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SENSOR SELECTION COMPARISON BETWEEN FUZZY TOPSIS ALGORITHM AND SIMPLE ADDITIVE WEIGHTING ALGORITHM IN AUTOMATIC INFUSE MONITORING SYSTEM APPLICATION

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Abstract -- *One of the critical equipment to support a patient in the hospital would be an infuse system. One of the main problems with the infuse system was manual monitoring. Few researchers try to build a low cost infuse system using a low-cost sensor and microcontroller. This paper proposes a fuzzy Topsis algorithm and Simple Additive Weighting (SAW) algorithm to choose the best sensor for a low cost to the infuse system, which is one of the Multiple Criteria Decision Making (MCDM) problems. Several simulations using three sensors, such as LDR (photoresistor), phototransistor, and photodiode, are performed. By using these two algorithms, it can be shown that the phototransistor emerges as the best sensor with value 1, even though it has the price six times higher from the LDR sensor and three times higher from the photodiode.*

Keywords: *Fuzzy Topsis; Photo Resistor; Photo Diode; Photo Transistor; Infuse System; MCDM*

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INTRODUCTION

In this digital age of information, everything will be done automatically, and thus less work will be done manually [1]. The automation process was favored better than manual because it could reduce human error and improve system performance [2]. From building a car and motorcycle to flying a plane, the automatic process covers broad fields. Unfortunately, even though the automation process was advantageous over the manual process, some jobs still process manually. Even at emergency systems that involve human life, such as hospital service.

One of the medical processes that still be done manually would be an infusion process by the nurse. Infusion consists of the administration of medication through a needle or catheter, as can be seen Figure 1. It is prescribed for patients whose condition is so severe that they cannot be treated effectively by oral medications [3]. One of the manual infusion processes is the nurse needs to check to infuse level regularly to prevent the infusion liquid from empty [4]. This manual process infusion check proved to be fatal for the patient if the nurse made a human error, such as empty infusion lead to death to the patient [5].

To prevent this problem, it needs an automatic infusion monitoring system. Several researchers propose a simple and cost reduction using a general microcontroller and sensor. Wadianto proposes Arduino as a microcontroller and photodiode as a sensor [6]. Arslan proposes to add wireless communication capabilities using the XBee module [7]. Gil and colleagues are adding monitor capabilities using a PC and android app [8]. Another researcher, Zhihui, was adding speed droplet capabilities using the motor drive to the pull-infuse system [9].

Figure 1. Infusion Manual Process

Even though a lot of researchers already made the automatic infusion monitoring system, unfortunately, they all focused on the system. Meanwhile, there is not a study about how to select the best sensor for the automatic infusion monitoring system. This problem is one of many Multiple Criteria Decision Making (MCDM) problems. Therefore, to solve the MCDM problem such as this, in this paper, we propose the use of a fuzzy Topsis and Simple Additive Weighting (SAW) method to select the best sensor for automatic infusion monitoring system. The sensor needs to compare and choose was LDR (photoresistor), phototransistor, and photodiode.

METHOD

Simple Additive Weighting (SAW) Algorithm

Simple Additive Weighting (SAW) often also known as the method of addition weighted. The basic concept of the SAW method is looking for a weighted sum of rating performance on each alternative on all attributes. SAW method was developed by Fishburn to show a product sets can be arranged with priority orderings and assignments [10]. The SAW algorithm steps were shown from Equations (1) to (3) and the flowchart in Figure 2.

Weighted Criteria Matrix

The Weighted Criteria Matrix of every alternative of all attributes.

$$N_{ij} = x_{ij}.w_{ij} \tag{1}$$

Where N = number of alternatives, i = 1,2,….,m and j = 1,2,….,n

Normalize Weighted Criteria Matrix

Normalization needs to be done so that it can be compared all criteria.

$$rij = \begin{Bmatrix} \left(\left(\dfrac{Nij}{\max Nij}\right)\right| \in Benefit \\ \left(\dfrac{Nij}{\max Nij}\right)\Big| \in Cost \end{Bmatrix} \tag{2}$$

Where r = Normalize weighted number of alternatives, i = 1,2,….,m, and j = 1,2,….,n

Preference Criteria Matrix

Preference for each alternative was given by:

$$\sum_{j=1}^{n} w_j\, a_{ij} \tag{3}$$

Where W = Preference of alternatives, α = criteria Preference alternatives of i = 1,2,….,m and j = 1,2,….,n

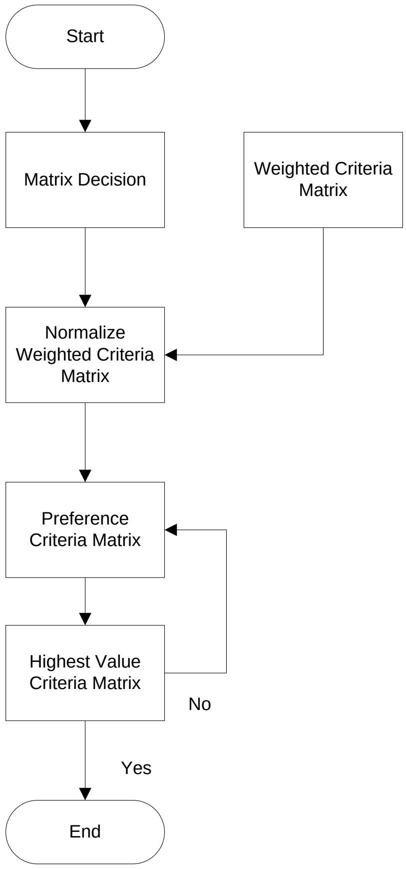

Figure 2. SAW Algorithm Flowchart

Fuzzy Topsis Algorithm

A fuzzy algorithm was introduced by Zadeh at first in 1965 [11], [12]. He and colleagues invented it to solving real-world problems using human logic, which is approximate reasoning from precise and not precise. As the world becomes more complex and new issues arise, so is the fuzzy. Until now a lot of new fuzzy methods are born to solve real-world problems such as monitoring [13], control [14], supplier selection [15], traffic light [16], data forecasting [17], failure analysis [18], selection admission [19] and many others.

To solve MCDM problems such as sensor selection for automatic infusion systems, we propose the use of Fuzzy Topsis. Fuzzy Topsis was a method to solve the MCDM problem using the nearest from the best alternative and hence the farthest from the worst alternative. Therefore, the ideal option has the best score better from other possibilities [20]. The fuzzy algorithm steps were shown flowchart in Figure 3 and from Equation (4) to (10).

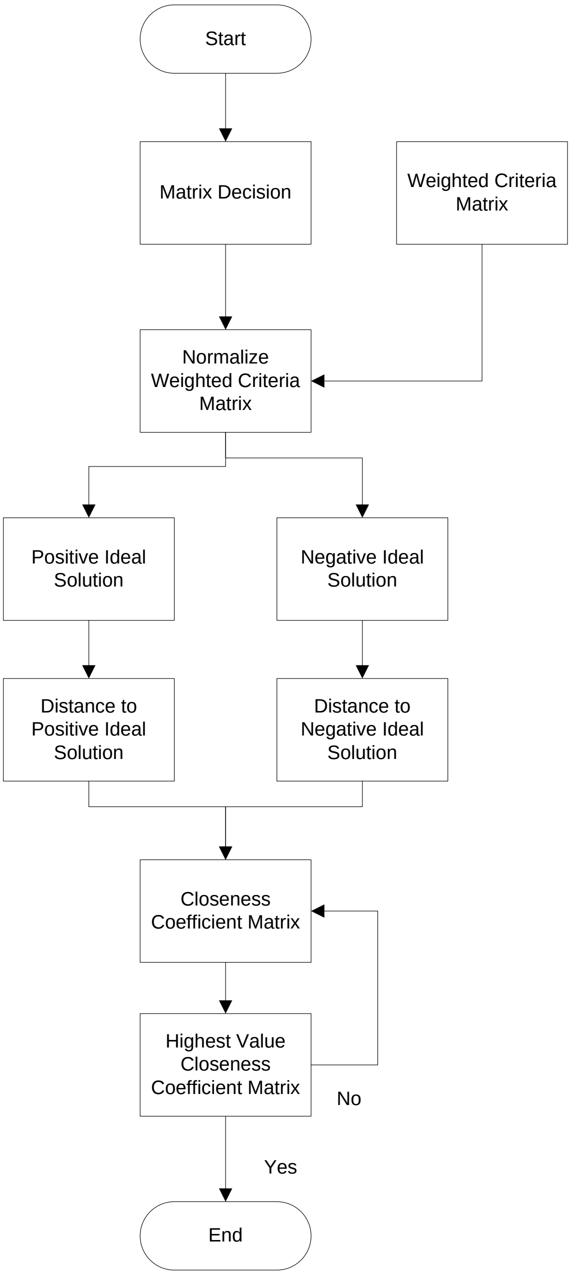

Figure 3. Fuzzy Topsis Algorithm Flowchart

Matrix Decision

The matrix decision was built using multiple sensor choice and criteria.

Normalize Matrix Decision

For every criterion comparison, the normalization needs to be done. This step was to limit the criterion between 0 and to 1 [21].

$$r_{ij} = \frac{x_{ij}}{\sqrt{\sum_{i=1}^{m} x_{ij}{}^2}} \quad (4)$$

Where *r* = Normalize number of alternatives, *x* = number of alternatives, *i* = 1,2,….,m and *j* = 1,2,….,n

Weighted Normalize Matrix Decision

The weight of the normalized matrix needs to be weighted. With this, this was to emphasize criteria that had the most impact value for the user/system. Therefore, for weight criteria and their value, we are using a human decision. The Weighted Criteria Matrix of every alternative of all attributes.

$$N_{ij} = r_{ij}.w_{ij} \quad (5)$$

Where *N* = Weighted Normalize number of alternatives, *r* = Normalize number of alternatives, *i* = 1,2,….,*m* and *j* = 1,2,….,*n*

For Positive Ideal Solution

The weight of the normalized matrix decision can be shown as a positive ideal solution, as shown in Equation (5).

$$A_b = \begin{Bmatrix} (\min(t_{ij}|i = 1,2,\dots,m)|j \in J-) \\ (\max(t_{ij}|i = 1,2,\dots,m)|j \in J+) \end{Bmatrix} \{t_{bj}|j = 1,2,\dots,n\} \quad (6)$$

Where A_b = best Ideal Solution alternatives, *J+* = {*j* = 1,2,….,*n*│*j*} criteria that having a positive impact.

For Negative Ideal Solution

The weight of the normalized matrix decision can be shown as a negative ideal solution, as shown in Equation (6).

$$A_w = \begin{Bmatrix} (\max(t_{ij}|i = 1,2,\dots,m)|j \in J-) \\ (\min(t_{ij}|i = 1,2,\dots,m)|j \in J+) \end{Bmatrix} \{t_{wj}|j = 1,2,\dots,n\} \quad (7)$$

Where A_b = Worst Ideal Solution alternatives, *J-* = {*j* = 1,2,….,n│*j*} criteria that having a negative impact

Distance for Positive Ideal Solution

The alternative was the nearest with the best is:

$$d_{ib} = \sqrt{\sum_{j=1}^{n} (t_{ij} - t_{bj})} \quad (8)$$

Where, d_{ib} = distance to the best Ideal Solution alternatives, *i* = 1,2,….,*m*

Distance for Negative Ideal Solution

The alternative was the nearest with the best:

$$d_{iw} = \sqrt{\sum_{j=1}^{n} (t_{ij} - t_{wj})} \quad (9)$$

Where, d_{iw} = distance to the worst Ideal Solution alternatives, i = 1,2,….,m

Closeness Coefficient

By using the worst alternative distance and the best alternative distance, closeness coefficient is calculated to show the best of the performance of the alternative, as shown below:

$$CC^* = \frac{d_{iw}^{-}}{d_{iw}+d_{ib}}, 0 \leq C_i^* \leq 1 \quad (10)$$

Where, CC = Closeness Coefficients of alternatives, i = 1,2,….,n

RESULTS AND DISCUSSION

In this simulation, three sensors, such as LDR (photoresistor), phototransistor, and photodiode, are used. For criteria, the authors would propose using two components, such as cost and sensitivity. The cost was shown to see which component has the highest price. For the price of 3 sensors above, we see into the marketplace in Indonesian sites.

Meanwhile, sensitivity was taken from each component standard deviation value. This deviation means an electrical response concerning light, where a better variation profile in terms of sensitivity and precision [22]. For the deviation value for each sensor, the authors would like to propose using Wendy's and colleague's research results [23]. Based on sensor characteristics and price, thus a decision matrix for each method was built.

SAW Algorithm Result

First, we decide to give weight value for each criterion. The weight value for each method (SAW and Fuzzy Topsis) is the same. Table 1 shown the weighted criteria matrix based on user experience.

Table 1. Weight-based on User Experience

Item	Sensitivities	Price
Linguistic Weight	3	1

Matrix weighted decision was given in Table 2, based on every criterion.

Table 2. Matrix weighted decision

Sensor	Sensitivities	Price (IDR)
Light Dependent Resistor	0,792	400,00
Photo Diode	0,645	800,00
Photo Transistor	0,975	2500,00

Matrix normalization was given in Table 3 using Equation (3).

Table 3. Matrix Normalization

Sensor	Sensitivities	Value
Light Dependent Resistor	0,8123076923	1,0000000000
Photo Diode	0,6615384615	2,0000000000
Photo Transistor	1,0000000000	6,2500000000

Matrix preference was given in Table 4 using Equation (3). Table 4 has shown the best alternative sensor using the SAW algorithm.

Table 4. Matrix Preference

Sensor	Value
Light Dependent Resistor	0,8123076923
Photo Diode	1,3230769231
Photo Transistor	6,2500000000

Topsis Algorithm Result

First, a matrix decision was built for all criteria and items please see Table 5.

Table 5. Topsis Matrix decision

Sensor	Sensitivities	Price (IDR)
Light Dependent Resistor	0.264	400.00
Photo Diode	0.215	800.00
Photo Transistor	0.325	2500.00

Fuzzy Topsis matrix decision also needs to be normalized before it can be processed, for Matrix normalization was given in Table 6 using Equation (4).

Table 6. Normalize matrix decision

Sensor	Sensitivities	Value
Light Dependent Resistor	0.0006599999	0.9999997822
Photo Diode	0.0002687500	0.9999999639
Photo Transistor	0.0001300000	0.9999999916

The weight is applied to the normalization decision matrix. We can get it from Table 1. In Table 7 we can see the weighted Topsis Normalize matrix decision

Table 7. Normalize matrix decision weighted

Sensor	Sensitivities	Value
Light Dependent Resistor	0.0019799996	0.9999997822
Photo Diode	0.0008062500	0.9999999639
Photo Transistor	0.0003900000	0.9999999916

Using weighted decision matrix normalization, for positive ideal solution would be:

y1+ = Min { 0. 0019799996; 0. 0008062500; 0. 0003900000} = 0.0003900000
y2+ = Max { 0. 9999997822; 0. 9999999639; 0. 9999999916} = 0.0019799996

Therefore, for positive ideal solution would be:

A+ = {0.0003900000; 0.9999999916}

Using weighted decision matrix normalization, for negative ideal solution would be:

y1+ = Max { 0. 0019799996; 0. 0008062500; 0. 0003900000} = 0.0019799996
y2+ = Min { 0. 9999997822; 0. 9999999639; 0. 9999999916} = 0.9999997822

Therefore for negative ideal solution would be:

A- = { 0.0019799996; 0.9999997822}

Using Equation (8), distances with a positive ideal solution becomes a value as listed in Table 8.

Table 8. Distance Alternative from Positive Ideal solution

Sensor	Value
Light Dependent Resistor	0.0015899996
Photo Diode	0.0004162500
Photo Transistor	0.0000000000

Using Equation (9), distances with a positive ideal solution becomes a value as listed in Table 9.

Table 9. Distance Alternative from Negative Ideal solution

Sensor	Value
Light Dependent Resistor	0.0000000000
Photo Diode	0.0011737496
Photo Transistor	0.0015899996

By using Equation (6), closeness coefficient becomes:

Table 10. Closeness Coefficient

Sensor	Value
Light Dependent Resistor	0.0000000000
Photo Diode	0.7382074948
Photo Transistor	1.0000000000

From the simulation using the SAW and fuzzy Topsis algorithm above, it can be got the best sensor for the automatic infusion system. Based on Table 4 SAW matrix preference, and Table 10, the fuzzy Topsis Closeness Coefficient, it shows in Table 11 comparison values and its decision.

Table 11. Comparison values and its decision using SAW and Fuzzy Topsis Methods

Sensor	SAW & Fuzzy Topsis Rankings	SAW Methods Value	Fuzzy Topsis Methods Value
Light Dependent Resistor	3	0,8123076923	0,0000000000
Photo Diode	2	1,3230769231	0,7382074948
Photo Transistor	1	6,2500000000	1,0000000000

Using the SAW and Fuzzy Topsis algorithm, the phototransistor emerges as the best sensor in the infusion system. This result was shown in Table 11 that the phototransistor sensor has the most considerable value compare with another sensor.

CONCLUSION

In this paper, we try to find the best sensor for the infusion system. Because this problem has alternatives and criteria, this problem falls under MCDM. Therefore, to solve this problem, we would like to propose it using the SAW and Fuzzy Topsis algorithm. We compare three sensors, such as a phototransistor sensor, Photo Diode Sensor, and a Light Dependent Resistor sensor. By using these two methods, the phototransistor is emerged as the best sensor with value one according to fuzzy Topsis and value 6.25 according to the SAW method, even though it has the price six times higher from LDR sensor and three times higher from the photodiode.

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