Early Detection of Acute Myocardial Infarction Using The Dempster Shafer Method

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Abstract. This study aims to design an android application to detect indications of Acute Myocardial Infarction (AMI) using the Dempster Shafer method. The system is built with initial symptoms input parameters and risk factor indicated by AMI. The system output consists of 2 classes, namely AMI and non-AMI. The test results obtained system accuracy of 98%.

INTRODUCTION

Coronary heart disease occurs due to the blockage of blood vessels that disrupts the heart function. According to the data from American Heart Association in 2013, coronary heart disease accounted for 1 in 7 deaths, killing over 0.5% or 883,447 people in Indonesia. The most severe manifestations of coronary heart disease are Acute Myocardial Infarction (AMI) which induced more than 2 to 4 million deaths in the United States, more than 4 million deaths in Europe and North Asia, and more than one-third of deaths in developed countries each year (Reed , 2017) and based on WHO, It is estimated that this number will continue to increase to 11 million people in 2020. In line with the data from Ministry of Health in 2014, AMI was included into the category of the top ten non-communicable diseases causing death in hospitals throughout Indonesia, such as 6.25%.

The high mortality rate caused by AMI is influenced by several factors such as delay in seeking treatment, rapidity and accuracy of diagnosis, and treatment of a doctor (Pratiwi, 2012). The slowness of accuracy in obtaining a diagnosis was affected by the lack of early information on AMI, the patient ignorance of the disease and the lack of patient knowledge which was only considered as a common illness such as colds (Ermiati et al, 2017). The lack of early information on AMI also affected the provision of inappropriate treatment, even though early information was appropriate and prompt treatment was needed to reduce the high number of deaths suffering from AMI. In addition, the number of cardiologists in Indonesia with a large number of AMI patients was not balanced, for example, in the Province of DKI Jakarta, it has a ratio of 1: 268, which mean that 1 cardiologist treats 268 AMI patients (Ministry of Health, 2014). There was an imbalance between the needs and the number of experts, hence an expert system was needed (Siswanto, 2010).

Kojuri, Boostani, Dehghani, Nowroozipour and Saki conducted research in 2015 about the prediction of a patient diagnosed with AMI by using an artificial neural network (ANN) method, namely multi-layer perceptron (MLP) and radial basis function (RBF). This study was carried out on 964 patients with complaints of chest pain at Fatimah Azzahra Hospital and obtained an accuracy value of MLP of 84.5% and an accuracy value of RBF of 78%.

Satria Suhada and Dwiza Rianna also established research on the diagnosis of heart disease by comparing centroid defuzzication with maximum defuzzier in the fuzzy inference system method in 2016. The heart disease referred to in this study such as when cardiac emergencies occured or in medical terminology is defined as AMI. In this study the process began with the formation of a universal set of 13 input variables used and one output variable. In accordance with this research, the accuracy value when using maximum defuzzier was 86.5 and when using centroid defuzzier, the accuracy value was 90.3%.

Arreta in 2017 did a research about designing an expert system application for preterm labor risk detection using the Android-based dempster shafer method. In this research, the design and manufacture of an expert system was used to detect the risk of preterm labor based on risk factors and symptoms that occured by a expectant. Each risk factor and symptoms had their respective weights and would affect the detection results. The accuracy value obtained was very high at 100%.

These studies form the basis for conducting research entitled "Early Detection of Acute Myocardial Infarction Using the Android-Based Dempster-Shafer Method" as a equipment to detect AMI which is expected to reduce mortality due to AMI. This research will build an Android-based application for AMI risk detection and determine its accuracy value using the Dempster-Shafer method.

EXPERIMENTAL METHOD

This research was conducted in Medical Instrumentation Laboratory, Department of Physics, Faculty of Science and Technology, Universitas Airlangga and Polyclinic in dr. Ramelan Hospital Surabaya.

2.1 Application of Dempster Shafer Theory

Dempster Shafer theory is a representation, combination and uncertainty propogation, this theory has several characteristics that are intuitively appropriate to the way of thinking of an expert, yet still apply a strong mathematical basis.

In principle, Dempster Shafer theory is written at an interval: [Belief, Plausibility] (Kusumadewi, 2008). Belief (Bel) is a measure of the strength of evidence in supporting a set of propositions. When a fact has a value of 1 indicating that there is certainty, and when a fact has a value of 0 then it indicates that there is no evidence. Plausibility (Pls) will reduce the level of certainty of the evidence. Plausibility has values from 0 to 1. If you believe in X ', then it can be said that Bel (X') = 1, thus the formula above is from Pls (X) = 0.

There are three stages in the calculation of Dempster Shafer's theory: determining the initial density value (m), determining the new density value (m), and determining the maximum density value (Sindilas, 2017).

2.1.1 Determining the Initial Density Value (m)

The initial density (m) consists of belief and plausibility. There were 14 risk factors and symptoms that can affect AMI (Levinne, 2014). Of the 14 risk factors and symptoms are distributed into 36 risk factors and symptoms hence the risk factors and symptoms are easily understood based on the knowledge of an expert, a cardiologist. From the risk factors and symptoms chosen by the user then the value of belief is obtained from an expert, while the value of plausibility is acquired from the result of 1, the value of belief that refers to the equation 1.

$$Pls\ (X) = 1 - Bel(X) = 1 - \sum_{Y \subseteq X} m(X) \tag{1}$$

Notes :
Bel (X) = *Belief* (X)
Pls (X) = *Plausibility* (X)
m (X) = *mass function* of (X)
m (Y) = *mass function* of (Y)

As the value of the belief is getting closer to 1, the greater the level of diagnosis possibilìty criteria influencing the results of diagnosis decisions. The following is a table that represents the relationship between each risk factor, symptoms and the belief value of AMI.

Table 1. Belief and Plausibility of risk factor and Symptoms of AMI

Risk Factors and Symptoms	Belief Value C1	Belief Value C2	Plausibility Value
Is the chest pain was the first time?	0,772	0	0,228
Is the chest pain more than 20 minutes?	0,772	0	0,228
Has it ever diagnosed by a doctor that had heart attack previously?	0,866	0	0,134
Has it ever diagnosed by a doctor that had coronary heart disease previously?	0,866	0	0,134

Has it ever diagnosed by a doctor that had stroke previously?	0,772	0	0,228
Has it ever diagnosed by a doctor that had diabetic previously?	0,772	0	0,228
Is there any relatives that suffering coronary heart disease?	0,772	0	0,228
Does the chest pain occur frequently?	0,545	0	0,455
Is the chest pain getting worse?	0,772	0	0,228
Does the chest pain occur more often?	0,772	0	0,228
Is the chest pain getting worse and longer?	0,772	0	0,228
Does the chest pain feel like squeezing?	0,772	0	0,228
Does the chest pain feel like burning?	0,772	0	0,228
Does the chest pain feel like being crushed by heavy object?	0,886	0	0,114
Does the chest pain spread to the neck?	0,318	0	0,682
Does the chest pain spread to the chin?	0,318	0	0,682
Does the chest pain spread to the left arm?	0,545	0	0,455
Does the chest pain spread to the right arm?	0,318	0	0,682
Does the chest pain spread to the right shoulder?	0,318	0	0,682
Does the chest pain spread to the left shoulder?	0,545	0	0,455
Is the chest pain getting worse when walking further?	0,772	0	0,228
Is the chest pain getting worse when walking faster?	0,772	0	0,228
Is the chest pain getting worse when carrying heavy object?	0,772	0	0,228
Does the pain decrease/disappear by lying/sitting (resting)?	0,772	0	0,228
Is the chest pain accompanied by cold sweat?	0,772	0	0,228
Is the chest pain accompanied by nausea?	0,545	0	0,455
Is the chest pain accompanied by retch?	0,545	0	0,455
Is the chest pain able to appropriately denoted?	0	0,886	0,114
Is the chest pain moving around?	0	0,772	0,228
Does the pain feel like being sliced?	0	0,886	0,114
Does the chest pain feel like being pierced by sharp object?	0	0,886	0,114
Is the chest pain getting worse when taking a deep breath?	0	0,772	0,228
Is the chest pain related to body movement?	0	0,772	0,228
Is the chest pain getting worse when being pressed?	0	0,772	0,228
Is there any skin abnormality in the pain area?	0	0,545	0,455
Does the chest pain occur in certain position?	0	0,545	0,455

2.1.2 Determining the New Density Value (m)

The new density value (m) is obtained when there is a combination of two risk factors and symptoms. Determination of the new density (m) value is calculated by creating a combination rule table. Then the result will be applied as representing new risk factors or symptoms. The new density is acquired by using the equation:

$$m3(Z) = \frac{\sum_{X \cap Y = Z} m_1(X).m_2(Y)}{1 - \sum_{X \cap Y = \emptyset} m_1(X).m_2(Y)} \quad (2)$$

m3(Z) = *mass function* of *evidence* (Z)
m1(X)= *mass function* of *evidence* (X), obtained from the belief value of an evidence multiplied by the disbelief value of the evidence.
m2(Y) = *mass function* of *evidence* (Y), obtained from the belief value of an evidence multiplied by the disbelief value of the evidence.
∑m 1(X).m2(Y) = is the value of the strength of evidence Z obtained from the combination of the belief value of a set of evidence.

2.1.3 Determining the Maximum Density Value
Detection result was yielded up from the calculation of the Dempster Shafer with the last density value. With a Citas value C1 was greater than C2, the system will provide result of chest detection caused by AMI and will also assess the value of the problem discussed by the patient, yet compilation of the density value at C2 was greater than C1, the system will provide pain of the chest is not caused by AMI and will determine the probability value of the patient

2.2 Analysis and Evaluation
This study was using 50 data to observe the results of the match between the results produced by the application and by an expert. In accordance with the concordance results was obtained the accuracy value of the diagnosis of expert system application using the Dempster Shafer method.

RESULT AND DISCUSSION

3.1 Analysis of Dempster Shafer Theory
This research was applying Dempster Shafer method to do computational calculation or probability in detecting AMI based on risk factor or symptoms from a patient. In calculating by Dempster Shafer method, using detection criteria that was chosen by the user from one of these criteria, such as :

1. Is the chest pain felt was the first time?
2. Is the chest pain more than 20 minutes?
3. Has it ever diagnosed by a doctor that had diabetic previously?
4. Is the chest pain getting worse?
5. Does the chest pain feel like burning?
6. Does the chest pain feel like being crushed by heavy object?
7. Is the chest pain accompanied by cold sweat?

Risk factor 1 : Is the chest pain was the first time?
Based on table 1, density value of the first risk factor which was felt by patient, such as :
M1{C1} = 0,772
M1{C2} = 0
M1{θ} = 1 - 0,772 = 0,228

Symptom 2 : Is the chest pain more than 20 minutes?
In line with table 1, density value of the second symptom which was felt by patient, namely :
M2 {C1} = 0,772
M1{C2} = 0
M2 {θ} = 1 – 0,772 = 0,228
As a result of two combination of risk factor and symptom above, by using combination function of Dempster Shafer method, is stated in this table below :

TABLE 2. Combination Arrangement for M3

		M2{C1} 0,772	M2{C2} 0	M2 { θ } 0,228
M1 {C1}	0,772	0,596	0	0,176
M1 {C2}	0	0	0	0
M1 { θ }	0,228	0,176	0	0,052

In accordance with the result of combination function, a new density value will appear using the equation of the dempster shafer method. The new density values is as follows:
M3 {C1} = $\frac{0,596+0,176+0,176}{1-(0+0)}$ = 0,948
M3 {C2} = $\frac{0+0+0}{1-(0+0)}$ = 0
M3 {θ} = $\frac{0,052}{1-(0+0)}$ = 0,052
The new density value based on the calculation of G1 and G2 was obtained the new density value, namely M3{C1} = 0,948

Risk factor 3 : Has it ever diagnosed by a doctor that had diabetic previously?

According to table 1, density value of the third risk factor which was felt by patient, such as :
M4 {C1} = 0,772
M4 {C2} = 0
M4 {θ} = 1 – 0,772 = 0,228

As a result of two combination of risk factor and symptom above, by using combination function of Dempster Shafer method, is shiown in this table below :

TABLE 3. Combination Arrangement for M5

		M4{C1} 0,772	M4{C2} 0	M4 { θ } 0,228
M3 {C1}	0,948	0,732	0	0,216
M3 {C2}	0	0	0	0
M3 { θ }	0,052	0,040	0	0,012

Based on the result of combination function, a new density value will appear using the equation of the dempster shafer method. The new density values is :

M5 {C1} = $\frac{0,732+0,216+0,040}{1-(0+0)}$ = 0,988

M5 {C2} = $\frac{0+0+0}{1-(0+0)}$ = 0

M5 {θ} = $\frac{0,012}{1-(0+0)}$ = 0,012

The new density value in line with the calculation of M4 and G6 was obtained the new density value, such as M5{C1} = 0,988

Symptom 4 : Is the chest pain getting worse?

In accordance with table 1, density value of the fourth symptom which was felt by patient, such as :
M6 {C1} = 0,772
M6 {C2} = 0
M6 {θ} = 1 – 0,772 = 0,228

As a result of two combination of risk factor and symptom above, by using combination function of Dempster Shafer method, is shiown in this table below :

TABLE 4. Combination Arrangement for M7

		M6{C1} 0,772	M6{C2} 0	M6 { θ } 0,228
M5 {C1}	0,988	0,763	0	0,225
M5 {C2}	0	0	0	0
M5 { θ }	0,012	0,009	0	0,003

In line with the result of combination function, a new density value will appear using the equation of the dempster shafer method. The new density values is :

M7 {C1} = $\frac{0,763+0,225+0,009}{1-(0+0)}$ = 0,997

M7 {C2} = $\frac{0+0+0}{1-(0+0)}$ = 0

M7 {θ} = $\frac{0,003}{1-(0+0)}$ = 0,003

The new density value according to the calculation of M6 and G9 was obtained the new density value, such as M7{C1} = 0,997

Symptom 5 : Does the chest pain feel like burning?

In line with table 1, density value of the fifth symptom which was felt by patient, namely:
M8 {C1} = 0,772
M8 {C2} = 0
M8 {θ} = 1 – 0,772 = 0,228

As a result of two combination of risk factor and symptom above, by using combination function of Dempster Shafer method, is shiown in this table below :

TABLE 5. Combination Arrangement for M9

		M8{C1}	M8{C2}	M8 { θ }
		0,772	0	0,228
M7 {C1}	0,997297664	0,770	0	0,227
M7 {C2}	0	0	0	0
M7 { θ }	0,002702336	0,002	0	0,000

From the result of combination function, a new density value will appear using the equation of the dempster shafer method, such as :

M9 {C1} = $\frac{0,770+0,227+0,002}{1-(0+0)}$ = 0,999

M9 {C2} = $\frac{0+0+0}{1-(0+0)}$ = 0

M9 {θ} = $\frac{0,000}{1-(0+0)}$ = 0,000

The new density value based on the calculation of M8 and G13 was obtained new density value, such as M9{C1} = 0,999

Symptom 6 : Does the chest pain feel like being crushed by heavy object?

Based on table 1, density value of the sixth symptom which was felt by patient, namely:

M10 {C1} = 0,886

M10 {C2} = 0

M10 {θ} = 1 – 0,886 = 0,114

As a result of two combination of risk factor and symptom above, by using combination function of Dempster Shafer method, is shiown in this table below :

TABLE 6. Combination Arrangement for M11

		M10{C1}	M10{C2}	M10 { θ }
		0,886	0	0,114
M9 {C1}	0,999	0,885	0	0,114
M9 {C2}	0	0	0	0
M9 { θ }	0,000616133	0,001	0	0

Based on the result of combination function, a new density value will appear using the equation of the dempster shafer method, such as :

M11 {C1} = $\frac{0,885+0,114+0,001}{1-(0+0)}$ = 1,0

M11 {C2} = $\frac{0+0+0}{1-(0+0)}$ = 0

M11 {θ} = $\frac{0}{1-(0+0)}$ = 0

The new density according to the calculation of M10 and G14 was obtained the new density value, such as M11{C1} = 1,0

Symptom 7 : Is the chest pain accompanied by cold sweat?

According to table 1, density value of the seventh symptom which was felt by patient, such as :

M12 {C1} = 0,772

M12 {C2} = 0

M12 {θ} = 1 – 0,772 = 0,228

As a result of two combination of risk factor and symptom above, by using combination function of Dempster Shafer method, is shiown in this table below :

TABLE 7. Combination Arrangement for M13

		M12{C1}	M12{C2}	M12 { θ }
		0,772	0	0,228
M11 {C1}	1,0	0,772	0	0,228
M11 {C2}	0	0	0	0
M11 { θ }	0	0	0	0

From the result of the combination function, a new density value will appear using the equation of the dempster shafer method. The new density value is as follows:

M13 {C1} = $\frac{0,772+0,228}{1-(0+0)}$ = 1,0

M13 {C2} = $\frac{0+0+0}{1-(0+0)}$ = 0

M13 {θ} = $\frac{0}{1-(0+0)}$ = 0

The new density value from the calculation results between M12 and G9 obtained a new density value that is M13 {C1} = 1.00 or obtained a result of chest pain caused by acute myocardial infarction with a probability value of 100%.

Based on the result above using the Dempster Shafer expert system calculation method stated that when parameters which had belief and plausibility values were added in parameters, belief values and Plausibility would be calculated by Dempster Shafer calculations to generate new values from belief and Plausibility. In this case, when the new value of belief and plausibility were obtained, the two previous combined parameters would not be recalculated or the calculation of the combination would stop after obtaining a new value of belief and plausibility. This value then would be used to carry out further calculations when new parameters were added. This repetition would continue until no more parameters were added.

This method was simple due to there were no interruptions between the previous parameter and the following parameters, for example there was no interruption between the first combination of parameter 3 and the 5th parameter. This method would continue to calculate the combination of 2 parameters sequentially according to the parameters given or in accordance with the mindset of a cardiologist, accompanied by new belief and plausibility values that indicated an increase in the probability of output, ie pain caused by AMI or pain that is not caused by AMI and then the highest value of the two outputs was obtained. The last highest computational calculation value was used as a result of the probability of the Dempster Shafer expert system.

3.2 Data Validation Result

The test was carried out using 50 data of patients with complaints of chest pain in the cardiac and gastro clinic at Dr.Ramelan Hospital Surabaya, with details of 32 cardiac polyclinic patients and 18 gastro polyclinics. The data was compared between the results of expert diagnoses and results released by the dempster shafer expert system as in table 8.

TABLE 8. System Test Result

Data	Application Diagnosis Result	Expert Diagnosis Result	Note
1	Caused by Acute Myocardial Infarction	Caused by Acute Myocardial Infarction	Appropriate
2	Caused by Acute Myocardial Infarction	Caused by Acute Myocardial Infarction	Appropriate
3	Caused by Acute Myocardial Infarction	Caused by Acute Myocardial Infarction	Appropriate
4	Caused by Acute Myocardial Infarction	Caused by Acute Myocardial Infarction	Appropriate
5	Caused by Acute Myocardial Infarction	Caused by Acute Myocardial Infarction	Appropriate
6	Caused by Acute Myocardial Infarction	Caused by Acute Myocardial Infarction	Appropriate

7	Caused by Acute Myocardial Infarction	Caused by Acute Myocardial Infarction	Appropriate
8	Caused by Acute Myocardial Infarction	Caused by Acute Myocardial Infarction	Appropriate
9	Caused by Acute Myocardial Infarction	Caused by Acute Myocardial Infarction	Appropriate
10	Caused by Acute Myocardial Infarction	Caused by Acute Myocardial Infarction	Appropriate
11	Caused by Acute Myocardial Infarction	Caused by Acute Myocardial Infarction	Appropriate
12	Caused by Acute Myocardial Infarction	Caused by Acute Myocardial Infarction	Appropriate
13	Caused by Acute Myocardial Infarction	Caused by Acute Myocardial Infarction	Appropriate
14	Caused by Acute Myocardial Infarction	Caused by Acute Myocardial Infarction	Appropriate
15	Caused by Acute Myocardial Infarction	Caused by Acute Myocardial Infarction	Appropriate
16	Caused by Acute Myocardial Infarction	Caused by Acute Myocardial Infarction	Appropriate
17	Caused by Acute Myocardial Infarction	Caused by Acute Myocardial Infarction	Appropriate
18	Caused by Acute Myocardial Infarction	Caused by Acute Myocardial Infarction	Appropriate
19	Caused by Acute Myocardial Infarction	Caused by Acute Myocardial Infarction	Appropriate
20	Caused by Acute Myocardial Infarction	Caused by Acute Myocardial Infarction	Appropriate
21	Caused by Acute Myocardial Infarction	Caused by Acute Myocardial Infarction	Appropriate
22	Caused by Acute Myocardial Infarction	Caused by Acute Myocardial Infarction	Appropriate
23	Caused by Acute Myocardial Infarction	Caused by Acute Myocardial Infarction	Appropriate
24	Caused by Acute Myocardial Infarction	Caused by Acute Myocardial Infarction	Appropriate
25	Caused by Acute Myocardial Infarction	Caused by Acute Myocardial Infarction	Appropriate
26	Caused by Acute Myocardial Infarction	Caused by Acute Myocardial Infarction	Appropriate
27	Caused by Acute Myocardial Infarction	Caused by Acute Myocardial Infarction	Appropriate
28	Caused by Acute Myocardial Infarction	Caused by Acute Myocardial Infarction	Appropriate
29	Caused by Acute Myocardial Infarction	Caused by Acute Myocardial Infarction	Appropriate
30	Caused by Acute Myocardial Infarction	Caused by Acute Myocardial Infarction	Appropriate
31	Caused by Acute Myocardial Infarction	Caused by Acute Myocardial Infarction	Appropriate
32	Caused by Acute Myocardial Infarction	Caused by Acute Myocardial Infarction	Appropriate
33	Not caused by Acute Myocardial Infarction	Not caused by Acute Myocardial Infarction	Appropriate
34	Not caused by Acute Myocardial Infarction	Not caused by Acute Myocardial Infarction	Appropriate
35	Not caused by Acute Myocardial Infarction	Not caused by Acute Myocardial Infarction	Appropriate
36	Not caused by Acute Myocardial Infarction	Not caused by Acute Myocardial Infarction	Appropriate

37	Not caused by Acute Myocardial Infarction	Not caused by Acute Myocardial Infarction	Appropriate
38	Not caused by Acute Myocardial Infarction	Not caused by Acute Myocardial Infarction	Appropriate
39	Not caused by Acute Myocardial Infarction	Not caused by Acute Myocardial Infarction	Appropriate
40	Not caused by Acute Myocardial Infarction	Not caused by Acute Myocardial Infarction	Appropriate
41	Caused by Acute Myocardial Infarction	Not caused by Acute Myocardial Infarction	Not Appropriate
42	Not caused by Acute Myocardial Infarction	Not caused by Acute Myocardial Infarction	Appropriate
43	Not caused by Acute Myocardial Infarction	Not caused by Acute Myocardial Infarction	Appropriate
44	Not caused by Acute Myocardial Infarction	Not caused by Acute Myocardial Infarction	Appropriate
45	Not caused by Acute Myocardial Infarction	Not caused by Acute Myocardial Infarction	Appropriate
46	Not caused by Acute Myocardial Infarction	Not caused by Acute Myocardial Infarction	Appropriate
47	Not caused by Acute Myocardial Infarction	Not caused by Acute Myocardial Infarction	Appropriate
48	Not caused by Acute Myocardial Infarction	Not caused by Acute Myocardial Infarction	Appropriate
49	Not caused by Acute Myocardial Infarction	Not caused by Acute Myocardial Infarction	Appropriate
50	Not caused by Acute Myocardial Infarction	Not caused by Acute Myocardial Infarction	Appropriate

Thus the accuracy value of the output that caused by AMI was 100% and the accuracy value of non-AMI was 94%. According to the calculation using Dempster Shafer method, the overall accuracy was 98%.

CONCLUSION

The overall accuracy of the detection of Acute Myocardial Infarction (AMI) applying dempster shafer expert system was 98%, involving 50 data consisting of 32 patient data with the chest pain detection result caused by AMI and 18 patient data was non-AMI in the cardiac polyclinic and gastro polyclinic of Dr., Ramelan Hospital Surabaya. Accuracy results from patient data with chest pain detection result caused by AMI was 100% and accuracy result fom non-AMI was 94%.

REFERENCES

1. Pratiwi, Inne . 2012 . *Komplikasi pada pasien infark miokard akut st- elevasi (stemi) yang mendapat maupun tidak mendapat terapi reperfusi.* Semarang. Fakultas Kedokteran , Universitas Diponegoro.
2. Reed, G. W., Rossi, J. E., & Cannon, C. P. (2017). *Acute Myocardial Infarction*. The Lancet, *389*(10065), 197–210
3. Wiryowidagdo, Sudjaswadi dan M. Sitanggang. *Tanaman Obat untuk Penyakit Jantung, Darah Tinggi dan Kolesterol*. Jakarta Selatan : Agromedia. 2008.
4. Kojuri, J., Boostani, R., Dehghani, P., Nowroozipour, F., & Saki, N. 2015. *Prediction of acute myocardial infarction with artificial neural networks in patients with nondiagnostic electrocardiogram*. Journal of Cardiovascular Disease Research, *6*(2), 51–59.
5. Ermiati, Rampengan,S.H., Joseph.V,F,F., 2017. Angka Keberhasilan Terapi Reperfusi pada Pasien ST Elevasi Miokard Infark. Manado. Program Studi Pendidikan Dokter. Fakultas Kedokteran. Universitas Sam Ratulangi.
6. Suhada, S., & Riana, D. (2016). Perbandingan Defuzzifikasi Centroid Dan Maximum Defuzzifier Pada Metode Fuzzy Inference System Untuk Diagnosis Penyakit Jantung, IV(2), 84–96.

7. Arreta, H.S. 2017. *Perancangan Aplikasi Sistem pakar untuk Deteksi Resiko Persalinan Prematur dengan Metode Dempster Shafer.* Surabaya. Teknik Biomedis, Fakultas Sains dan Teknologi, Universitas Airlangga.
8. Kusumadewi, S. (2003). *Artificial Intelegent (Teknik dan Aplikasinya).* Yogyakata. : Penerbit Graha Ilmu.
9. Levinne, Glenn N., 2014. *Cardiology Secrets* (4th edition), Elsevier Saunders, USA, pp. 117-140.
10. Pusat Data dan Informasi Kementrian Kesehatan RI. 2014. *Situasi Kesehatan Jantung*. Jakarta: Kementerian Kesehatan Republik Indonesia.
11. Siswanto. 2010. *Kecerdasan Tiruan*. Yogyakarta: Graha ilmu.