Application of A* Algorithm in Finding The Shortest Path to Travel Around Indonesia

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***Abstract*—It is scientifically proven that travelling can benefit someone's mental health. But travelling often costs high due to the distance and difficulty-to-be-reached of the place that an individual is going to. Indonesia is a very large country, therefore when someone wishes to visit at least every major city in Indonesia, it is of course expected to be pricey if they don't strategize well. With the knowledge of the shortest path to travel around Indonesia, it is expected that an individual can estimate the cost they need to prepare and have the refreshment they need.**

***Keywords*—travel, Indonesia, shortest path.**

I. Introduction

As time goes by, technology develops. Along with the development of technology, the opportunity to be employed increases. Jobs that never existed before are now mushrooming everywhere. It helps people to have a better life, but it also causes some unavoidable side effects such as stress and depression caused by the demands of his/her job.

Luckily, thanks to technology, recently experts have discovered ways to improve someone's mental health. One of the which is to travel.

Some people may associated the world 'travelling' with 'deep pockets', meaning only someone who has abundant financial resources can do travelling. It is usually said so for people always connected travelling to go to somewhere beautiful and luxurious on other side of the earth they are living. Especially in Indonesia, where the average amount of wage of the citizen is in between IDR 1,570,922.00 to IDR 3,940,972.00. To some, they have barely enough money to live, not to mention to give their children the education they deserve, to pay for the house they lived in, and the taxes too. It is almost unimaginable to travel somewhere just because they have some difficulties at work that risks their mental health.

But to enjoy some place beautiful and luxurious, you do not have to go to other side of the world you are living. If you live in Indonesia, then you are extremely fortunate to live in a country known for its beauty that even people from other continents are willing to spend their money enjoying Indonesia.

Also thanks to the development of the technology, now scientists have developed algorithms that, not only useful in solving health-issues and other kind of world-class problems, it is also useful to solve problem such as finding the shortest path to go somewhere.

One of the algorithm developed is called A* algorithm. The basic idea of this algorithm is to avoid expanding paths that are already expensive. Therefore, it is safe to say that not only that this algorithm makes sure to find the shortest path, it is also makes sure that the time taken is the most minimum.

II. Basic Theories

A. *A* Algorithm*

In 1964, Nils Nilsson invented an algorithm that was based on heuristic approach to increase the speed of Dijkstra's algorithm—this algorithm was called A1.

And then in 1967, Bertram Raphael made improvements upon this algorithm. But his algorithm failed to show optimality. This algorithm was called A2.

Finally, in 1968, Peter E. Hart argumented that Bertram Raphael's algorithm, A2 was proved to be optimal when used with a consistent heurictic with only minor changes. He then named this algorithm in a star syntax which means it includes all possible version number of A, hence the A*.

A* algorithm is widely used as a way to finding path in games. It is simple to implement, very efficient and has a lot of scope for optimization.

This algorithm is identical to Dijkstra's Algorithm in that it can be used to find the shortest path—its goal is to find a minimum sum-cost path. Rather than considering the node with the lowest cost so far, in this algorithm we choose the node that is most likely lead to the shortest overall path. The term "most likely" is calculated by a heuristic function.

The evaluation function used by A* algorithm to calculate the shortest path to goal is

$$f(n) = g(n) + h(n)$$

With g(n) as cost so far to reach *n* and h(n) as estimated cost from *n* to goal.

A* algorithm is a combination of UCS algorithm and Greedy Best First Search algorithm. That is why the evaluation function used by A* algorithm to calculate the shortest path to goal are cost to reach current node and an estimated cost from current node to goal.

The heuristic function h(n) is an estimate of the minimum cost from any vertex n to the goal. Dijkstra is a special case where h(n) is equal to zero.

We must decide the heuristic function carefully, for if the heuristic function h(n) always underestimates (smaller than) the true cheapest cost from vertex n to a goal (h*(n)), A* is guaranteed to find an optimal solution. So it is safe to conclude that, if the heuristic is accurate, then the algorithm will be efficient. If not, then the algorithm may be a worse way to find path than using Dijkstra's algorithm.

There are generally three approximation that can be used to calculate heuristic functions. They are manhattan distance, diagonal distance, and euclidean distance.

Manhattan distance is the distance between two nodes measured diagonally, or more commonly known as the straight-line distance. One basically just needs to draw a straight-line between the nodes which need to be calculated and calculate the length of the straight line in order to find a manhattan distance. It is done by calculating the sum of absolute values of the horizontal distance and the vertical distance.

As for diagonal distance, it is the maximum of absolute values of the differences between the horizontal distance and the vertical distance.

Euclidean distance is the distance between the current node and the goal node using the distance formula as follows:

$$h(n) = \sqrt{(x_2 - x_1)^2 + (y_2 - y_1)^2}$$

with x_2 and y_2 as the current coordinate and the x_1 and y_1 as the goal coordinate.

To make it easier to illustrate, below is the example of the implementation of A* algorithm in Python:

```
#heuristic
def manhattan_distance(a,b,x,y):
    return abs(a-x) + abs(b-y)

def takeFirst(element):
    return element[0]

#algoritma A*
def algoritmaAstar(i,j,a,b):
    queue = []
    current_i = i
    current_j = j
    goal_i = a
    goal_j = b
    hasVisited[current_i][current_j] = 1
    pathToNode[current_i][current_j] =
makePathToNode(pathToNode[current_i][current_j],curren
t_i,current_j)
    langkah[current_i][current_j] = 0
    heuristic = langkah[current_i][current_j]
+manhattan_distance(current_i,current_j,goal_i,goal_j)
    queue.insert(0,(heuristic,current_i,current_j))
          while (not ((current_i==goal_i) and (current_j==goal_j)))
and (len(queue)>0):
        heuristic,current_i, current_j = queue.pop()
        if (not ((current_i==goal_i) and (current_j==goal_j))):
            neighbors = findNeighbors(current_i,current_j,maze)
            for neighbor in neighbors:
                if (hasVisited[neighbor[0]][neighbor[1]]==0):
                    langkah[neighbor[0]][neighbor[1]] =
langkah[current_i][current_j] + 1
                    heuristic = langkah[neighbor[0]][neighbor[1]] +
manhattan_distance(current_i,current_j,goal_i,goal_j)
                    queue.insert(0,(heuristic,neighbor[0],neighbor[1]))
                    queue.sort(key=takeFirst)
                    pathToNode[neighbor[0]][neighbor[1]] =
makePathToNode(pathToNode[current_i][current_j],current_i,curre
nt_j)
                    hasVisited[neighbor[0]][neighbor[1]] = 1
    pathToNode[goal_i][goal_j] =
makePathToNode(pathToNode[goal_i][goal_j],goal_i,goal_j)


    return pathToNode[goal_i][goal_j]
```

III. Travelling Around Indonesia

A. Indonesia

Indonesia is located between the Pacific and the Indian Ocean and also is a home for over 250 million souls. It has over 17,000 islands (although almost half of them are inhabited) from which it earned the title the largest archipelagic country in the world.

Figure 3.1 Indonesian Map

Source: https://www.cia.gov/library/publications/the-world-factbook/geos/id.html accessed on 25th of April 2019 at 01.42

Over 300 languanges are spoken and with more than 200 ethnic groups, it is no wonder that Indonesia is blessed with different cultures in every corner of the country. It is also the natural habitat of exotic animals such as the well-known Komodo, Orangutan, and so much more. Its soil, due to the fact that Indonesian land is surrounded by volcanos, is rich of vitamins and minerals that almost every plant can grow, and beyond its sea lies the most diverse coral reef in the world.

With history that dates back for centuries, it is no wonder that Indonesia has marvellous evidence of the human civilization back in the day such as the largest Buddha temple, the Borobudur and one of the biggest temple in Southeast Asia, the Prambanan. Those landmarks that still exist to this day are one of the main reasons which attract tourists to come by each year.

In matter of tourism, courtesy of The Travel and Tourism Competitiveness Report 2017, Indonesia ranks 42 out of 136 countries.

Indonesia is not only famous for its landmarks, diversity of the culture, and the hospitality of the people, it is also well-known for its beaches—a heaven on earth for every surfer in the world. It has hundreds of beaches for surfing and 30 of which are considered world-class beaches. Out of the 30 beaches, there will be 11 beaches used for the World Surfing League (WSL) in 2019.

Unfortunately, some infrastructures in Indonesia is poorly undeveloped and therefore in the tourist service infrastructure section in The Travel and Tourism Competitiveness Report, it is rated poorly—a two out of seven.

Generally, Indonesia is a must-visit and a recommended place by if one decides to looking forward for some adventure to somewhere not expensive but has breath-taking view and nice hospitality.

B. The Advantages of Travelling Around Indonesia

Tourism is Indonesia's one of the most important factor that supports the growth of the country's economy. So if one is an Indonesian, and she/he has the need to go somewhere to refreshes her/his mind from the usual routine, no need to go farther since her/his country itself is also a good spot to clean their head. Not only that they will be able to get the refreshment they need, they will also be helping their own country to develop.

Researches prove that travel can enhances one's creativity. It is known that our brains are sensitive to change and its influenced by new environment and experiences, which are both the key to getting a creativity boost, according to Adam Galinsky, an expert from Colombia Business School. Both of which are able to be gotten from travelling.

Emotion is also impacted by travelling. Adaptation to local culture will help in making a person less emotionally reactive, which means it will improve one's emotional stability.

It is also a stress reliever. By travelling to places new, it helps in taking a person away from the usual causes that contribute their stress levels.

A study by the University of Surrey found that travelling will make someone be more positive about their general quality of life. They will be happy not just when the trip starts, but also since the preparation has begun. It is comparable to that of an anticipation of buying a new possession.

IV. Application of A* Algorithm in Finding The Shortest Path To Travel Around Indonesia

If the price of the transportation ticket is calculated based on the difficulty of reaching a place and based on the distance between two places, then the information of the distance between places is important. It is somewhat hard to calculate the distance between places accurately, but with technology nowadays we can approximate the distance calculation. One of the tools to calculate total distance or path it takes to go to some places from the other, is to use the A* algorithm in finding the shortest path. Therefore, it is expected that, if we define the sentence 'travel around Indonesia' is to go from one point to another point farthest away from that point, we are able to decide which city to go first after our starting city to have the shortest amount of distance to the finishing city.

First of all we have to decide which city is the starting point and which is the finish line. It is assumed that if one is visiting all provinces in Indonesia thus it can be said that one is travelling around Indonesia.

Since we are going to calculate the path to travel around Indonesia, it will be making more sense if the starting point is the city of Banda Aceh in Aceh province and the finishing point is going to be a city as far away as possible from Aceh, in this case we choose the city of Manokwari in the West Papua province.

The next step is to create a graph that contains all possible path from Banda Aceh to Manokwari.

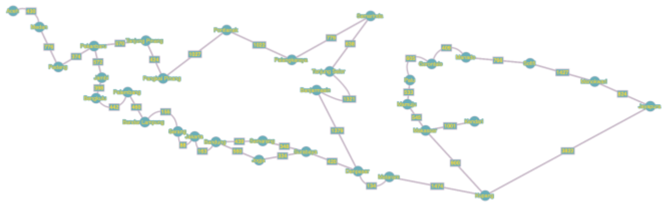


Figure 4.1 All path possible from Aceh to Manokwari

Then we need to find the g(n) and h(n) function for evaluating the estimated shortest path to travel around Indonesia. In finding the g(n) function, we can use Google Maps and pin one place to another and calculate the distance.

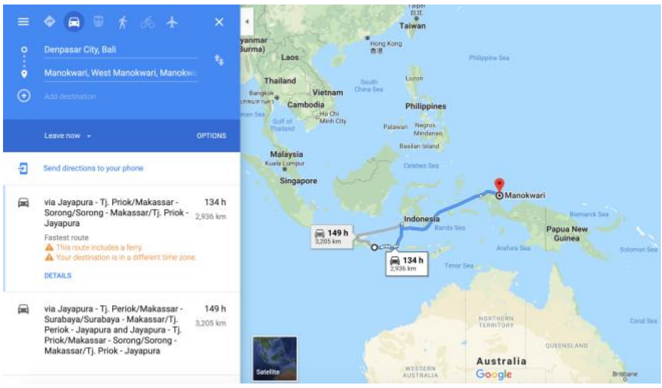


Figure 4.2 Calculating the g(n) function between Denpasar and Manokwari

If two calculations show, choose one that has the farthest distance as we are going to assume the worst case scenario which is when someone travels by car only (not taking a ferry) or by foot (since apparently some road infrastructures have not been developed well that it is unlikely to travel by vehicle) hence, some places that looked like close to each other may actually distance farther than others that is similar.

While in finding h(n), it is easier to calculate it with the approximation of the manhattan distance. Therefore, we also may be able to use Google Maps and use the straight-line distance feature. Thus, from the explanation above we will obtain:

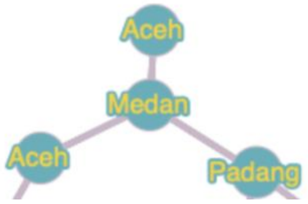
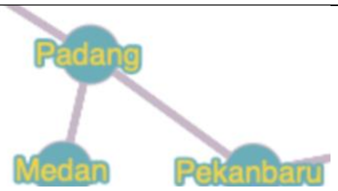
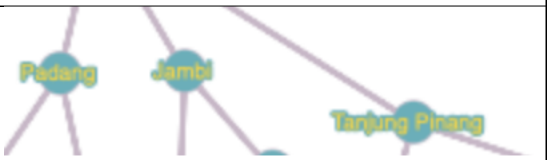
Table I. Straight-line distance to Manokwari in kilometers

Aceh	**4220**
Denpasar	2262
Pangkal Pinang	3130
Serang	3158
Bengkulu	3563
Semarang	2706
Palangkaraya	2259
Palu	1570
Surabaya	2460
Samarinda	1915
Kupang	1544
Gorontalo	1236
Jakarta	3080
Jambi	3391
Bandar Lampung	3246
Ambon	721
Tanjung Selor	1915
Sofifi	743
Manado	1055
Medan	3985
Jayapura	754
Pekanbaru	3637
Tanjung Pinang	3303
Kendari	1333
Banjarmasin	2170
Makassar	1697
Palembang	3247
Bandung	3018
Pontianak	2771
Mataram	2162
Manokwari	0
Mamuju	1641
Padang	3737
Jogja	2744

The next step is to calculate the shortest path from Aceh to Manokwari. Due to the size of the graph, it can not be showed completely in this paper. Below are one of the steps of the calculation to define the shortest path from Aceh to Manokwari is as follows:

Table II. Some of the calculation of A* Algorithm to calculate shortest path to Manokwari

f(n) = g(n) + h(n)	**Graph**
Aceh = 0 + 4220 = 4220	
Medan = 430 + 3985 = 4415	

Padang = 430 + 776 + 3737 = 4943 Aceh (below) = 860 + 4200 = 5080	
Medan = 1982 + 3985 = 5967 Pekanbaru = 1580 + 3637 = 5217	
Medan = 1290 + 3985 = 5275	
Padang = 1954 + 3137 = 5691 Jambi = 2152 + 3291 = 5543 Tanjung Pinang = 2150 + 3303 = 5453	

We first compute the f(n) of Aceh in the first row of the table. Next, we only see the child of Aceh is Medan only, hence we compute the f(n) value of Medan and it is as shown above.

After that, we must check the children of Medan. It turns out that Medan has two child (or neighbour in the graph) which are Aceh and Padang. Even if we already computed f(n) value for Aceh in the first step, we still need to calculate the f(n) value for this step for the two value are different due to the g(n) function. In the first step, the g(n) value is 0 (zero) because there is no cost to go from Aceh to Aceh. In this step, the road we take is a little bit longer—that is Aceh, Medan, and then come back to Aceh. This means the g(n) value is also different. In this case, the g(n) value is 430 + 430 = 860. After that, we sum the value of the g(n) with the h(n) that is acquired from the Table I. above.

As for Padang, we compute the g(n) value as usual which is to sum all the weight of the graph from Aceh via Medan to Padang. Hence, the g(n) result is 430 + 776 = 1206. And after that, we shall not forget to compute the h(n) value for Padang, which is the distance estimated to go to Manokwari from Padang, as shown in the Table I. above.

The next step is to choose which one of the two children that we computed before which has the smallest result of f(n). By doing this until the finishing city is reached hopefully will lead us to the most minimum path that we have been looking for.

It is as turned out the smallest amount out of the two is the f(n) value for Padang. Hence, we expand the Padang node.

Padang, as shown in the graph above, has two neighbours which are Medan and Pekanbaru. As mentioned above, it is okay if the city that we computed before shows up again. We still need to calculate its f(n) value for it is expected to be different from the ones calculated before.

In this case, Medan's g(n) value is 1982, acquired from summing all the weighted node from Aceh to Medan to Padang and go back again to Medan. While the h(n) value is always the same as before, which is 3985. Hence, the value of f(n) is 1982 + 3985 = 5967.

For Pekanbaru, it is computed the same the way we computed f(n) value for Padang before.

After that, we need to compute the difference between the children's value of f(n) as usual. In this case, it is Pekanbaru with the value of 5217 which has the smallest value out of the two.

Now we have three living nodes which are the second Aceh we computed, Medan, and Pekanbaru. We shall not forget that we still have living nodes beside Medan and Pekanbaru. Therefore, the second Aceh we calculated before is now also among the candidates nodes to be expanded. It is known that Aceh has now the smallest f(n) value out of the three, hence we expand Aceh first. After that we get the value of the third Medan which is 5275. Now the living nodes are Medan with f(n) equals to 5275, Medan with f(n) equals to 5967, and Pekanbaru with f(n) equals to 5217.

Then, we expand the Pekanbaru node and hence we compute the three neighbour nodes of Pekanbaru which are Padang, Jambi, and Tanjung Pinang.

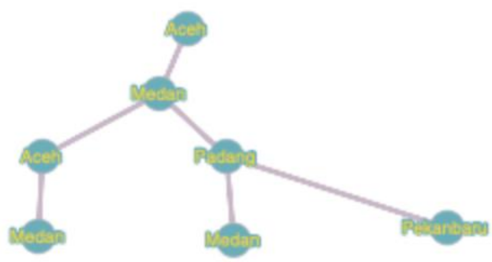


Figure 4.3 Example of graph used in computing f(n) value

With the same way as described in the explanation above, we keep on computing until we find the shortest path (signed by the smallest f(n) value) to go to Manokwari from Aceh.

After doing some calculation, it is known that the shortest path from Aceh to Manokwari is Aceh, Medan, Padang, Pekanbaru, Jambi, Bengkulu, Palembang, Bandar Lampung, Serang, Jakarta, Bandung, Semarang, Surabaya, Denpasar, Mataram, Kupang with the total amount of distance up to 10495 kilometers.

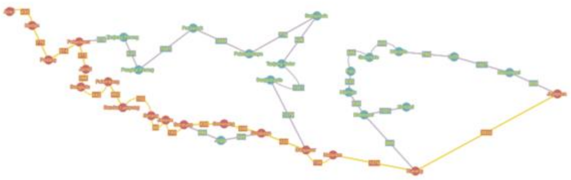


Figure 4.4 The Shortest Path from Aceh to Manokwari

V. CONCLUSION

From the explanation on above, it can be concluded that travelling can do your mental health some good and to go to somewhere luxurious and beautiful you do not have to go to other country (if you are Indonesian) because Indonesia itself is extra ordinary. A trip around Indonesia can be cheap if one calculate well. By calculating the shortest path for a trip around Indonesia, it is known that based on the route taken above, the total amount of distance it takes to travel Indonesia is up to 10495 kilometers.

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PERNYATAAN

Dengan ini saya menyatakan bahwa makalah yang saya tulis ini adalah tulisan saya sendiri, bukan saduran, atau terjemahan dari makalah orang lain, dan bukan plagiasi.

Bandung, 26 April 2019

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