PERFORMANCE EVALUATION OF THE DEEP LEARNING MODELS IN THE CLASSIFICATION OF HEART ATTACK AND DETERMINATION OF RELATED FACTORS

Z. Kucukakcali, I. Balikci Cicek, and E. Guldogan

Abstract*— *Aim: The aim of this study is to classify the condition of having a heart attack and determine the related factors by applying the deep learning method, one of the machine learning methods, on the open-access data set.

Materials and Methods: In this study, deep learning method was applied to an open-access data set named "Health care: Data set on Heart attack possibility". The performance of the method used was evaluated with accuracy, sensitivity, selectivity, positive predictive value, negative predictive value. The factors associated with having a heart attack were determined by deep learning methods and the most important factors were identified.

Results: Accuracy, sensitivity, specificity, positive predictive value and negative predictive value obtained from the model were 0.814, 0.804, 0.823, 0.809 and 0.834 respectively. The most important 3 factors that may be associated with having a heart attack were obtained as thal, age, ca.

Conclusion: The findings obtained from this study showed that successful predictions were obtained in the classification of having a heart attack by the deep learning method used. In addition, the importance values of the factors associated with the model used were estimated.

Keywords— Heart attack, machine learning, deep learning, classification, variable importance

1. INTRODUCTION

CARDIOVASCULAR diseases are the most common cause of mortality and morbidity in western countries today. Studies show that the mortality rate seen as a result of cardiovascular diseases worldwide will increase from 28.9% to 36.3% between 1990 and 2020 [1]. The most common cardiovascular disease is myocardial infarction (MI), which is usually called a heart attack [2]. MI is the condition of damage to the heart muscle cells that do not receive enough oxygen due to the deterioration of the blood supply of a part of the heart. In addition, if the heart muscle is without oxygen for a long time, death may occur. 50% of deaths from MI occur within the first hour, and this rate reaches 80% within the first 24 hours [3]. MI is an important public health problem that is frequently seen in the productive age group of the population, causes serious problems due to post-acute period complications and can result in death. Despite the advances in diagnosis and treatment in recent years, it is one of the most important causes of morbidity and mortality in our country and industrialized societies [4].

Deep learning is a field of study that has emerged with reference to the way the human brain works and deals with computer systems evaluating a problem based on existing data and producing outputs to solve the problem. Especially in recent years, its popularity has increased with the development of technology and the breakthroughs made in the field of software. Deep learning is considered within the fields of machine learning and artificial intelligence. Machine learning is concerned with computer systems learning certain operations that humans can do and automatically performing these operations.

Artificial intelligence, which includes machine learning, is concerned with the realization of intelligence-based personal evaluations and thoughts by computer systems. Therefore, deep learning artificial intelligence is a wide field of the study evaluated within the scope of machine learning fields. The deep learning field, which has been developing gradually over the years, has achieved successful and important results in problems that cannot be solved with machine learning [5, 6].

In this study, it is aimed to classify the situation of having a heart attack and to determine the related factors by applying the deep learning method on the open-access heart attack data set.

2. MATERIAL AND METHODS

2.1. Dataset

In order to examine the working principle of the deep learning method and to evaluate the model, an open-access data set named "Health care: Data set on Heart attack possibility" is available at https://www.kaggle.com/nareshbhat/health-care-data-set-on- Obtained from heart-attack-possibility. There are 303 patients in the data set used. While 138 (45.5%) of these patients had a low risk of heart attack, 165 (54.5%) of them had a high risk of heart attack.

Explanations about the variables in the data set and their properties are given in Table 1.

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TABLE I
EXPLANATIONS ABOUT THE VARIABLES IN THE DATASET AND THEIR PROPERTIES

Variable	Variable Description	Variable Type	Variable Role
age	age	Quantitative	Predictor
sex	sex	Qualitative	Predictor
cp	chest pain type (4 values)	Qualitative	Predictor
trestbps	resting blood pressure	Quantitative	Predictor
chol	serum cholestoral in mg/dl	Quantitative	Predictor
fbs	fasting blood sugar > 120 mg/dl	Qualitative	Predictor
restecg	resting electrocardiographic results (values 0,1,2)	Qualitative	Predictor
thalach	maximum heart rate achieved	Quantitative	Predictor
exang	exercise induced angina	Qualitative	Predictor
oldpeak	oldpeak = ST depression induced by exercise relative to rest	Quantitative	Predictor
slope	the slope of the peak exercise ST segment	Qualitative	Predictor
ca	number of major vessels (0-3) colored by flourosopy	Qualitative	Predictor
thal	thal: 0 = normal; 1 = fixed defect; 2 = reversable defect	Qualitative	Predictor
target	target: 0= less chance of heart attack 1= more chance of heart attack	Qualitative	Output

3. DEEP LEARNING

Deep learning is the methods that learn the representations at different levels on data with complex relationships and are included in the machine learning sub-field. Since 2006, researches in the field of deep structured learning or deep learning in its short form have opened a new page in the field of machine learning [6]. When the definitions in the literature are examined, deep learning, in its most general form, is a machine learning technique that is used to solve problems and perform actions such as analysis, inference, observation, and learning using large amounts of data. Unlike traditional machine learning algorithms, they can be in different hierarchical structures [7].

Deep learning is a sub-field of artificial neural networks (ANN). It is the type of ANN that works to get a certain output value from pure data with nonlinear transformations. Deep learning explores the complex structure of multidimensional data sets using the backpropagation algorithm. It does this by comparing the values of the parameters calculated in each layer with the values obtained in the previous layer and deciding what change should be made. Deep learning is based on multi-layered neural networks. Multi-layer neural networks consist of the input layer where the inputs are represented, hidden layers where the information from the input layer is processed into an output, and the output layer where the results from the last hidden layer are converted into output values. Thanks to deep learning methods, the success rate has increased significantly in the fields of natural language processing, image processing, visual object detection, and drug discovery [8].

3.1. Performance evaluation criteria

The classification matrix for the calculation of performance metrics is given in Table 2.

TABLE II
THE METRICS OF THE MODEL'S CLASSIFICATION PERFORMANCE

		Real		
		Positive	**Negative**	**Total**
Predicted	Positive	True positive (TP)	(FN) False negative	TP+FN
	Negative	False positive (FP)	(TN) True negative	FP+TN
	Total	TP+FP	FN+TN	TP+TN+FP+FN

Accuracy = (TP+TN)/(TP+TN+FP+FN)

Sensitivity = TP/(TP+FP)

Specificity = TN/(TN+FN)

Positive predictive value = TP/(TP+FN)

Negative predictive value =TN/(TN+FP)

4. DATA ANALYSIS

Quantitative data are summarized by median (minimum-maximum) and qualitative variables are given by number and percentage. Normal distribution was evaluated with the Kolmogorov-Smirnov test. In terms of input variables, the existence of a statistically significant difference and relationship between the categories of output variable, " less chance of heart attack " and " more chance of heart attack " groups, was examined using Mann-Whitney U, Pearson Chi-square test and Yates's correction chi-square test. $p<0.05$ values were considered statistically significant. In all analyzes, IBM SPSS Statistics 26.0 for the Windows package program was used.

For the validity of the model, a 10-fold cross-validation method was used. In the 10-fold cross-validation method, all data is divided into 10 equal parts. One part is used as a test set and the remaining 9 parts are used as a training data set and this process is repeated 10 times. Hyperparameters related to the deep learning model were selected as activation function (Rectifier), hidden layer sizes (50), the number of revolutions (10), epsilon (1.0 e8) and rho (0.99). RapidMiner Studio software was used in all modeling and analysis [9].

5. RESULTS

Descriptive statistics related to the target variable examined in this study are presented in Table 3 and Table 4. There is a statistically significant difference between the dependent variable classes in terms of other variables other than the "fbs" variable.

TABLE III
DESCRIPTIVE STATISTICS FOR QUANTITATIVE INPUT VARIABLES

Variables	Predicted Class: more chance of heart attack Median (min-max)	Predicted Class: less chance of heart attack Median (min-max)	P* value
age	52(29-76)	58(35-77)	<0,001
trestbps	130(94-180)	130(100-200)	0,035
chol	234(126-564)	249(131-409)	<0,036
thalach	161(96-202)	142(71-195)	<0,001
oldpeak	0,2(0-4,2)	1,4(0-6,2)	<0,001

*: Mann Whitney U test

TABLE IV
DESCRIPTIVE STATISTICS FOR QUALITATIVE INPUT VARIABLES

Variables		Predicted Class: more chance of heart attack	Predicted Class: less chance of heart attack	P value
sex	0	72(43,6%)	24(17,4%)	<0,001**
	1	93(56,4%)	114(82,6%)	
cp	0	39(23,6%)	104(75,4%)	<0,001*
	1	41(24,8%)	9(6,5%)	
	2	69(41,8%)	18(13,0%)	
	3	16(9,7%)	7(5,1%)	
fbs	0	142(86,1%)	116(84,1%)	0,744
	1	23(13,9%)	22(15,9%)	
restecg	0	68(41,2%)	79(57,2%)	0,007*
	1	96(58,2%)	56(40,6%)	
	2	1(0,6%)	3(2,2%)	
exang	0	142(86,1%)	62(44,9%)	<0,001**
	1	23(13,9%)	76(55,1%)	
slope	0	9(5,5%)	12(8,7%)	<0,001*
	1	49(29,7%)	91(65,9%)	
	2	107(64,8%)	35(25,4%)	
ca	0	130(78,8%)	45(32,6%)	<0,001*
	1	21(12,7%)	44(31,9%)	
	2	7(4,2%)	31(22,5%)	
	3	3(1,8%)	17(12,3%)	
	4	4(2,4%)	1(0,7%)	
thal	0	1(0,6%)	1(0,7%)	<0,001*
	1	6(3,6%)	12(8,7%)	
	2	130(78,8%)	36(26,1%)	
	3	28(17,0%)	89(64,5%)	

*: Pearson's chi-square test;** Yates's correction chi-square test

The classification matrix of the deep learning model used to classify the situation of having a heart attack in this study is given in Table 5 below.

TABLE V
CLASSIFICATION MATRICES OF DEEP LEARNING MODELS

Prediction	Reference: more chance of heart attack	Reference: less chance of heart attack	Total
more chance of heart attack	140	31	171
less chance of heart attack	25	107	132
Total	165	138	303

The values for the metrics of the classification performance of the model are given in Table 6. Accuracy, sensitivity, specificity, positive predictive value and negative predictive value obtained from the model were 0.814, 0.804, 0.823, 0.809 and 0.834 respectively.

TABLE VI
VALUES FOR THE METRICS OF THE CLASSIFICATION PERFORMANCE OF DEEP LEARNING MODELS

Metric	Value(%)
Accuracy	0.814
Sensitivity	0.804
Specificity	0.823
Positive predictive value	0.809
Negative predictive value	0.834

In Figure 1, values related to performance criteria are given graphically.

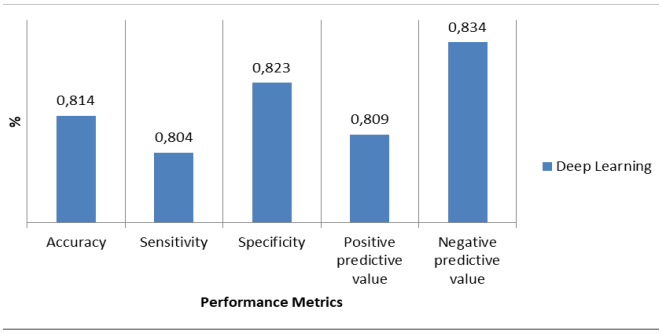

Fig. 1. Values related to performance criteria

The values showing the importance of the variables are shown in Table 6, from high to low. The most important variable is thal (0,086966) followed by age (0,082903) and ca (0,081892) respectively.

TABLE VII
IMPORTANCE VALUES OF EXPLANATORY VARIABLES ACCORDING TO DEEP LEARNING

Variables	Importance
thal	0,086966
age	0,082903
ca	0,081892
oldpeak	0,080578
exang	0,079877
sex	0,079097
cp	0,077245
trestbps	0,076191
slope	0,07378
fbs	0,072506
thalach	0,06997
restecg	0,069702
chol	0,069293

The values for these importance percentages are shown in Figure 2.

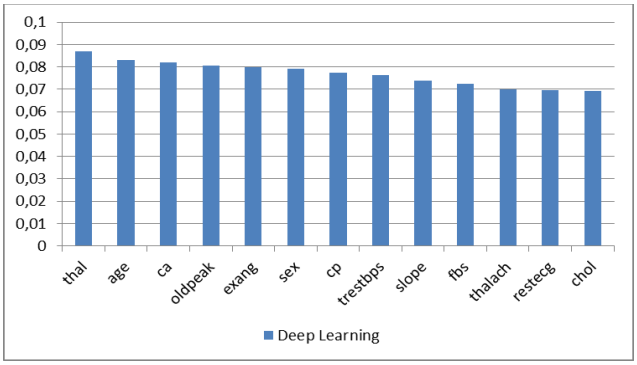

Fig. 2. The importance values for possible risk factors

6. DISCUSSION

Ischemic heart disease (IHD) is one of the diseases that cause mortality and morbidity worldwide [10]. One of these diseases is MI, defined as myocardial cell damage caused by prolonged ischemia. Heart attack is a physiological condition that occurs with severe chest pain and is likely to result in death, as a result of failure after a disorder in the coronary arteries of the heart. Heart attack occurs as a result of oxygen interruption due to a sudden decrease or interruption of blood flow in the vessels that feed the heart. It can cause various degrees of damage or death of the heart muscle fed by the occluded vessel [11]. Heart attack is the most important health problem in developed countries and a serious health problem of increasing importance in developing countries. MI is an important public health problem, which is frequently seen in the productive age group of the population, causes serious problems due to post-acute period complications and can result in death. According to the data of the World Health Organization (WHO), 16.7 million people die each year due to a heart attack. This number is one-third of deaths in the world [12].

Machine learning is a science that deals with the design and development processes of algorithms that allow computers to learn based on data types. Machine learning is not only a database problem but also a field of artificial intelligence that allows experiences gained from existing data to predict and model future events [13]. Deep learning methods are an increasingly popular machine learning method. With the development of graphics processing units (GPU), the Deep learning approach has gained popularity [14]. The deep learning approach is designed inspired by the working principle of the brain. It is a method developed by taking human learning systems as an example and consists of many hidden layers and neurons. With the contribution of hardware features that develop over time (especially the participation of graphics processors in the calculation), the deep learning method is used for processing large-sized data sets. Deep learning works in areas such as motion detection, face recognition, health technologies, object recognition, and object detection [15].

In the study, deep learning method was applied to the data set named “Health care: Data set on Heart attack possibility” which is an open-source data set. Accuracy, sensitivity, specificity, positive predictive value and negative predictive value obtained from the model were 0.814, 0.804, 0.823, 0.809 and 0.834 respectively. Deep learning method gave successful predictive results in the classification of having a heart attack according to the results of the performance criteria calculated in this study. In addition, the importance of risk factors related to having a heart attack was obtained with the experimental findings. The most important 3 factors that may be associated with having a heart attack were obtained as thal, age, ca.

In conclusion, the findings obtained from this study showed that the classification of heart attack status gives successful predictions. In addition, with the classification model used, the importance values of the factors associated with having a heart attack were estimated and the most important factors were determined.

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