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IMPLEMENTATION OF A-STAR ALGORITHM IN FINDING THE SHORTEST ROUTE OF COOKING OIL DISTRIBUTION IN KARO REGENCY USING GRAPH

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ABSTRACT

PT. XYZ is a company that distributes cooking oil in Karo Regency. Based on what has been observed at PT. XYZ, the distribution of goods has not contained standard provisions in determining the route of delivery of goods, large areas cause great difficulties in the distribution of goods because they require greater transportation costs. To overcome the distribution problem, a workable solution is the A-Star algorithm using graphs. The A-Star algorithm has two points, namely *Open* List and *Close List.* Where conceptually open list means a point that can be skipped while close list means a point that cannot be passed. And usability the Close *List* is needed so that the algorithm does not need to check the points it passes, so that it can more quickly complete the search process and the checking process at each point can be less, In general, the concept of determining the closest path in an algorithm is that it can stop when the open list is not found and the endpoint has been obtained. while the company's route was 30.95 km. Then the percentage of mileage savings is 62.16%. This shows that the A-Star algorithm can minimize distance and also save companies costs.

Keywords: A-Star Algorithm, Shortest Route, Graph, Distribution

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PRELIMINARY

Distribution is a group of companies that distribute products from one location to another. Distribution is part of sales (Nurdian, Prasidyajyandalu, Masyhuri, & Rolliawati, 2020). The role of distribution is very important to ensure the availability of products needed by the community (Natasya, Sitepu, Ngurah, & Cahyadi, 2022). Distribution aims to make the goods produced reach consumers smoothly, provided that the conditions of producers and buyers must still be considered. One of the factors that greatly influence the sales success of a company is the issue of distribution (Bakhtiar & Rahmi, 2017). The distribution of goods can be more profitable if you can optimize the distribution of these

goods, it is necessary to analyze the shortest path. Of course, if time efficiency is not achieved, this causes consumer dissatisfaction because the desired or even needed goods cannot be delivered on time. When determining the shortest route, the shortest distance is sought among the available travel route alternatives (Wahyuni, Affandi, & Setiawan, 2022).

Distribution often experiences disruptions in the delivery of goods, for example slow travel times and difficulty determining which destination should come first. PT. XYZ in Karo Regency is also experiencing this issue. PT. XYZ is one of the cooking oil distributors in Karo Regency. Distribution of goods at PT. XYZ has no standard rules to determine the route of delivery of goods, the large area makes the distribution of goods very difficult, because it requires higher transportation costs. Another reason is the large number of highways, and the large number of vehicles often make it difficult to find the shortest route to the next destination, both in terms of distance and travel time (Natasya et al., 2022). The A-Star algorithm using graphs is one solution that can be used in solving such distribution problems. There are many algorithms that can be applied to determine the shortest path, the A-Star algorithm is one of them (Gede Wahyu Antara Dalem, 2018). Many researchers have done the same research. Among them is the A-Star algorithm to find the shortest route at tourist attractions. The A-Star algorithm is very good for solving the shortest route finding problem because it can produce optimal results.

The A-Star algorithm is a graph search method applied in finding the path from the initial node to the specified destination node (Suyitno, Indrajit, & Fauzi, 2017). Graph theory is one of the branches of mathematics that can solve problems in many fields (Rohmawati, Fathoni, & Ismanto, 2022). A graph is a combination of vertices and sides with each side associated with one or two vertices. A graph can also be interpreted as a collection of points linked by sides (Fadilah, Mansyur, & Purnawansyah, 2022). The purpose of graphs is to show each object and the relationship between each object. The purpose of using a graph is to show objects with a point, while the relationship between objects is shown by lines. Determination of the closest route from the starting point to the end with the least weight compared to all known route (Gede Wahyu Antara Dalem, 2018).

The A-Star algorithm is an algorithm used to determine the optimal distance and can be used in solving problems related to finding the minimum distance (Sulastio, Anggono, & Putra, 2021). The A-Star algorithm has two points, namely *Open* List and *Close List.* Where conceptually open list means a point that can be skipped while close list means a point that cannot be passed (Maulana & Chandra, 2018). And usability Close *List*

is needed so that the algorithm does not need to check the points it passes, so that it can more quickly complete the search process and the checking process at each point can be less. In general, the concept of determining the closest path in an algorithm is that it can stop when the open list is not found and the endpoint has been obtained.

The A-Star algorithm can be used to find the shortest path so that costs incurred are minimum. The A-Star algorithm has advantages such as being able to minimize costs, make it easier to find the shortest route and provide the best solution with optimal time, from the advantages that can be obtained, the A-Star algorithm also has disadvantages. The weakness of the A-Star algorithm are that the results of the data obtained are still invalid and the data collection process is limited by the value and distance from the point of influence (Suhendri, Dede Abdurahman, & Dani Irfan Maulana, 2021). with the implementation of the A-Star algorithm, information on cooking oil distribution facilities and the shortest path will be more accurate because this method chooses the side with the minimum weight. Apart from using the A-Star algorithm, you can also use other algorithms such as Dijkstra (Prasetyo, Arnandi, Hudnanto, & Setiaji, 2019).

METHODS

This research was conducted at PT. XYZ Kabanjahe Branch, North Sumatra. In this study the data were obtained directly from the company and the results of interviews. The steps taken in this study are 3 stages, namely data collection, data processing and making conclusions.

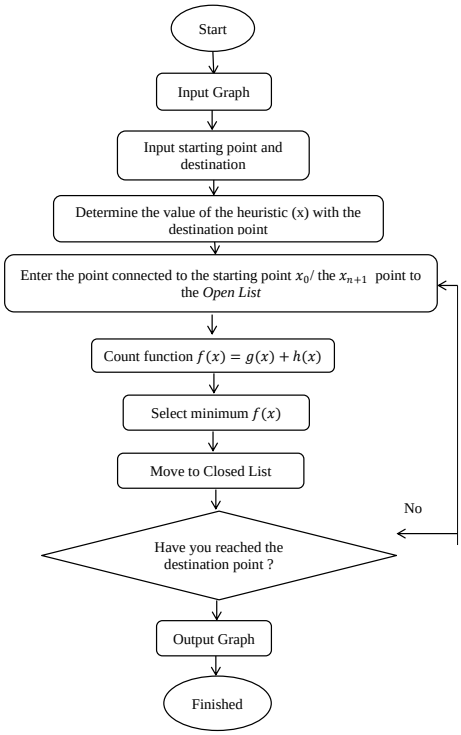

Figure 1 Research Flow

The A-Star algorithm has the following terms (Simbolon, 2022) :

1. *Starting point* is the term for the starting point.
2. Nodes are points that represent a goal. The shape can be square, triangle, or circle.
3. A is the *node* that is in the process of determining the shortest path.
4. *Open list is a node* that is likely to be reached from the starting point or symbol that is in process.
5. *A closed list* is a *node* selected as a selection of the shortest route.
6. Cost (F) is the value obtained from the sum of the G values, the total value of each node on the shortest route from *the starting point* to A, and H, the estimated total value of *nodes* to the destination *node*.

This algorithm has the principle of finding the shortest route from the starting point to the destination *node* by looking at the cost (F) the least (Natasya et al., 2022).

Shortest Route

A route that passes from one point to another and has a value on a side of the last number from the starting point to the smallest end point is called the shortest route (F. D. Putra, Rakhmawati, & Cipta, 2021). The shortest route is needed to reach the destination from the current location to the final destination at the least cost. The shortest route is the

route that can be completed with a graph to get optimal results (Ramadan et al., 2018). The graph form is usually used in problems like this where the nodes are related to determining the scope and transitions that occur inthe edge form (Syathirah, Kusuma, & ..., 2021).

A-Star Algorithm

The A-Star algorithm is an algorithm for obtaining the shortest distance guided by its heuristic function, in determining the sequence of nodes to be visited earlier (Natasya et al., 2022). Heuristic values are used to reduce search space. The A-Star method provides optimum route results starting from the destination point (A. B. W. Putra, Rachman, Santoso, & Mulyanto, 2020). The implementation of the A-Star algorithm is able to provide the best solution at the optimal time. The main feature of the A-Star algorithm is the development of a closed list for storing the regions to be analyzed. This closed list is a list for storing estimates of adjacent areas and then calculating the distance visited from the star point with the estimated distance to the end point. Algorithm A-Star evaluates to the-n nodes by concatening $g(n)$. That is the cost to reach the node and $h(n)$ is the cost to reach the node. The A-Star algorithm has the formula: (John & Rochmawati, 2022)

$$\boldsymbol{f(n) = g(n) + h(n)} \qquad \textbf{(1)}$$

Information:

$h(n) = Estimated\ cost\ from\ point\ n\ to\ endpoint.$

$g(n) = cost\ from\ initial\ point\ to\ point\ n.$

$f(n) = lowest\ estimated\ cost.$

$h(n)$ can be obtained by the *Euclidien Distance Heuristic* formula. Here is *the Euclidien Distance Heuristic* formula (Damayanti, Kusumaningrum, Susanty, & Islam, 2020):

$$\boldsymbol{d(a,b) = \sqrt{(x_b - x_a)^2 + (y_b - y_a)^2}} \qquad \textbf{(2)}$$

Information:

$d(a,b) = distance\ between\ points\ a\ and\ b$

$x = latitude$

$y = longtitude$

The more precise the heuristic values applied, the fewer iterations the A-Star algorithm implements (Fernando, Mustaqov, & Megawaty, 2020). The application of the A-Star algorithm can obtain optimum results with the use of appropriate heuristic functions (Suhendri et al., 2021).

RESULT AND DISCUSSION

In this study, location data will be determined based on *latitude* and *longitude* from *google maps*. *Latitude* is the *latitude* south and north of the equator and longitude is the *longitude* that shows the west or east and north south lines which are commonly called meridians. Table 1 below is the destination point for which the goods will be used.

Table 1. *Latitude* And *Longitude* Of Destination Point

No	Store Name	Latitude	Longitude
0	PT. XYZ	3.0969229	98.481256
1	Store A	3.099849889	98.48595647
2	Store B	3.101573293	98.48719195
3	Store C	3.169323733	98.50796665
4	Shop D	3.180233788	98.51057646
5	Store E	3.189708	98.508851
6	Store F	3.189745066	98.50969274
7	G Store	3.191106	98.51025
8	Shop H	3.190822534	98.50889163
9	Shop I	3.19127817	98.50869962
10	Store J	3.191665	98.508459

In finding the distance matrix used the formula:

$$d(a,b) = \sqrt{(x_b - x_a)^2 + (y_b - y_a)^2}$$

For example, to get a distance of $d(0,A)$, it is done in the following way:

$$d(0,A) = \sqrt{(3{,}0969229 - 3{,}099849889)^2 + (98{,}481256 - 98{,}48595647)^2}$$

$$d(0,A) = \sqrt{(-0{,}002926989)^2 + (-0{,}00470047)^2}$$

$$d(0,A) = \sqrt{0{,}0000305}$$

$$d(0,A) = 0.0055226 \; x \; 111.322 \; (1 \; degree \; earth)$$

$$d(0,A) = 0.62 \; km$$

So the distance from the depot to the first agent with Euclidean distance is $0.62\ km$. For the pick-up of goods by land travel, the calculation of the distance must take into account whether there is a road that is passed by the company's vehicles. Therefore, the calculation of the distance from the depot to each agent to other agents is searched with the help of *Google Maps*. To obtain the next distance, it can be done in the same way.

Table 2. Distance Matrix

	0	A	B	C	D	E	F	G	H	I	J
0	0										
A	0.62	0									
B	0.84	0.24	0								
C	8.59	8.11	7.89	0							

	0	A	B	C	D	E	F	G	H	I	J
D	9.83	9.36	9.14	1.25	0						
E	10.78	10.32	10.10	2.27	1.07	0					
F	10.81	10.35	10.13	2.28	1.06	0.09	0				
G	10.97	10.51	10.29	2.44	1.21	0.22	0.16	0			
H	10.90	10.44	10.22	2.40	1.19	0.12	0.15	0.15	0		
I	10.94	10.49	10.27	2.45	1.25	0.18	0.20	0.17	0.06	0	
J	10.98	10.52	10.30	2.49	1.29	0.22	0.25	0.21	0.11	0.05	0

Graph creation

The graph in this study can be seen in the following figure. Where several nodes are interrelated with each other. The estimated distance from the starting point to the destination point can be more accurate if more nodes are used.

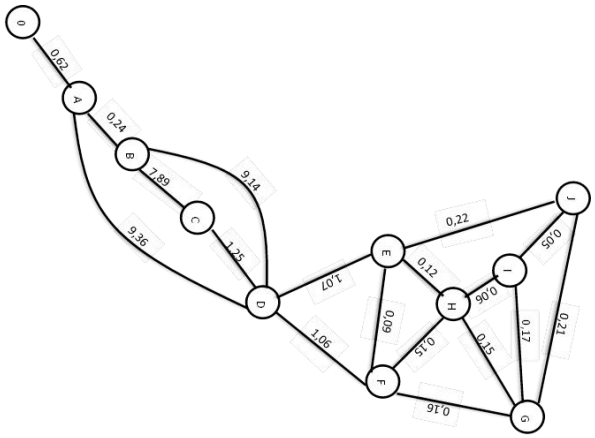

Figure 2. Graph *Maps* Between Stores

The next stage is to find heuristic values.

Table 3. The First Route of Heuristic Calculation Results

N	0	A	B	C	D	E	F	G	H	I
h(n)	10,52	10,30	2,49	1,24	0,22	0,25	0,21	0,21	0,11	0,01

The first stage, because in *open* only has 1 node (ie 0), then 0 is chosen as the best node. The next best node is $f(A) = g(0) + g(0\ to\ A) + h(n) = 0.62 + 10.52 = 11.14$

Closed : 0

Open : A

In the second stage, A with the lowest cost is selected as the best node and moved to the *closed* list, all successors A and B are opened, then added to the *open list*. The next best node is $f(B) = 0.24 + 10.30 = 10.54.$

Closed : 0, A

Open : B, D

In the third stage, B with the lowest cost is selected as the best node and moved to the *closed* list, all successors B are opened, namely C and D, and then added to *the open list*. The next best node is $f(C) = 7.89 + 2.49 = 11.38$.

Closed : A, B

Open : C,D

In the fourth stage, the lowest-cost C is selected as the best node and moved to the *closed* list, all successors to C are opened, namely D, and then added to the *open list*. The next best node is $f(D) = 1.25 + 1.29 = 2.54$.

Closed : A, B, C.

Open : D.

In the fifth stage, the D with the lowest cost is selected as the best node and moved to the *closed* list, all successors D are opened namely E and F, then added to the *open list*. The next best node is $f(E) = 1.07 + 0.22 = 1.29$.

Closed : A, B, C, D.

Open : E, F.

In the sixth stage, the lowest-cost E is selected as the best node and moved to the *closed* list, all successors to E are opened, namely F and J, and then added to the *open list*. The next best node is $f(J) = 0.22 + 0 = 1.31$.

Closed : A, B, C, D, E, J.

Open : F

Table 4. *Open Node Value*

Open List		
Purpose	**f(n)**	**from**
D	10,65	A
D	10,43	B
F	1,31	D
H	0,23	E

Table 5. *Closed Node Value*

Closed List		
Purpose	f(n)	from
A	11,14	0
B	10,54	A

Closed List		
C	10,38	B
D	2,54	C
E	1,29	D
J	0,22	E
Total	36,11	

From tables 4 and 5 it can be concluded as follows: starting with determining the starting and ending points. Then look for the $f(n)$ value, after finding the $f(n)$ value, the next step is to enter the smallest $f(n)$ value into the closed clay and do it repeatedly until the goal point is reached.

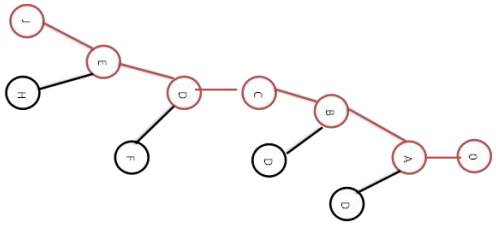

Figure 3. First Stage to Sixth Stage

After getting the shortest route 0 – J is 0-A-B-C-D-E-J with a total distance of 11.29 km. Because this case study is about distribution, all stores must be visited, therefore proceed to choose the final destination with the store farthest from store J. And get store F with a distance of 0.25 km.

Table 6. Second Route Results of Heuristic Values

n	**J**	**I**	**G**	**H**	**F**
h(n)	0,25	0,20	0,16	0,15	0

The first stage, because previously ended in J, then in Open there is only 1 node (ie J), then J is chosen as the best node. The next best node is f (I) = 0.05 + 0.20 = 0.25 km.

In the second stage, the I with the lowest cost is selected as the best node and moved to the *closed* list, all successors I are opened, namely H and G, and then added to the *open list*. The next best node is f(H) = 0.06 + 0.15 = 0.21.

In the third stage, the lowest-cost H is selected as the best node and moved to the *closed* list, all successors to H are unlocked, namely F and G, and then added to *the open list*. The next best node is f(F) = 0.16 + 0 = 0.16.

Table 7. *Open Node Value*

Open List		
Purpose	**f(n)**	**from**
G	0,37	J
G	0,32	I
G	0,31	H

Table 8. *Closed Node Value*

Closed List		
Purpose	**f(n)**	**from**
I	0,25	J
H	0,21	I
F	0,15	H
Total	0,61	

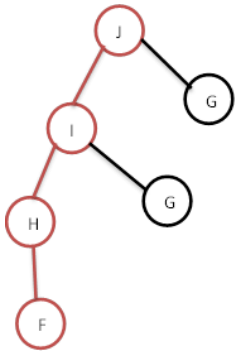

Figure 4. Second Route Stages One to Three

There is one more store that has not been served, namely store G. Due to distribution, all stores must be served. Then directly distributed to G stores with f(g) = 0.16 + 0 = 0.16 km.

So the results of the A-Star algorithm in distributing cooking oil are divided into two routes. With the first route 0- A-B-C-D-E-J with a total distance of 11.29 km. And the second route J-I-H-F and G with a total distance of 0.42 km so that the overall distance is 11.71 km.

The data obtained from the company is the delivery of cooking oil 2 times / route.

Table 9. Corporate Routes

No	Route	Mileage (Km)
1	0-J-E-G-F-I-H	11,83
2	0-A-D-C-B	19,12
	Total	30,95

Based on the table above, a comparison of the company's route and the A-Star algorithm is obtained as follows:

Table 10. Comparison of Company Routes with A-Star Algorithm

Route	Company Route Mileage (Km)	A-Star Algorithm Mileage (Km)
1	11,83	11,71
2	19,12	
Total Mileage (Km)	30,95	11,71

Based on the route of the company and the route using the A-Star algorithm, the percentage of total mileage savings value is obtained as follows (Arifta & Rakhmawati, 2023):

$$= x\ 100\% \frac{The\ total\ distance\ of\ the\ company's\ route\ -\ The\ total\ distance\ of\ the\ A-Star\ algorithm}{The\ total\ distance\ of\ the\ company's\ route}$$

$$= x\ 100\% \frac{30,95-11,71}{30,95}$$

$$= 62.16\%$$

So the percentage of total route mileage savings value is 62.16%. This shows that the A-Star algorithm can minimize distance and save company expenses.

CONCLUSION

Research on the distribution of cooking oil was conducted at PT. XYZ Karo Regency, where there are obstacles in determining the route of distribution of goods. This study aims to minimize cooking oil distribution costs and find the optimal shortest route. The A-Star algorithm is a distance determination algorithm that has the optimum ability to solve problems related to determining the shortest route. So the results of the A-Star algorithm in distributing cooking oil are divided into two routes. With the first route 0- A-B-C-D-E-J with a total distance of 11.29 km. And the second route J-I-H-F and G with a total distance of 0.42 km so that the overall distance is 11.71 km. While the company's route is 30.95 km. Then the percentage of mileage savings is 62.16%. So that the A-Star algorithm can be used to minimize distance and save company costs.

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REFERENCES

Arifta, E., & Rakhmawati, F. (2023). Analysis of Book Distribution Routes Using the Capacity Vehicle Routing Problem (CVRP) Method Using the Sweep Algorithm. *Sinkron*, *8*(1),360-367. https://doi.org/10.33395/sinkron.v8i1.12013

Bakhtiar, M., & Rahmi, M. (2017). Penentuan Rute Distribusi Sirup Untuk Meminimalkan Biaya Transportasi. *Industrial Engineering Journal*, 6(1),10–15. https://doi.org/10.53912/iejm.v6i1.152

Damayanti, T. R., Kusumaningrum, A. L., Susanty, Y. D., & Islam, S. S. (2020). Route Optimization Using Saving Matrix Method – A Case Study at Public Logistics Company in Indonesia. *Proceedings of the 5th NA International Conference on Industrial Engineering and Operations Management*, 10–14. http://www.ieomsociety.org/detroit2020/papers/372.pdf

Fadilah, A., Mansyur, H. St., & Purnawansyah. (2022). Analisis Perbandingan Algoritma Floyd Warshall dan A Star dalam Penentuan Lintasan Terpendek. *Jurnal Teknik Informatika Dan Sistem Informasi*, *9*(4),2736-2751. https://jurnal.mdp.ac.id/index.php/jatisi/article/download/2663/1002/

Fernando, Y., Mustaqov, M. A., & Megawaty, D. A. (2020). Penerapan Algoritma A-Star Pada Aplikasi Pencarian Lokasi Fotografi Di Bandar Lampung Berbasis Android. *Jurnal Teknoinfo*, *14*(1), 27-34. https://doi.org/10.33365/jti.v14i1.509

Gede Wahyu Antara Dalem, I. B. (2018). Penerapan Algoritma A* (Star) Menggunakan Graph Untuk Menghitung Jarak Terpendek. *Jurnal RESISTOR (Rekayasa Sistem Komputer)*, *1*(1),41-47. https://doi.org/10.31598/jurnalresistor.v1i1.253

Maulana, I., & Chandra, J. C. (2018). Implementasi Prim's Algorithm dan A* Pathfinding Pada Game Roguelike Sederhana. *Sistem Komputer Dan Teknik Informatika*, *1*(3), 1018-1025. https://jom.fti.budiluhur.ac.id/index.php/SKANIKA/article/view/2520

Natasya, R., Sitepu, B., Ngurah, I. G., & Cahyadi, A. (2022). Penentuan Rute Terpendek Menggunakan Algoritma A Star. *Jurnal Nasiona Teknologi Informasi Dan Aplikasinya*, 1(1), 431–440. https://ojs.unud.ac.id/index.php/jnatia/article/download/92697/47070

Nurdian, R. A., Prasidyajyandalu, R., Masyhuri, Moch. B. A., & Rolliawati, D. (2020). Pemodelan Simulasi Produksi Bakso Dan Sistem Distribusi. *Jurnal Technopreneur (JTech)*, *8*(1), 59-64. https://doi.org/10.30869/jtech.v8i1.413

Prasetyo, A. C., Arnandi, M. P., Hudnanto, H. S., & Setiaji, B. (2019). Perbandingan Algoritma Astar dan Djikstra dalam Menentukan Rute Terdekat. *Jurnal Ilmiah SISFOTENIKA*, *9*(1), 36-46. http://dx.doi.org/10.30700/jst.v9i1.456

Putra, A. B. W., Rachman, A. A., Santoso, A., & Mulyanto, M. (2020). Perbandingan Hasil Rute Terdekat Antar Rumah Sakit di Samarinda Menggunakan Algoritma A*(star) dan Floyd-Warshall. *Jurnal Sisfokom (Sistem Informasi Dan Komputer)*, *9*(1), 59-68. https://doi.org/10.32736/sisfokom.v9i1.685

Putra, F. D., Rakhmawati, F., & Cipta, H. (2021). Penentuan Rute Transportasi Kendaraan Umum Kota Medan Dengan Menggunakan Nearest Neighbor Method Dan Closed Insertion Method. *Zeta - Math Journal*, *6*(2),6-10. https://doi.org/10.31102/zeta.2021.6.2.6-10

Ramadhan, Z., Zarlis, M., Efendi, S., & Andysah. (2018). Perbandingan Algoritma Prim Dengan Algoritma Floyed-Warshall Dalam Menentukan Rute Terpendek (Shortest

Path Problem). *Jurnal Riset Komputer (JURIKOM)*, 5(2),130-139. http://ejurnal.stmik-budidarma.ac.id/index.php/jurikom

Rohmawati, R. M., Fathoni, M. I. A., & Ismanto, I. (2022). Penerapan Algoritma Welch-Powell Pada Penyusunan Jadwal Perkuliahan di Program Studi Pendidikan Matematika. *Euler : Jurnal Ilmiah Matematika, Sains Dan Teknologi*, *10*(2),200-210. https://doi.org/10.34312/euler.v10i2.16649

Simbolon, O. J. (2022). Simulasi Pencarian Rute Terpendek dengan Metode Algoritma A Star. *Login: Jurnal Teknologi Komputer*, *16*(1), 23-32. http://login.seaninstitute.org/index.php/Login

Suhendri, S., Dede Abdurahman, & Dani Irfan Maulana. (2021). Implementasi Algoritma A-Star Untuk Pemetaan Lokasi Sarana Kesehatan Kabupaten Majalengka Berbasis Geographic Information System (GIS). *INFOTECH Journal*,7(2), 57-65. https://doi.org/10.31949/infotech.v7i2.1512

Sulastio, B. S., Anggono, H., & Putra, A. D. (2021). Sistem Informasi Geografis Untuk Menentukan Lokasi Rawan Macet Di Jam Kerja Pada Kota Bandarlampung Pada Berbasis Android. *Jurnal Teknologi Dan Sistem Informasi (JTSI)*, *2*(1), 104-111. http://jim.teknokrat.ac.id/index.php/JTSI

Suyitno, P. P. W., Indrajit, R. E., & Fauzi, M. (2017). Penerapan Data Mining Dalam Menangani Kemacetan Di Jakarta. *Ikraith-Informatika*, *1*(2), 53-60. https://journals.upi-yai.ac.id/index.php/ikraith-informatika/article/view/110

Syathirah, A. S., Kusuma, P. D., & Ningsih, C.S. (2021). Analisa Sistem Pencarian Jalur Pada Aplikasi Panggilan Darurat Menggunakan Algoritma Hill Climbing Dan Greedy. *EProceedings Of Engineering*, 8(5), 6022-6029. https://openlibrarypublications.telkomuniversity.ac.id/index.php/engineering/article/view/16207

Wahyuni, M. S., Affandi, E., & Setiawan, D. (2022). Jaringan Syaraf Tiruan Hopfield Dalam Mencari Rute Terpendek Untuk Pendistribusian Barang. *Jurnal Teknisi*, *2*(1), 1-4. https://jurnal.goretanpena.com/index.php/teknisi/article/view/852

Yohanes, D. N., & Rochmawati, N. (2022). Implementasi Algoritma Collision Detection dan A*(A Star) pada Non Player Character Game World Of New Normal. *Journal of Informatics and Computer Science (JINACS)*, *3*(3), 322-333. https://doi.org/10.26740/jinacs.v3n03.p322-333