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ResearchArticle

Prediction of Heart Attack Using Fuzzy Logic Method and Determination of Factors Affecting Heart Attacks

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Abstract:

As a result of the researches, it has been revealed that heart attack is the number one cause of death in the world. This problem will continue to increase, especially today and in the future. In this study, a heart attack was predicted by considering the factors affecting heart attack. Due to the uncertain conditions in heart attack, the fuzzy logic method, which is frequently used in healthcare, was used and expert opinions were taken into account in the model created. 576 rules were defined using the Mamdani fuzzy inference method. The study was tested with 10 patient data and the results were compared with the actual values. In addition, multiple regression analysis was performed, variables that had a significant effect on heart attack were determined, and the relationship between dependent and independent variables was examined. It was shown in the study that dependent variables explained the independent variable by 41.9% thanks to the multiple regression analysis. The regression equation obtained in line with these results significantly predicted the heart attack and the effect levels of the independent variables were determined.

1. Introduction

When a sudden blockage occurs in the arteries feeding the heart for any reason, the heart muscle cannot get enough oxygen and causes damage to the heart tissue. Substances such as fat and cholesterol accumulate in the artery walls responsible for blood flow and form structures called plaques. These plaques multiply as time passes and cause cracks on them by narrowing the vessels. Clots occur in these cracks, occlude the vessels and cause a heart attack [1].Tobacco use, excessive alcohol consumption, high cholesterol and fat, age (men over 40, women over 50), diabetes, obesity, use of illegal drugs, high blood pressure, chronic high levels of stress, previous heart attack, arrhythmia are important risk factors [2,3,4]. The risk of heart attack increases after the age of 40 in men and 50 in women, and women are less likely to have a heart attack than men [1]. Among family members, people who have had a previous heart attack or have a history of heart disease, the elderly and men are more likely to have a heart attack than other risk factors [5]. The main symptom seen in a heart attack is heart pain in the chest. Apart from this area, pain is felt everywhere from the stomach to the jaw or teeth, from the shoulder blade to the right and left arm, fingers and wrists. Symptoms such as shortness of breath, excessive sweating, dizziness, nausea or vomiting, restlessness, and feeling of depression may be experienced [1,6,7]. The World Health Organization (WHO) states that heart disease is the # 1 cause of death worldwide. Approximately 17 million people die from these diseases each year, representing 31% of global deaths. 85% of these deaths are caused by heart attack and stroke [8]. WHO stated that 36% of deaths that will occur in 2020 will be caused by heart diseases [9]. In addition, WHO stated that heart diseases increase the risk of Covid-19. According to a recent study, it was revealed that 43% of those with Covid-19 in Spain have heart disease [10]. In the Turkey Statistical Institute (TSI) in total deaths, according

to the measurement data, it is observed that the increasing trend of heart disease. Heart diseases are in the first place among the total deaths with 40% in 1989, 45% in 1993, 40% in 2009, 39.6% in 2013 and 40.4% in 2014.In 2030, it is estimated that cardiovascular diseases will be 22.2 million [11]. Considering the mortality rates due to heart diseases, it is seen that our country ranks first among European countries [12]. Many studies have been conducted in the literature concerning many factors that cause heart disease. Fuzzy logic is one of these studies. The concept of fuzzy logic was introduced by Zadeh in 1965 [13]. Fuzzy logic, which is a control system, is in the form of range to point or range to interval [13]. Kumar and Kaur (2013) created a fuzzy model for heart disease risk prediction using the Mamdani inference method [14]. Lee and Wang (2011) conducted a study on diabetes using fuzzy expert system[15]. Rustempasic and Can (2013) tried to diagnose Parkinson's disease using the fuzzy C-mean clustering method and pattern recognition method [16]. Samuel, Omisore, and Ojokoh (2013) conducted a study diagnosing typhoid fever using fuzzy logic [17]. Biouki, Turksen, and FazelZarandi (2015) diagnosed Thyroid disease using fuzzy expert system [18]. Thakur, Raw, and Sharma (2016) diagnosed Thalassemia using the Mamdani fuzzy inference system [19]. Saikia and Dutta (2016) predicted dengue disease using fuzzy inference system [20]. Apart from these studies, many studies have been conducted in the literature as a result of the increase in mortality rates due to heart diseases. Different techniques were used in these studies. Torun (2007) designed a hierarchical fuzzy expert system to determine the patient's risk of coronary heart disease [21]. The 10-year risk of the patient was determined in the study. As a result of the study, the risk ratio was given to the user and the treatment method was recommended. Palaniappan and Awang (2008) developed a prototype heart disease prediction system using data mining techniques (decision trees, pure Bayesian and neural network) [22]. Patil and Kumaraswamy (2009) proposed a system that predicts heart attack using a multilayer perceptron neural network [23]. Adeli and Neshat (2010) designed a fuzzy system with 13 inputs and conducted a study to reveal heart disease, and as a result of this study, they reached 94% accuracy [24]. Bhatla and Kiran (2012) conducted a study to diagnose heart diseases using data mining and fuzzy modeling[25]. Devi and Anto (2014) conducted a study to diagnose coronary artery disease by designing a fuzzy expert system [26]. A smart health system has been proposed for heart disease prediction using deep learning and fusion approaches [27]. In this study, it was tried to predict heart attack by using fuzzy logic method. While establishing the model, seven input data and one output data were used. Entries; Exercise-induced St depression (oldpeak) according to age, gender, type of chest pain (Cp), cholesterol, fasting blood glucose (Fbs), exercise-induced pain (Exang) and rest. The desired output is heart attack prediction. Afterwards, the variables that had a significant effect on heart attack were determined by performing regression analysis and the results obtained were interpreted. In the second part of the study, fuzzy logic method is explained, application is made in third parts, and the conclusion part is included in the fourth part.

2. Material and Method

The concept of fuzzy logic was first introduced in 1965 by Prof. Dr Zadeh [13]. It emerged with the "FuzySets" article published by Lotfi A. Zadeh [13,21].Using the data related to the study to be conducted and at the same time benefiting from the professional experiences of the people, processing the obtained data with algorithms and using mathematical equations depending on the rules to be written is defined as "Fuzzy Logic" [28,29,30].
Classical set theory and fuzzy set theory are different from each other. While {0,1} notation is used in classical sets, the interval [0-1] is used in fuzzy sets. Because in classical set theory, an entity is either an element of that set or it is not. In fuzzy set theory, each entity receives a membership degree in the range [0-1].Membership degrees are indicated by membership function μ (x) [31]. According to this information, the membership degree of element x in fuzzy set A is,

$$\mu A(x): x \rightarrow [0,1] \text{ ie } 0 \leq \mu A \leq 1$$

shown in the form. The expression $\mu A = 0$ indicates that the x element does not belong to the fuzzy A set, and the expression $\mu A = 1$ indicates that the x element belongs to the fuzzy A set [32].

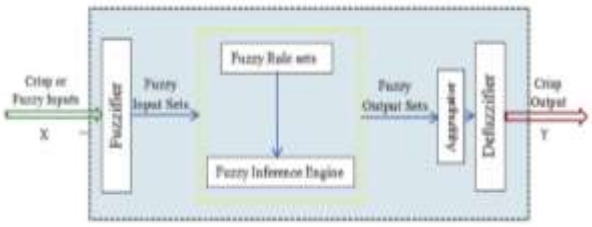

Figure 1. *General structure of the fuzzy logic model [33].*

The general structure of the fuzzy logic model is given in Figure 1. It consists of four components. These are: blur, rule base, inference engine, and clarification.

1. Blurring: Converts the input values to fuzzy values using the membership function. This process varies according to the membership function [21].
2. Rule Base: It is the relationship between inputs and outputs using various operators (fuzzy and implication operators) and interpreting the rules [34].
3. Inference Engine: In this section, rules based on rules are interpreted and fuzzy outputs are created [35].
4. Clarification: Incoming blurred information is clarified and converted into numbers [36].

First, entries are blurred using membership functions. Using fuzzy input and output values, fuzzy rules to be used in the solution of the problem are created and inference is performed with these rules. Finally, fuzzy information is clarified and turned into numbers [29]. Fuzzy logic has found wide application in many areas. The reason for this is the easy and useful solution-finding approach it provides in solving problems [37].It has been the subject of many fields such as medicine, manufacturing and engineering [38]. Another reason for its use in large areas is that it can model uncertain events, unclear data and functions by using expert opinions [39].Fuzzy logic is very important in the field of health, so it has many applications in medicine [40]. Problems are solved by using fuzzy sets for unclear conditions in medicine [41].

3. Results

This study was conducted using fuzzy logic in line with the data obtained from Kaggle. Fuzzy Logic Model was created using 7 input parameters and 1 output parameter, and it was estimated whether individuals would have a heart attack or not. Input parameters are St depression induced by exercise according to age, sex, type of chest pain, cholesterol, fasting blood glucose, exercise-induced pain, and listening. The output parameter is the heart attack prediction. All inputs are factors that will affect a heart attack. Input and output parameters are shown in Table 1. Triangle membership function (trimf) was used for age, gender, Chol, Fbs, Exang, Oldpeak and Heart attack prediction variables, and trapezoidal membership function (trapmf) was used for Cp variable. Since each variable is divided into classes within itself, the classes are expressed with linguistic variables when creating membership functions. Table 2 shows linguistic variables. Membership functions of the input parameters are shown from Figure 2 to Figure 8. In Figure 9, membership function of output parameter is given. In this study, Mamdani's Max-Min fuzzy inference method was used [42]. Centroid (Center of Gravity Method) method was used in the defuzzification stage.

Table 1. *Input and output parameters and their meanings*

Parameters	Meanings
Age	It is divided into 3 classes as young, middle-aged and elderly.
Gender	Men and women
Cp	It is divided into 4 classes: Typical pain, Atypical pain, No pain, and Asymptomatic pain.
Chol	It is divided into 3 classes as low, medium and high.
Fbs	It is divided into 2 classes as normal and high.
Exang	It means pain induced by exercise. It is divided into 2 classes: no pain and pain.
Oldpeak	It is ST depression induced by exercise compared to listening. It is divided into 2 classes as 2 mm below and 2 mm above.
Heart Attack Prediction	Output parameter. It is divided into two classes. Heart attack and heart attack proof

Table 2. *Classification of parameters*

Parameters	Linguistic variables
Age	40 years and under → Young 40–60 age → Middle age 60 years and older → Old
Cinsiyet	0=Woman 1=Man
Cp	0 = Typical pain, 1 = Atypical pain, 2 = No pain, 3 = Non-symptomatic pain
Chol	200 and below → Low 200 - 240 → Medium 240 and above → High
Fbs	125 and below → Normal 126 and above → High
Exang	0= No 1= Yes
Oldpeak	2 mm and under → 2 mm bottom 2 mm and older → 2 mm top
Heart attack prediction	0=No 1=Yes

First, the data were taken from Kaggle and the input and output parameters to be used in the study were determined. Limit values, linguistic variables and membership functions of these parameters have been created. In order to create the rule base, a relationship between input and output has been established and transferred to the Rule Editor section on the Fuzzy interface. The total number of rules created is 576. After the rule bases are created in the Rule Editor section, the rule index can be seen graphically thanks to the inference screen in the fuzzy interface (Figure 10).

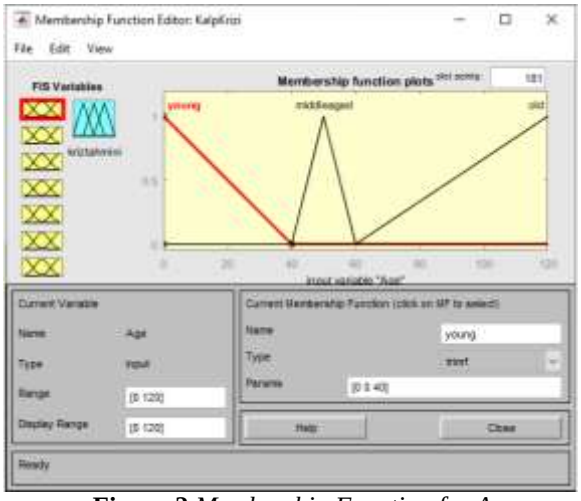

Figure 2.*Membership Function for Age*

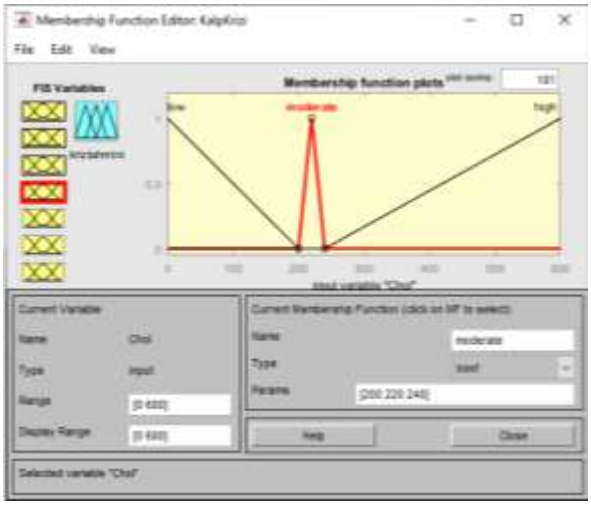

Figure 5. *Membership Function for chol*

Figure 3.*Membership Function for gender*

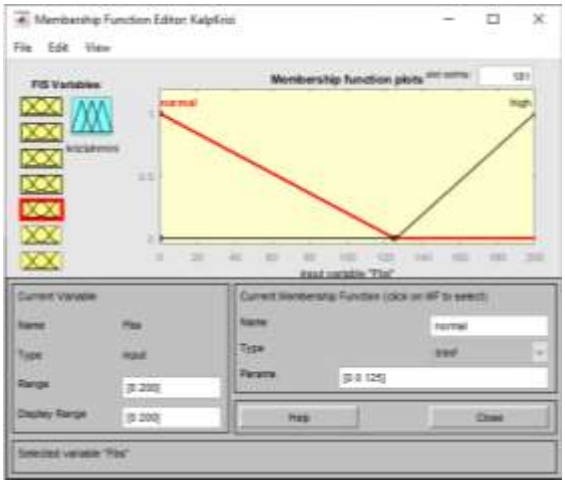

Figure 6. *Membership Function for Fbs*

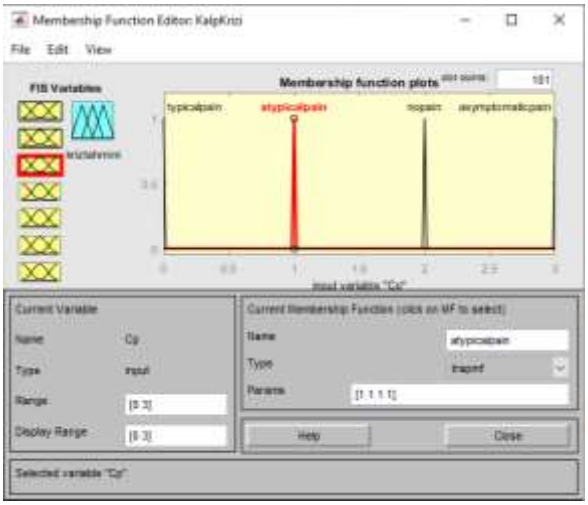

Figure 4. *Membership Function for Cp*

Figure 7. *Membership Function for Exang*

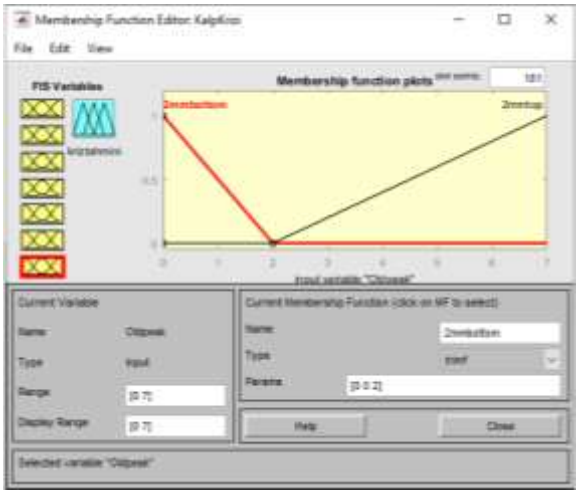

Figure 8. *Membership Function for old peak*

Figure 9.*Heart attack Fuzzy Logic Output*

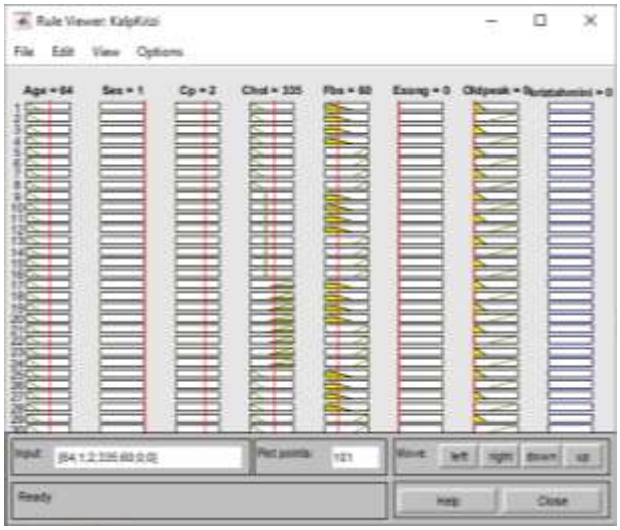

Figure 10. *Inference Screen*

Thanks to the data entered in the inference screen, whether the individual will have a heart attack or not can be seen in 0 or 1 format. 10 patient input data and heart attack prediction.

It is shown in Table 3.According to the results of the trial performed for 10 patients with the developed fuzzy logic model, all data were correctly estimated.

3.1. Regression Analysis

Table 3. *Input data and heart attack prediction for 10 patients*

No	Age	sex	Cp	Chol	Fbs	Exang	Oldpeak	Heart Attack real data	Heart Attack Prediction
1	63	1	3	233	135	0	2.3	1	1
2	57	0	1	236	110	0	0	0	0
3	37	1	2	250	72	0	3.5	1	1
4	52	1	2	199	127	0	0.5	1	1
5	44	1	0	120	56	1	2.8	0	0
6	61	1	0	203	85	0	0	0	0
7	71	0	2	265	140	0	0	1	1
8	43	1	0	177	120	1	2.5	0	0
9	64	1	2	335	60	0	0	0	0
10	45	0	0	236	80	1	0.2	1	1

The technique used to examine the relationship between dependent and independent variables is called Regression Analysis [43].

The value of the dependent variable is estimated by using the known values of the independent variables [44].

First, a heart attack prediction was made using fuzzy logic model. Then, multiple regression analysis was performed using dependent (output parameter) and independent variables (input parameters).In Table 4, variables entered in the model are shown in the Variables Entered column. It was stated that a heart attack was predicted using the data obtained from the variables entered.

Table 4. *"VariablesEntered / Removed" results*

VariablesEntered/Removed[a]			
Model	**Variables Entered**	**Variables Removed**	**Method**
1	oldpeak, fbs, chol, cp, sex, age, exang[b]	.	Enter

a. DependentVariable: kalpkrizi

b. Allrequestedvariablesentered.

Table 5 shows the multiple correlation value (R), how much the input values explain the variance of the heart attack prediction (R Square), the estimated standard error (Std. Error of the Estimate). It is seen that dependent variables determined according to Table 5 explain the independent variable at a rate of 41.9%. Table 6 Sig. Since its value is below 0.05, the regression equation obtained as a result of this analysis significantly predicts the heart attack. Table 7 shows the average value, standard deviation and sample number of each variable. Looking at the "Standardized Coefficients Beta"

Table 5. *Model Summary table*

Model Summary				
Model	**R**	**R Square**	**Adjusted R Square**	**Std. Error of the Estimate**
1	,658[a]	,433	,419	,380

a. Preictors: (Constant), oldpeak , fbs, chol , cp , sex , Age , exan

Table 6 *Anova test results*

ANOVA[a]					
Model	**Sum of Squares**	**df**	**Mean Square**	**F**	**Sig.**
Regression	32,505	7	4,644	32,123	,000[b]
Residual	42,644	295	0,145		
Total	75,149	302			

a. DependentVariable: kalpkrizi

b. Predictors: (Constant), oldpeak , fbs, chol , cp , sex , Age , exang

value in Table 8, the independent variables can be arranged in order of impact level. A one-unit increase in the Cp value takes the first place in the effect level because it causes an increase of 0.294 in the standard deviation of the heart attack prediction. Since a one-unit increase in Oldpeak value will cause a 0.277 decrease in the standard deviation of the heart attack estimate, it is in the last place in the effect level. By making this interpretation in other variables, the effect level order was determined as Cp, Fbs, Chol, Age, Exang, Sex, Oldpeak.

Table 7. *"Descriptive Statistics" results*

DescriptiveStatistics

	Mean	**Std. Deviation**	**N**
kalpkrizi	,54	,499	303
Age	54,37	9,082	303
sex	,68	,466	303
cp	,97	1,032	303
chol	246,26	51,831	303
fbs	,15	,356	303
exang	,33	,470	303
oldpeak	1,040	1,1611	303

Table 8. *"Coefficients" results*

Coefficients[a]												
Model	**Unstandardized Coefficients**		**Standardized Coefficients**	**t**	**Sig.**	**95,0% Confidence Inter val for B**		**Correlations**			**Collinearity Statistics**	
	B	**Std. Error**	**Beta**			**Lower Bound**	**Upper Bound**	**Zero-order**	**Partial**	**Part**	**Tolerance**	**VIF**
(Constant)	1,309	,171		7,658	,000	,972	1,645					
Age	-,008	,003	-,138	-2,974	,003	-,013	-,003	-,225	-,171	-,130	,892	1,122
sex	-,252	,049	-,236	-5,161	,000	-,349	-,156	-,281	-,288	-,226	,922	1,084
cp	,142	,023	,294	6,112	,000	,096	,188	,434	,335	,268	,829	1,206
chol	,000	,000	-,052	-1,129	,260	-,001	,000	-,085	-,066	-,049	,915	1,093
fbs	-,030	,062	-,021	-,478	,633	-,153	,093	-,028	-,028	-,021	,967	1,034
exang	-,202	,053	-,190	-3,812	,000	-,306	-,098	-,437	-,217	-,167	,775	1,291
oldpeak	-,119	,020	-,277	-5,920	,000	-,159	-,080	-,431	-,326	-,260	,876	1,142

a. DependentVariable: kalpkrizi

4. Conclusion

Heart attack is a very common health problem worldwide. According to researches, the number 1 cause of deaths is heart attack. Therefore, many studies have been done in the literature and are still being done. Different techniques were used in these studies. Artificial neural networks, data mining, fuzzy logic, deep learning are just a few of these techniques.

In this study, the fuzzy logic method, which is widely used in the diagnosis, treatment and risk estimation of many diseases in the field of health, was used.7 input parameters and 1 output parameter were used and a fuzzy model was created. At the end of the study, the data of 10 patients were shown in the model and whether they would have a heart attack or not was given as an output. Multiple regression analysis was conducted to determine the effect of other independent variables on the prediction of heart attack, which is the dependent variable, and to examine the relationship between them. According to the regression results, it is seen that the fuzzy logic equation significantly predicts the heart attack.

In the future, it is expected that studies will be carried out on different diseases using fuzzy logic method. In line with these studies, fuzzy logic will be of vital importance by increasing efficiency in health services and will become a powerful tool.

Author Statements:

- The authors declare that they have equal right on this paper.
- The authors declare that they have no known competing financial interests or personal

relationships that could have appeared to influence the work reported in this paper

- The authors declare that they have no-one to acknowledge.

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