Fuzzy-Dijkstra Algorithm Implementation on Determining Logistic Distribution Route for Evacuation Post of Merapi Eruption Victims

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***Abstract*—Distribution of logistics is one of the important actions and must be done quickly in disaster relief. The action requires real-time field knowledge and quick handling. Therefore, the determination of the logistic distribution route is important. The study aims to find a logistic distribution route with multi-parameter combining Dijkstra algorithm and Fuzzy logic. Sugeno Fuzzy Inference System considers 3 parameters i.e., distance between posts, road density, and number of refugees and processed to obtain vertex and edge weight on the graph. Implementation Dijkstra's algorithm is used in the search of distribution routes in the model graph because the Dijkstra algorithm has the principle of finding a route with a minimum of total weights between 2 vertexes given so that it fits the case of searching for distribution routes that require fast handling as it concerns the souls of many people. The results showed that from 52 experiments on a graph containing 13 vertex and 44 edges, and 4 times that is, best time, morning, afternoon, and night. Graph formed and graded worth 48 graphs or 92.31 percent; proving that the route determination of Fuzzy-Dijkstra Algorithm can be performed and produce an effective and efficient route.**

***Index Terms*—Dijkstra Algorithm; Logistic Distribution Route; Sugeno Fuzzy Inference System.**

I. INTRODUCTION

Merapi is the most active Volcano on Java and even Indonesia [1]. Merapi is located between two provinces of Central Java and Yogyakarta [1]. Since the 1600s, it had erupted more than 80 times. Among 2010 that caused a lot of damage, loss and fatalities. The death toll of 347 people. Most victims were in Sleman Regency, 246 people. While the refugees reached 410,388 Persons [2]. Distribution of logistics is one of the important actions and must be done quickly in disaster relief. The action requires real-time field knowledge and quick handling. The problem that often happens is the distribution of logistics that are less effective and efficient [3]. Therefore, the determination of the logistic distribution route is important.

Setyadi's research determined the evacuation route based on the case model of Traveling Salesman Problem (TSP) using the Greedy-Fuzzy algorithm [4]. The results of the study found that 88% of the paths of 25 experiments were found to be feasible, with a 5% upper tolerance of exhaustive search results. Santoso, Setiawan, and Prajogo compared the performance of Dijkstra, A *, and Ant algorithms in search of the shortest path of single-source case model [5]. The result of the research shows that the search of Dijkstra and A* algorithm path requires simultaneous operation.

This research performs the search of logistic distribution route with multi-parameter combining Dijkstra algorithm and Fuzzy logic. The distribution route considers three parameters: distance between posts, road density, and number of refugees. Processed with Sugeno Fuzzy Inference System to get vertex and edge weight on graph. Sugeno's method is chosen because it uses a linear output membership function or a constant [6]. Further Implementation Dijkstra's algorithm is used in searching the distribution route by checking the cost of the vertex to be passed and selecting the vertex with the lowest total cost. Because Dijkstra's algorithm has the principle of "finding a route with a minimum of total weights between 2 given vertex" [7]. Therefore the search for distribution routes that require fast handling as it concerns the souls of many people can be performed efficiently and effectively.

II. LITERATURE REVIEW

A. Graph

Graph is a set of dots or vertex that are connected to one another via arc or edge [8]. The graph can be grouped by the presence or absence of direction on its edge; and whether or not there is a weight on its edge [9].

B. Fuzzy Logic

Set of elements represent in continuous intervals with range [0,1]. If X is a set of elements denoted x, then the fuzzy set A in X is a set of consecutive pairs, with $\mu_A(x)$ is a degree of membership of x [10]:

$$A=\{(x,\ \mu_A(x))|x\ \in X\} \quad (1)$$

The membership function of the fuzzy set plays a very important role to represent the problems and produce an accurate decision [10].

C. Fuzzy Inference System

Fuzzification **-** The process maps the numerical values into the fuzzy set and determines the degree of membership in the fuzzy set [11]. This is done because the process data that are not in the fuzzy set must be changed.

Inference Machine **-** The reasoning machine is the process of implication in the reasoning of the input value in order to determine the output value as a form of decision-making. Reasoning using fuzzy input and fuzzy rules has been specified to produce fuzzy output [12].

Rule-Based **-** Fuzzy logic is a rule-based system, essentially on the application of IF-THEN rules. Each IF-THEN rule on a fuzzy knowledge base relates to a fuzzy relation. Sugeno's method implication function is Min

Defuzzification - Input of defuzzification process is fuzzy set obtained from the composition of the fuzzy rules, while the resulting output is number of the fuzzy set. Sugeno's method uses Weight Average to perform defuzzification (Z *)[13].

$$Z* = \frac{\sum_{i=1}^{n} aizi}{\sum_{i=1}^{n} ai} \quad (2)$$

With αi is the degree of membership of the implication function on rule i. Zi is the output value of the i rule whereas n is the number of rules used.

D. Dijkstra Algorithm

Dijkstra's algorithm solves the problem of finding the shortest route in a weighted graph [7]. Performed by examining the weights of the vertex passed and selecting the vertex with the lowest total cost [14]. The step in determining the shortest route on Dijkstra's algorithm is:

1. Select the initial vertex initialized with '0' and infinity values on the other vertex.
2. Form a table consisting of vertex, label, weight, and predecessor. Complete the weighted column obtained from the initial vertex distance to all vertex directly connected to the initial vertex.
3. If the initial vertex is found, set it as the selected vertex.
4. Set the selected vertex with permanent labels and update the vertex directly connected.
5. Specify a temporary vertex that is connected to a previously selected vertex and is the smallest weight seen from the table and specify as the next selected vertex.
6. Is the selected vertex a destination vertex? If yes, then the set of selected vertex or predecessor is the circuit that shows the shortest path.

III. PROPOSED METHOD

A. Data Collection

Collecting data needed is location map of disaster that covers the map of Sleman Regency. It's limited to the location of refugee evacuation posts along with the road network and posts accommodation needs.

B. Preprocessing

At this step, the data that has been collected will be selected to be processed into system.

Data Processing - Spatial data processing is processed into vertex, edges, and weights for both graph modeling. There are 3 variances of parameter that processed from spatial data, namely distance between 2 posts; road density on morning, evening, afternoon; and refuges number.

Graph Modeling - This stage implements the data that has been processed. Then modeled into a weighted graph. So the graph formed consists of:

1. Vertex: longitude and latitude of evacuation post location.
2. Edge: connectedness between 2 vertexes or road network.
3. Weight: the weight for each edge. The weights are taken from the parameter processing of the Fuzzy Inference System.

C. Fuzzification

Fuzzification stage determines the boundary value of parameters for distance, density of the road, and number of refugees as shown in Table 1. Distance parameter is divided by 3 conditions, namely; near, enough, far away. Road density parameter divided by 3 conditions, namely; quiet, normal, crowded. Number of refugees parameter divided by 3 conditions, namely: few, medium, and many. Then look for the degree of membership of each parameter.

Table 1
Boundary Value of Parameters

Distance (D)		Road Density (RD)		Refugees (R)	
Near	0 – 1500 metre(s)	Quiet	0-400 units/hours	Few	0 – 600 victim(s)
Enough	1500 – 3500 m	Normal	400-800 units/hours	Medium	600 – 1200 vtms
Far Away	>=3500 m	Crowded	>=800 units/hours	Many	>=1200 victims

Membership function of distance:

$$\mu_{\text{near}}[y] = \begin{cases} 0, & y \geq 2500 \\ \frac{(2500-y)}{(2500-1500)}, & 1500 < y < 2500 \\ 1, & y \leq 1500 \end{cases} \quad (3)$$

$$\mu_{\text{enough}}[y] = \begin{cases} 0, & y \leq 1500 \text{ or } y \geq 3500 \\ \frac{(y-1500)}{(2500-1500)}, & 1500 < y < 2500 \\ \frac{(3500-y)}{(3500-2500)}, & 2500 < y < 3500 \\ 1, & y = 2500 \end{cases} \quad (4)$$

$$\mu_{\text{faraway}}[y] = \begin{cases} 0, & y \leq 2500 \\ \frac{(y-2500)}{(3500-2500)}, & 2500 < y < 3500 \\ 1, & y \geq 3500 \end{cases} \quad (5)$$

Membership function of road density:

$$\mu_{\text{quiet}}[y] = \begin{cases} 0, & y \geq 600 \\ \frac{(600-y)}{(600-400)}, & 400 < y < 600 \\ 1, & y \leq 400 \end{cases} \quad (6)$$

$$\mu_{\text{normal}}[y] = \begin{cases} 0, & y \leq 400 \text{ or } y \geq 800 \\ \frac{(y-400)}{(600-400)}, & 400 < y < 600 \\ \frac{(800-y)}{(800-600)}, & 600 < y < 800 \\ 1, & y = 600 \end{cases} \quad (7)$$

$$\mu_{\text{crowded}}[y] = \begin{cases} 0, & y \leq 600 \\ \frac{(y-600)}{(800-600)}, & 600 < y < 800 \\ 1, & y \geq 800 \end{cases} \quad (8)$$

Membership function of number of refugees:

$$\mu_{\text{fex}}[y] = \begin{cases} 0, & y \geq 900 \\ \frac{(900-y)}{(900-600)}, & 600 < y < 900 \\ 1, & y \leq 600 \end{cases} \quad (9)$$

$$\mu_{\text{medium}}[y] = \begin{cases} 0, & y \leq 600 \text{ or } y \geq 1200 \\ \frac{(y-600)}{(900-600)}, & 600 < y < 900 \\ \frac{(1200-y)}{(1200-900)}, & 900 < y < 1200 \\ 1, & y = 900 \end{cases} \quad (10)$$

$$\mu_{many}[y] = \begin{cases} 0, y \leq 900 \\ \frac{(y-900)}{(1200-900)}, 900 < y < 1200 \\ 1, y \geq 1200 \end{cases} \quad (11)$$

D. Sugeno Fuzzy Inference System

Inference system using Fuzzy Input and Fuzzy rules that have been determined so as to produce Fuzzy output. The first step in the inference stage is establishing of Fuzzy rules. Fuzzy rules consist of 27 rules which are a combination of 3 parameters. Details of Sugeno's inference rules can be seen in Table 2. Each Fuzzy rule is then evaluated using the Min implication function.

Table 2
Sugeno's Inference Rules

No	D	RD	R	Weight (W)
1	Near	Quiet	Many	28
2	Near	Quiet	Medium	32
3	Near	Quiet	Few	36
4	Near	Normal	Many	40
5	Near	Normal	Medium	44
6	Near	Normal	Few	48
7	Near	Crowded	Many	52
8	Near	Crowded	Medium	56
9	Near	Crowded	Few	60
10	Enough	Quiet	Many	49
11	Enough	Quiet	Medium	53
12	Enough	Quiet	Few	57
13	Enough	Normal	Many	61
14	Enough	Normal	Medium	65
15	Enough	Normal	Few	69
16	Enough	Crowded	Many	73
17	Enough	Crowded	Medium	77
18	Enough	Crowded	Few	81
19	Faraway	Quiet	Many	68
20	Faraway	Quiet	Medium	72
21	Faraway	Quiet	Few	76
22	Faraway	Normal	Many	80
23	Faraway	Normal	Medium	84
24	Faraway	Normal	Few	88
25	Faraway	Crowded	Many	92
26	Faraway	Crowded	Medium	96
27	Faraway	Crowded	Few	100

E. Defuzzification

At the defuzzification stage, the output of the inference process is converted to firm value. The defuzzification process performs an average weight calculation as in Equation (2). Output is a firm value into the weight and direction of the graph used in Dijkstra's Algorithm.

F. Determining Dijkstra's Algorithm Route

Dijkstra's algorithm uses weighted and directed graph of defuzzification result input. The output is distribution route and total weight. Figure 1 shows the flowchart of the distribution route search by Dijkstra's algorithm method.

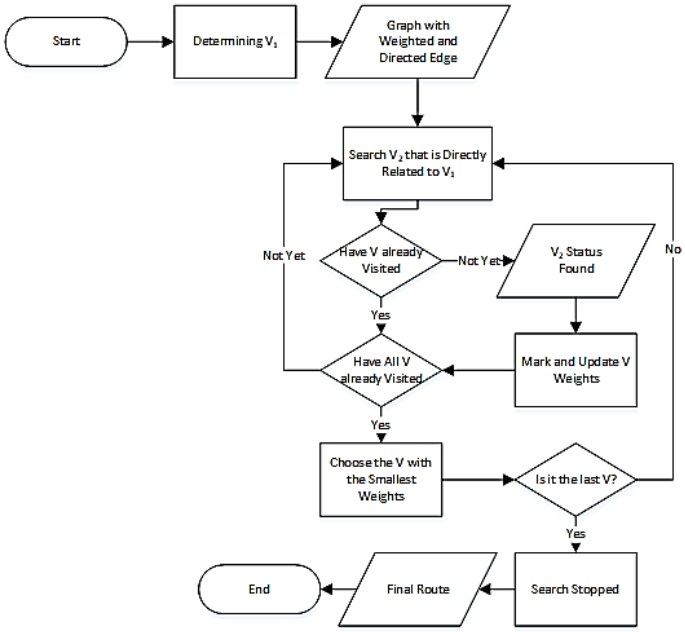

Figure 1: Flowchart of Distribution Route Search by Dijkstra Algorithm

IV. Result And Discussion

A. Data Description Result

Sleman District data obtained from Google Maps combined map of dissemination of disaster refugee camps Merapi volcano disaster and information table of the refugee post by Clinical Environment Disaster Mitigation Faculty of Geography Gadjah Mada University on the survey dated November 10, 2010 and on the web-based application http: / /graph.latcoding.com/. The data does not cover all of Sleman Regency. Because the data is limited to the coverage of areas where there are refugee posts.

B. Preprocessing Result

Spatial data processing of Sleman Regency is done to eliminate unnecessary spatial data so that only the remaining data such as vertex (V), edge, the weight of both as material of graph modeling. The area is only partly taken as a sample. 64 vertex were taken as many as 13 vertexes. Spatial data needed are: Distance between post with district, province and national road; Traffic road density (RD) along with a specified time (T) as a sample, T1= 08.30-09.30, T2= 16.00-17.00, T3= 20.00-21.00 (GMT+7); Number of refugees (R) of destination post; Spatial data that have been processed is shown in Table 3. Then modeled into a weighted graph as shown in Figure 2.

C. Result of Sugeno Fuzzy Inference System

Fuzzification - The inference stage generated the degree of membership of each parameter. The distance parameters use the functions in Equation (3), (4), and (5). The road density parameters use the functions in Equation (6), (7), and (8). While the parameter of number of refugees using the function in Equation (9), (10), and (11). The example we can take from Table 4.1. At Id. V. 8, ie from post 49 (P49) to post 51 (P51) with morning time. So we can take the data of each parameter, namely: parameter distance = 1596 meters; Density parameter = 364 units/hours; Refugee parameters = 850 people. Then total evaluation result shown as in Table 4.

Table 3
Example of Spatial Data Processing of Sleman Regency

Id. V	*V1*	*V2*	DR *T1*	*T2*	*T3*	D	R
8.	P49	P51	720	1384	364	1596	850
11.	P49	P45	452	365	259	2298	258

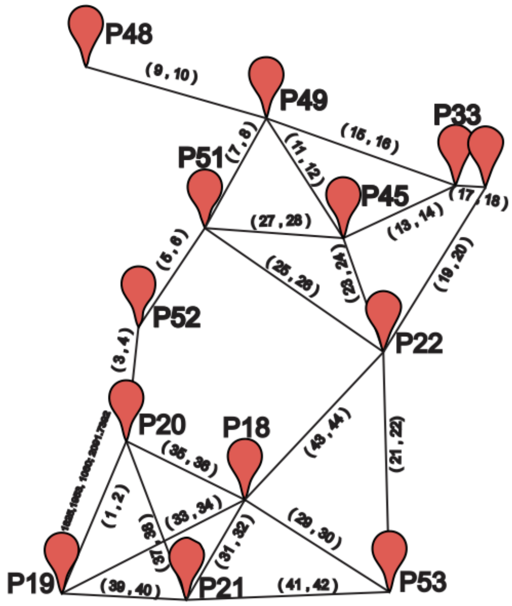

Figure 2: Graph Model of Spatial Data

Table 4
Total Evaluation Result

No	D	RD	R	W
2.	Near	Quiet	Medium	32
	$\alpha_1 = \text{Min}(0{,}904; 1; 0{,}833;) = 0{,}833$			
3.	Near	Quiet	Few	36
	$\alpha_1 = \text{Min}(0{,}904; 1; 0{,}167;) = 0{,}167$			
11.	Enough	Quiet	Medium	53
	$\alpha_1 = \text{Min}(0{,}096; 1; 0{,}833;) = 0{,}096$			
12.	Enough	Quiet	Few	57
	$\alpha_1 = \text{Min}(0{,}096; 1; 0{,}167;) = 0{,}096$			

Inference Machine and Rule-Based

For known distance membership function, y = 1596, so:
$y \equiv 1500 < y < 2500$, enter on terms Equation (3) and (4).
Equation (3) ≡ μ near [y] = $\frac{(2500-y)}{(2500-1500)} = \frac{904}{1000}$ = 0,904.
Equation (4) ≡ μ enough [y] = $\frac{(y-1500)}{(2500-1500)} = \frac{96}{1000}$ = 0,096.
Equation y ≡ $y \leq 2500$, enter on terms Equation (5) ≡ μ faraway [y] = 0.

For known density road membership function, y = 364 units/hours, so:
$y \equiv y \leq 400$, enter on terms eq. (6) ≡ μ quiet [y] = 1.
$y \equiv y \leq 400$, enter on terms eq. (7) ≡ μ normal [y] = 0.
$y \equiv y \leq 600$, enter on terms eq. (8) ≡ μ crowded [y] = 0.

For known density road membership function, y = 850 people, so:
$y \equiv 600 < y < 900$, enter on terms eq. (9) and eq. (10).
Equation (14) ≡ μ few [y] = $\frac{(900-y)}{(900-600)} = \frac{50}{300}$ = 0,167.
Equation (15) ≡ μ medium [y] = $\frac{(y-600)}{(900-600)} = \frac{250}{300}$ = 0,833.
Equation $y \equiv y \leq 900$, enter on terms Equation (11) ≡ μ many [y] = 0.

Defuzzification - The output of the inference process is converted back to firm value and processed by using the weight average calculation as in Equation (2). Then the result becomes a weight on each edge.

$$Z^* = \frac{\alpha_1 * z1 + \alpha_2 * z2 + \alpha_3 * z3 + \cdots + \alpha_9 * z9}{\alpha_1 + \alpha_2 + \alpha_3 + \cdots + \alpha_9}$$
$$= \frac{(0{,}833 * 32) + (0{,}167 * 36) + (0{,}096 * 53) + (0{,}096 * 57)}{0{,}833 + 0{,}167 + 0{,}096 + 0{,}096}$$
$$= \frac{43{,}228}{1{,}192} = 36{,}26510067114039$$

Thus, weighted edge after defuzzification with the Sugeno Fuzzy Inference System Method is as shown in Table 5.

Table 5
Weighted Edge

Id. V	V1	V2	Weight- *Update Edge* *T1*	*T2*	*T3*
8.	P49	P51	56.62	60.26	36.26
11.	P49	P45	54.91	52.76	52.76

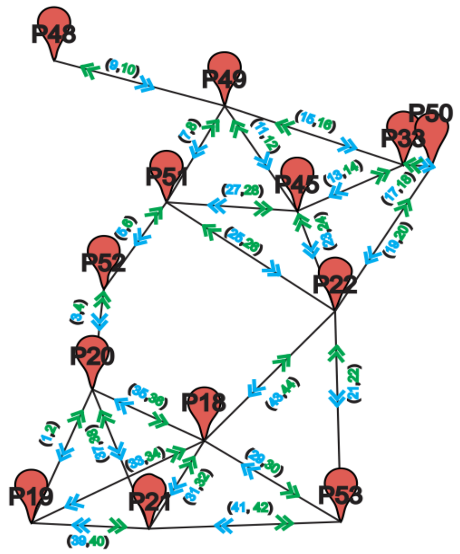

Figure 3: Graph with Weighted and Directed Edge

D. Determining Dijkstra's Algorithm Route

The first determining the evacuation post or the nearest starting vertex of the logistics post. Then finding the relationship with other vertex and the weights that have been obtained. In the process of getting the previous defuzzification value, we have got the value from fuzzification calculation. The defuzzification value is weighted. In this case, we take the example on P49 as shown in Table 6.

Table 6
The First Iteration of Determining Route

No	V1	V2	Weighted Edge *T1*	*T2*	*T3*
1.	P49	P51	56.62	60.26	36.26
2.	P49	P45	54.91	52.76	52.76
3.	P49	P48	68.27	64.94	57.2
4.	P49	P33	71.86	68.4	68.4

Then the destination vertex is taken with the smallest defuzzification value. In this process, it initiates the defuzzification value into the total weights on the route formed. Then the total weight now is 36.26. Next after getting the destination vertex, it is used as the starting vertex. In this case, P51 becomes the initial vertex after becoming the destination vertex. Then we form a table that has a relationship with P51 as shown in Table 7.

Table 7
The Second Iteration of Determining Route

V1	V2	Weighted Edge		
		T1	*T2*	*T3*
P51	P52	51.83	56.59	32.59
P51	P49	43.88	54.07	48.32
P51	P22	69.56	64.9	64.9
P51	P45	82.37	82.37	82.37

The first sequence with the smallest defuzzification taken that is 32.59. Then added to the total weight of the last obtained. Then the total route weight becomes 36.26 + 32.59 = 68.85. Dijkstra will do iteration and find the best route till the end of vertex was visited as shown in Table 8.

Table 8
Determined Route with Total Weight

Iteration	V1	V2	Wt
1	P49	P51	36.26
2	P51	P52	68.85
3	P52	P20	104.78

E. Testing

The test is performed to prove that the result of route with same start of vertex but in different time. That test has been processed on Fuzzy-Dijkstra Algorithm, can give different recommendation route that more effective and efficient as shown in Figure 4.

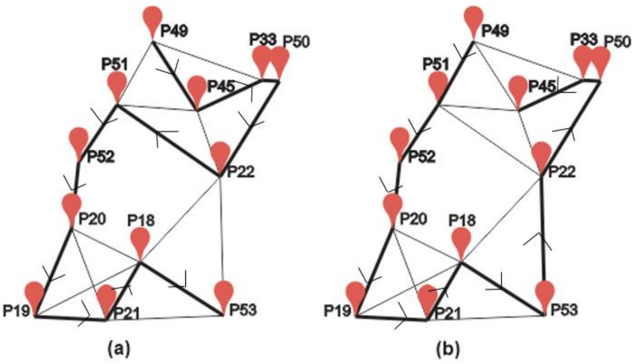

Figure 4: Result of Route with Same Start of Vertex and Different Time.

Table 9 shows six experimental samples of 52 on a graph that containing 13 vertex and 44 edges, and 4 times. Graphs are formed and graded worth 48 graphs or 92.31%. Proves that the Fuzzy-Dijkstra Algorithm route determination can be performed and produce an effective and efficient route.

Table 9
Result of Fuzzy-Dijkstra Algorithm

No	V	T	Result	
			Formed Route	Wt
1.	P49	T0	49-51-52-20-19-21-18-53-22-50-33-45	617.82
2.	P49	T1	49-45-33-50-22-51-52-20-19-21-18-53	649.19
3.	P19	T0	19-20-52-51-49-45-33-50-22-53-18-21	631.82
4.	P20	T0	20-52-51-49-45-33-50-22-53-18-21-19	651.57
5.	P53	T0	52-20-19-21-18-53-22-50-33-45-49-51	629.99
6.	P53	T1	52-51-49-45-33-50-22-53-18-21-20-19	684.26

V. CONCLUSION

Based on the results of research can be concluded that the logistics distribution route at evacuation posts can be determined by a combination of Fuzzy and Dijkstra Algorithms. The route can be accessed more efficient and effective than using manuals with approximate distance only. Recommendations for further research that using more parameters are considered then it will be closer to real-time.

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