) (m)	x1
0	450	A
1	200	A
2	300	A

Table 4.1 Dynammic Programming First Stage

x1 is the source node, f1(s) are the length of the side between s and A in metres. In this table, we don't use solution optimizer yet.

x2	f2(x2,s)			Optimal Solution	
s	0	1	2	f2(s)	x2
0	-	450	-	450	1
1	700	-	800	700	0
2	-	700	-	700	1
3	660	289	-	289	1
4	-	-	379	379	2

Table 4.2 Dynammic Programming Second Stage

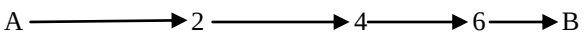
x2	f3(x3,s)					Optimal Solution	
s	0	1	2	3	4	f3(s)	x3
3	660	289	-	-	-	289	1
4	-	-	379	350	-	350	3
5	-	-	-	409	-	409	3
6	-	-	-	-	499	499	4

Table 4.3 Dynammic Programming Third Stage

x4	f4(x4,s)		Optimal Solution	
s	5	6	f4(s)	x4
B	1059	1049	1049	6

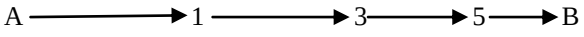
Table 4.4 Dynammic Programming Third Stage

As we can see above that the problem can be solved by divide it into subproblem four times. The 1049 is the optimal solution. That's mean it's the best if we follow this route to go to Institut Teknologi Bandung from Sekeloa.



Picture 4.3 The best path of the problem

Though, there is another route that second best to the first route. The difference of the distance is just 10 m.



Picture 4.4 The second best path of the problem

Smart GPS nowadays not only memorize the best path. They usually memorize the second or even third or fourth best path. It is quite a clever system because they can handle the probabilities if the user want to take another route suggestion than the best. Let's remember that the factor of route suggestion is not only the shortest path. It can be the condition of the road, the density of the road depend on the current time, and so on. So that's why smart GPS use several best paths if something like traffic jam occur in the best among the best paths.

Because there are a lot of possibilities way though the path could be disastrous such as A->1->3->4->2. It's

better for us to give some restriction so there are no redundancy in the calculation that can lead us to chaos. The boundary can be like each path can be added to a path just once.

V. Conclusion

GPS nowadays is very important for busy human beings who enjoy driving their personal cars than go by public cars. Then, GPS system can be implemented using Dynammic Programming in order to get the shortest path. But the best path cannot be determined by the shortest path alone, it's also affected by other factors.

VII. Acknowledgment

The Author happily thanks The Ultimate God. Without any of His Graces, this paper cannot be done. The author also would like to thanks his tutor, Ir Rinaldy Munir who already has given support such as knowledge about algorithm and the value of true writing. Cannot be forgotten, that Google has a lot of roles in the process of making of this paper(Google Search Engine and Google Maps). Also, thanks to all the people who support till this paper can be finished well.

References

[1] http://www.streetdirectory.com/travel_guide/12012/gps_vehicle_tracking/the_benefit_of_a_gps_system.html
[2] http://www.slipperybrick.com/category/gps/page/8/
[3] http://www.consumerreports.org/cro/cars/tires-auto-parts/gps/gps-buying-advice/gps-features/gps-features.htm
[4] http://en.wikipedia.org/wiki/Dynamic_programming
[5] http://fak-hukumuntan.blogspot.com/2011_07_01_archive.html
[6] http://syopian.net/blog/?p=2651
[7] http://www.me.utexas.edu/~jensen/ORMM/methods/unit/network/subunits/mst_spt/index.html
[8] http://maps.google.co.id/maps/myplaces?vpsrc=1&ctz=-420&abauth=1f794c4a:xt2wYbrY2t4IT1mePaOtwO4kQ_o&vps=1&ei=OFHhTp6CDc-s_Abr5e2LAw&num=10

Statement

With this words, I hereby state that my paper is my own work, it's not a copy, a translation or even a plagiarism.

Bandung,December 9th 2011

Reynald Alexander G.
13509006