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# IMPLEMENTATION OF A FUZZY LOGIC FOR EARLY DETECTING OF A PREGNANT WOMEN RISK OF HYPERTENSION

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**ABSTRACT**
Hypertension is one of the diseases that can cause fatal effects to health, especially for pregnant women. Hypertension during pregnancy can cause serious effects such as pre-eclampsia and eclampsia which can threaten the lives of pregnant women and fetuses. The purpose of this study is to determine the input and output variables related to hypertension during pregnancy and used for analysis using Tsukamoto FIS to determine risk factors for hypertension in pregnant women. This study uses input variables in the form of maternal age, systolic blood pressure (SBP), diastolic blood pressure (DBP), history of hypertension and genetic. Furthermore, it is analyzed using fuzzy logic through the process of fuzzyfication, inference engine and defuzzyfication. The examination of data samples of pregnant women with systolic and diastolic blood pressure categories included in the high category or potentially have hypertension. The Z value (defuzzyfication) shows that the output is in the category of severe hypertension so that the patient needs immediate treatment by medical personnel. The results showed that the risk of a mother having hypertension can be obtained through Tsukamoto FIS in the form of concrete values that can describe risk factors in the form of normal, hypertension and severe hypertension as well as recommended actions related to these risk factors.

Keywords: defuzzyfication; DBP; fuzzyfication; hypertension; SBP

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## INTRODUCTION

Based on data from The Provincial Health Office of Aceh on a Maternal Mortality Rate (MMR) and an Infant Mortality Rate in the period 2018 - 2020, namely for the number of MMR in 2018 of 138/100,000 KH and in 2019 an increase of 172/100,000 KH and in 2020 the number of MMR remained at 172/100,000 KH. The Maternal Mortality Rate (MMR) in Aceh province in 2018-2022 experienced fluctuations. In 2022, there was a very significant decrease from the previous year, namely 141/100,000 KH. On the other hand, for the IMR data in 2018 shows 10/1,000 KH and in 2020 of 10/1,000 KH. The infant mortality rate in 2022 of 10 /1000 KH has decreased from 2021 with an infant mortality rate of 11 per 1000 KH. The high rate is also evident from the data system that comes from villages in Aceh Province (Dinas Kesehatan Provinsi Aceh, 2023).

The main cause of maternal death is bleeding followed by hypertension in pregnancy, infection and others. A study shows that 61.5% of neonatal deaths have a risk since the mother's pregnancy, this can occur due to delays in recognizing danger signs during pregnancy (Shofi Jasmine et al., 2022). The diagnosis of hypertension in pregnancy can be confirmed in a pregnant woman with a gestational age > 20 weeks (trimester 3) with a systolic blood pressure > 140 mmHg and a diastolic blood pressure > 90 mmHg. Some research

results show that the age of a pregnant woman, the use of contraceptives, and a medical history of hypertension are associated with the hypertension in pregnancy (Kaimmudin et al., 2018). A Women with a previous history of pre-eclampsia have poorer cognitive function months to years after pregnancy and a 3-4 fold increased risk of a dementia later in his life, especially a vascular dementia. In addition, a women with previous pre-eclampsia and eclampsia have a 2 and 6 fold increased risk of epilepsy, respectively (Dayan et al., 2018). Therefore, early information related to a hypertension in a pregnant women and measures that can be taken through examining the risk level of a heart disease are important (Yuriah & Kartini, 2022). The research on the risk of a hypertension in adults uses the system inputs such as blood sugar, cholesterol, blood pressure, and body mass index (Athiyah et al., 2021).

Increasingly, a high blood pressure or a hypertension is one of the most serious and prevalent health problems in society. In Indonesia, there is a growing number of people suffering from hypertension. According to the minister of the health, 1 in 3 Indonesians has a hypertension, and this number continues to increase every year. Hypertension is often referred to as the silent killer because people with high blood pressure have no complaints. Prevalence of hypertension increases with age to a point where more than half of people aged 60-69 years old age and about three-quarters of those aged 70 years and older are affected. The age-related increase in a sistolic blood pressure is mainly responsible for the increase in the incidence and prevalence of hypertension with increasing age. A recent research study showed that the risk of suffering from hypertension increases by 90 percent for non-hypertensives at 55 or 65 years of age and persists until 80-85 years of age. Even when related to the factor of mortality, the risk of hypertension is 86-90 percent in a woman and 81-83 percent in man (Schwartz & Sheps, 2020).

Pregnancy is dangerous if pulmonary arterial hypertension is indicated. The combined incidence and percentage of maternal and perinatal outcomes showed that out of 272 pregnancies there were 214 pregnancies beyond 20 weeks gestation. Some congenital diseases such as idiopathic lungidiopathic pulmonary (22%), congenital heart disease (64%), and other (15%). There were 48% of women receiving specialised therapy for pulmonary arterial hypertension. Reported causes of death included right heart failure, cardiac, pulmonary arterial hypertension crisis, preeclampsia, and sepsis; 61% of maternal deaths occurred in the 0-4 days postpartum. The neonatal stillbirth rate was 3% and neonatal mortality rate was 1%. In conclusion, pulmonary arterial hypertension in pregnancy persists (Low et al., 2021).

Hypertension is the most commonly diagnosed health disorder during the pregnancy period. Hypertensive disorders in pregnancies are associated with increased maternal and fetal health risks. In 2017, the American College of Cardiology, American Heart American College of Cardiology and American Heart Association (ACC/AHA) released updated a clinical practice guideline in the domain of prevention, detection, evaluation and management of high blood pressure in adults (American Hearth Association, 2021). The guideline changes the diagnostic criteria for hypertension in non-pregnant adults to a systolic blood pressure (BP) of 130/80 mmHg or higher. This criterion is lower than the previous limit of 140/90 mmHg or higher. The institute also continues to stipulate that the threshold for hypertension in pregnancy is 140/90 mmHg or higher. The application of the lower threshold for women throughout pregnancy, not just before 20 weeks gestation is due to the increased prevalence of chronic hypertension (between 8.5% and 10.0%) (Bello et al., 2021).

The hypertensive disorders of the pregnancy, including a chronic hypertension with or without a pre-eclampsia/eclampsia, a gestational hypertension, a pre-eclampsia with or without severe symptoms, a Hemolysis, Elevated Liver Enzymes and Low Platelets (HELLP) syndrome, or an eclampsia, have a significant risk of morbidity for both mother and fetus (Cohen et al., 2024). Although the pregnant woman receives an appropriate level of prenatal care with a careful level of observation to detect signs of malfunctioning organs and a prompt delivery to reduce or avoid the adverse effects, there is still a reduction in the morbidity and the mortality (Iryaningrum et al., 2023). Although the hypertension itself is a problem during pregnancy, its side effects develop into pre-eclampsia/eclampsia along with HELLP syndrome (Simanjuntak, Veronica et al., 2024). One type of hypertension in pregnancy is the gestational hypertension which is defined as a blood pressure that is greater than or equal to up to 140 mmHg systolic or 90 mmHg diastolic at 20 weeks gestation with blood pressure measurements in two separate occasions with an interval of at least four hours (Braunthal & Brateanu, 2019). A pregnant woman with a systolic blood pressure greater than 160 mmHg or a diastolic blood pressure greater than 110 mmHg can be confirmed to have gestational hypertension if they have the same pressure after the pressure measurements with the interval (Luger, Richard K., Kight, 2022).

In the field of medicine in terms of diagnosis, treatment of diseases and therapy has increased and is related to other fields such as the implementation of computer applications to analyze domains that have a level of complexity and uncertainty factors. Fuzzy logic is one of the analysis methods that can be used to analyze factors that are unclear. Experts need accurate tools that consider risk factors that are sometimes quite numerous and in a gray area. Analysis of a risk factors in the form of diagnostic measures based on a blood pressure, a pulse and a kidney function values as several parameters to determine the level of risk and analyze with a fuzzy rules. The architecture of fuzzy logic consists of four main components, namely the fuzzifier. In the fuzzy inference process, blood pressure, pulse and kidney function values are inputs used to make decisions based on existing patterns. This study has a purpose to identify input variables, the implementation of using a fuzzy logic in an inference system with the main goal of obtaining an output in the form of a prediction of a pregnant woman with a risk of hypertension.

## METHOD

The stages in this research are include A literature study as the first stage. This stage includes a reference used in this research in the form of a study of references related to a pregnancy, a hypertension, a pregnancy problem, a hypertension in the pregnancy and a fuzzy logic and its application. The second phase is formulating inputs and outputs. This phase includes determining the input variables that can affect or the factors that support decision making on the determination of pregnant women at risk of hypertension. It also determines the output in the form of the results obtained from this research. The succeeding are determination of data range. This stage contains the determination of data limits arranged in a range of input and output variables so that linguistic data can be interpreted broadly to obtain results with a more in-depth review. Compilation of inference engine are the fourth stage. Based on discussions with experts related to the problem, a knowledge base is compiled that contains the causal relationship between the input variables and the output obtained. The final phase is defuzzification process. This stage is in the form of testing the inference engine and finalizing it so that the output is obtained and compared with the results that are the reference/standard of the expert. The following can be described as a flow chart of this research process:

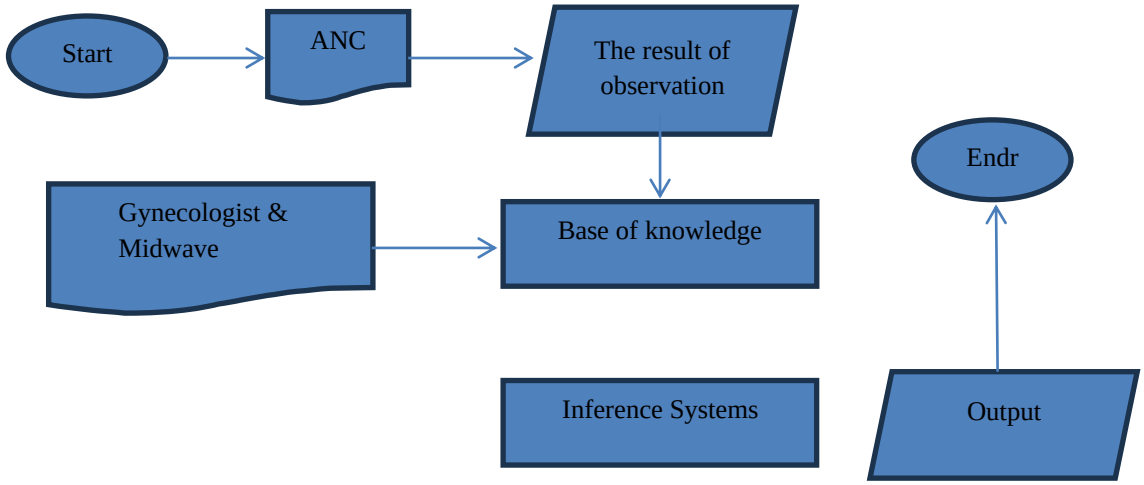


Figure 2. The flow chart of the research

## RESULTS

The stages of formulating the input data that is used as input for the fuzzyfication stage are as shown in the table below.

Table 1.
The data of input variables

| Input Variables |
|---|
| Mother's Age |
| Sistolic blood pressure |
| Diastolic blood pressure |
| Medical history of hypertension |
| Genetic factors |

Subsequently, the input variable data is assigned a range of data that describes certain limits in the form of fuzzy sets. The fuzzy sets data in this research can be seen in the following table.

Table 2.
The region of fuzzy sets

| Input variables | The boundaries | | |
|---|---|---|---|
| Mother's Age | Normal | Risk | |
| Sistolic blood pressure | Normal | High | Very High |
| Diastolic blood pressure | Normal | High | Very High |
| Medical history of hypertension | Normal | Risk | |
| Genetic factors | Normal | Risk | |

After the input variable sections are assigned the limitations in the form of a data range, the next step is to define the output along with data limitations that can describe opinions/recommendations or other things that can explain the things that must be implemented related to the results obtained in this study. The table below shows the expected output as follows.

Table 3.
The data of output variables

| Output Variables | Recommendations |
|---|---|
| Normal | Normal |
| Hypertension | be alert and consult a doctor immediately |
| Sever Hypertension | Must require immediate a medical treatment. |

The membership function for the input variable as described earlier is as follows:

The Systolic Blood Pressure

Based on table 2, the data range for normal is systolic blood pressure <= 120 mmHg. While

for the high category is in the range exceeding 120 mmHg and less than 140 mmHg. On the other hand, systolic blood pressure is categorized as very high if it exceeds 140 mmHg. The following is a table of the membership function of systolic blood pressure

Table 4.
The membership function of the input variable SBP

| The boundaries | The membership function | Data Range | Testing values |
|---|---|---|---|
| Normal | 1,00 | X<=120 | 110 mmHg |
| | 0,25 | 120<x<140 | 135 mmHg |
| | 0,00 | X>=120 | |
| High | 0,00 | X<=120 | 110 mmHg |
| | 0,50 | 120<X<130 | 125 mmHg |
| | 1,00 | X=130 | |
| | 0,50 | 130<X<140 | 135 mmHg |
| | 0,00 | X>=140 | |
| Very High | 0,00 | X<=140 | |
| | 0,10 | 120<X<140 | 125 mmHg |
| | 1,00 | X>=140 | |

The Systolic Blood Pressure
Based on table 2, the data range for normal is diastolic blood pressure <= 90 mmHg. While for the high category is in the range exceeding 90 mmHg and less than 110 mmHg. On the other hand, diastolic blood pressure is categorized as very high if it exceeds 110 mmHg. The following is a table of diastolic blood pressure membership functions.

Table 5.
The membership function of the input variable DBP

| The boundaries | The membership function | Data Range | Testing values |
|---|---|---|---|
| Normal | 1,00 | X<=90 | |
| | 0,75 | 90<X<110 | 95 mmHg |
| | 0,00 | X>=110 | |
| High | 0,00 | X<=90 | |
| | 0,50 | 90<X<100 | 95 mmHg |
| | 1,00 | X=100 | |
| | 0,90 | 100<X<110 | 101 mmHg |
| | 0,00 | X>=110 | |
| Very High | 0,00 | X<=110 | |
| | 0,25 | 90<X<110 | 95 mmHg |
| | 1,00 | X>=110 | |

**The Mother's Age**
Based on table 2, the data range for normal conditions is the age of the mother exceeding 16 years and less than 35 years. Pregnancy conditions can be risky if the mother's age is in the age range of less than 16 years and more than 35 years. The following is a table of the membership function of the input variable mother's age.

Table 6.
The membership function of the input variable of mother's age

| The boundaries | The membership function | Data Range | Testing values |
|---|---|---|---|
| Normal | 0,00 | 16<X<35 | 25 years old |
| Risk | 1,00 | X<=16 atau X>=35 | 15 or 40 years old |

**The Medical history of hypertension**

According to Table 2, the data range for normal conditions is when pregnant women have no medical history of hypertension and vice versa will be at risk if hypertension has been detected before.

Table 7.
The membership function of the input variable of the medical history of hypertension

| The boundaries | The membership function | Data Range |
|---|---|---|
| Normal | 0,00 | No |
| Risk | 1,00 | Hypertension |

The Genetic Factors

According to Table 2, Then the data range for normal conditions is obtained when the pregnant woman does not have hypertensive parents and vice versa will be at risk if she has parents who have hypertension before.

Table 8.
The membership function of the input variable of the genetic factors

| The boundaries | The membership function | Data Range |
|---|---|---|
| Normal | 0,00 | No Genetic |
| Risk | 1,00 | Genetic |

As a result of acquiring input from the expert, an inference engine is compiled according to the rule (R) of fuzzy logic as follows:

[R1] IF maternal age is normal AND Systolic BP is normal AND Diastolic BP is normal AND Medical history of hypertension is absent AND Genetic factor are absent THEN Normal;

[R2] IF maternal age is normal AND Systolic BP is normal AND Diastolic BP is normal AND Medical history of hypertension is absent AND Genetic factor are present THEN Normal;

[R3] IF maternal age is normal AND Systolic BP is normal AND Diastolic BP is normal AND Medical history of hypertension is present AND Genetic factor are absent THEN Normal;

..... .....;

[R4] IF maternal age is normal AND Systolic BP is normal AND Diastolic BP is normal AND Medical history of hypertension is present AND Genetic factor are absent THEN Normal;

[R8] IF maternal age is normal AND Systolic BP is normal AND Diastolic BP is high AND Medical history of hypertension is present AND Genetic factor are present THEN Mild-Moderate Hypertension;

..... .....;

[R24] IF maternal age is normal AND Systolic BP is high AND Diastolic BP is high AND Medical history of hypertension is present AND Genetic factor are present THEN Severe Hypertension;

..... .....;

[R71] IF maternal age is abnormal AND Systolic BP is very high AND Diastolic BP is very high AND Medical history of hypertension exists AND Genetic factor exist THEN Severe Hypertension.

Referring to the case above, based on one of the case samples obtained from the village midwife data, there is a 37-year-old pregnant woman with complaints of frequent dizziness and a history of hypertension and the male parent of the pregnant woman is a person with hypertension. The examination results showed that the systolic blood pressure was 140 mmHg and the diastolic blood pressure was 110 mmHg. Based on the case, we can formulate

the membership function of the input variables in the table below.

Table 9.
The membership function of the input variables based on case examples

| The Input Variables | The linguistic | The membership fuction | Testing values |
|---|---|---|---|
| The mother's Age | Risk | 1 | X > 35 yo |
| SBP | High | 0,50 | X = 140 mmHg |
| | Very High | 0,10 | |
| DBP | High | 0,00 | X = 110 mmHg |
| | Very High | 1,00 | |
| The Medical History | Risk | 1,00 | Hypertension |
| The Genetic factors | Risk | 1,00 | Genetic |

If the rules of the inference engine are followed, the alternatives will be obtained:
[R56] IF mother's age is at risk AND High Systolic BP AND High Diastolic BP AND History of Hypertension is at risk AND Hereditary factors are at risk THEN Severe hypertension;
[R56] = MIN(µMother's age, µSystolic BP, µDiastolic BP, µHistory of Hypertension, µDescent factor)
= MIN(0, 0.5, 0, 0, 0) = 0
[R60] = 0,5
[R68] = 0
[R72] = 0,1
After obtaining the lowest value or MIN, the value of fire strange (FS) by connecting the output variable data range with the minimum value of the rules that have been determined previously. Like the previous calculation, the results of the FS value calculation are as follows:
[R56] :
- µ[Low] : 4;
- µ[Normal] : 2
- µ[Normal] : 8
- µ[High] : 6, so the FS value for R56 is = 8.
[R56] : The FS value is 8;
[R72] : FS value is 7.7.
So the value of Z = (8*0) + (8*0.5) + (8*0) + (7.7*0.1) / (0 + 0.5 + 0 + 0.1) is obtained;
Z = 7,95
Based on the table 3, this result to describe the pregnant women who can be categorized into severe hypertension based on the emergency classification table based on Tsukamoto FIS. This results obtained by analyzing the correlation of the 5 (five) input parameters. While each input influences the decision-making process, there are inputs that are most dominant in determining the final decision such as SBP and DBP parameters. The other thing to be noted is that the membership function values of the input variables and output variables can describe the actual state of a problem condition related to pregnant women at risk of hypertension.

## DISCUSSION

Based on the results of the test, it can be seen that if a pregnant woman has a history of hypertension, then there is a possibility that the mother will have high systolic and diastolic blood pressure during pregnancy. This study only analyzes factors directly related to how much a pregnant mother is potentially or at risk of developing hypertension (Bello et al., 2021). The hypertensive disorders of the pregnancy, including a chronic hypertension, a gestational hypertension, a pre-eclampsia with or without severe symptoms, a Hemolysis, Elevated Liver Enzymes and Low Platelets (HELLP) syndrome, or an eclampsia, have a

significant risk of morbidity for both mother and fetus (Cohen et al., 2024). Other more detailed things like pregnancy length, frequency of pregnancies, urea protein, other diseases are not included in this study. Nevertheless, it is hoped that the presence of this study can support the establishment of information in the form of a diagnosis against one of the factors, namely hypertension, which will affect the occurrence of pre-eclampsia and eclampsia in pregnant mothers (Luger, Richard K., Kight, 2022). The Tsukamoto FIS shows that it is one of the methods that can be used and relied upon in calculating risk factors that may occur with approaches within a certain range and can be used as a data base to form an algorithm for a programming language-based application for early warning system detection of symptoms and examination results of pregnant women at risk of hypertension.

This research is related to determining the classification of hypertension and the risks that will be experienced over a lifetime according to the level of blood pressure that was previously considered normal. Based on the results of the study, the 'prehypertension' category for those with blood pressure ranging from 120-139 mmHg systolic and 80-89 mmHg diastolic. Based on the cases analysed in this study, it can be seen that the pregnant women showed hypertension because their blood pressure had exceeded the threshold for the prehypertension category. This suggests that such patients require early intervention with the adoption of a healthy lifestyle in order to reduce blood pressure. Decrease in the rate of progression of blood pressure to hypertensive level with age, or prevent hypertension completely (Barbounaki et al., 2021).

The evidence suggests that pregnant women who have hypertensive disorders of pregnancy (HDP) may have an increase postpartum depression, anxiety, or PTSD, as well as other mental health disorders (Mustafa et al., 2012). This is especially true for those women who experience a more severe form of HDP and/or give birth to a preterm birth (Roberts et al., 2019). A routine screening for hypertension symptoms may be key to reducing the impact of these mental health disorders (Radparvar et al., 2024). There is an increased need to screen pregnant women for postpartum depression, anxiety and other mental disorders (Lieskusumastuti et al., 2021). Therefore, this research can be used as an alternative in the screening process for pregnant women, especially related to hypertension symptoms.

The problem-solving method that will be used is the Fuzzy Inference System (FIS) algorithm which is one of the algorithms used for decision support. An algorithm used for decision support. The results of the research are in the form of system that can produce an initial diagnosis that can help someone diagnose a disorder or disease in diagnosing a disorder or a disease (Yuli Endra & Agus Saputra, 2022)(Mazenda, 2014). When compared the system that has been made with one patient's diagnosis data that has been done manually with an expert. In other words, the system can perform an initial diagnosis of a disease/ health disorder (Daivan et al., 2024). Therefore, this research can be an initial diagnosis related to the risk of pregnant women suffering from hypertension as well as an additional tool for an expert in analysing an initial disorder in a person including pregnant women.

In Tsukamoto's method, each consequence of an IF-THEN rule must be represented by a fuzzy set with a monotonous membership function. As a result, the inference output of each rule is given explicitly (crisp) based on the α-predicate (fire strength). The final result is obtained using a weighted average. In this research, there are 5 (five) input variables 1 (one) output variable. Based on the test, it shows that there is conformity between the inference engine compiled based on expert knowledge and the results of the Tsukamoto FIS test (Setyono & Aeni, 2018).Another study to diagnose the risk level of heart disease using the

Tsukamoto method involves 11 input variables such as cholesterol, blood pressure, ECG, and others, while the output variables are healthy, small, medium, large, and very large. The stages of this method consist of four main processes, namely literature review, fuzzy inference system design, fuzzy Tsukamoto application, and evaluation (Situmorang & Rindari, 2019)(Hakim et al., 2023). When associated with this research, the stages of applying Tsukamoto fuzzy can be used to diagnose the potential risk of hypertension in pregnant women through systematic steps.

The steps of problem-solving using fuzzy logic can be used as common algorithms for programming or simulation of early detection of hypertension in pregnancy risks. But of course, it has to be adapted to the programming language used. FIS Tsukamoto can analyze questions that have some linguistic interpretations that are translated into fuzzy logical reasoning to obtain a final decision. The results of FIS Tsukamoto's reasoning when implemented into everyday life allow the system to display results on a broader scale than crisp scales (Khairul Fuady & Zulisa, 2023). Some steps to solve the problem can be used as an algorithm for the application of the early warning system for risk detection of hypertension in pregnancy as follows:

1. Define Membership Functions.
   Each input variable (The mother's Age, Sistolic blood pressure, Diastolic Blood Pressure, The medical history of hypertension, the genetic factors) has fuzzy sets like `low`, `medium`, and `high` or in another level. The key factors is using the membership functions for simplicity.
2. Fuzzy Rules
   Defined as combinations of antecedents (`IF-THEN` rules) using `min` operators to compute the degree of membership for each rules.
3. Defuzzification: Calculates a weighted average of the aggregated rule strengths to determine the output (`risk`)
4. Main Program: Takes input values from the user, applies the fuzzy inference system to calculate the pregnancy risk, and provides a recommendation based on the risk level.
5. Recommendations: Based on the calculated risk level, the program outputs a recommendation for further action.

The Diagnosis of Heart Disease using Mamdani Fuzzy Inference (DHD-MFI) to diagnose heart disease. This research uses six variables for the purpose of diagnosing heart disease. These variables are input fields consisting of age, chest pain, electrocardiography, systolic blood pressure, diabetes and cholesterol are transmitted with the help of Fuzzy rules which are restricted in the range of data in the form of low, normal, high and very high intensity among the input variations. A single output is obtained as a clinical decision support system for cardiac diagnosis by using the Mamdani Inference Method. The proposed DHD-MFI based expert system gives an overall accuracy of 94% (Naseer et al., 2020). Based on this research, it is feasible in the future to test this research using DHD MFI and can be compared in terms of the best results.

## CONCLUSION

Implementation of the Tsukamoto fuzzy inference system (FIS) to determine the potential level of a pregnant woman at risk of hypertension can support the decision in order to enforce the diagnosis through physical examination. Furthermore, Tsukamoto's fuzzy inference system (FIS) can analyze problems based on input variables that are only described by linguistic factors such as low and high blood pressure, but can be overcome by turning into a fuzzy set of areas so that it can be accommodated by fuzzy logic to produce more accurate

results in the concrete calues.

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