Analysis and Prediction of Heart Attacks Based on Design of Intelligent Systems

Sozan Sulaiman Maghdid¹, Tarik Ahmed Rashid², Sheeraz Ahmed³, Khalid Zaman⁴, M.Khalid Rabbani⁵

¹College of Health Science, Hawler Medical University, Erbil, Kurdistan, Iraq
²Deptt of CS & Engineering, Kurdistan University, Erbil, Kurdistan, Iraq
³,⁵Faculty of Engineering and Technology, Gomal University, D.I.Khan, Pakistan
⁴Department of Computer Engineering, Near East University, Cyprus

Corresponding Author: Dr. Sheeraz Ahmed
Email: sheerazahmed306@gmail.com
https://doi.org/10.26782/jmcms.2019.08.000050

Abstract

Nowadays, artificial intelligence systems become actively used for the identification of different diseases using their medical data. Most of existing traditional medical systems are based on the knowledge of experts-doctors. In this thesis, the application of soft computing elements is considered to automate the process of diagnosing diseases, in particularly diagnosing of a heart attack. The research work will offer probable help to the medical practitioners and healthcare sector in making instantaneous resolution during the diagnosis of the diseases. The intelligent system will predict heart attacks from the patient dataset utilizing algorithms and help doctors in making diagnose of these illnesses. In this study, three techniques such as a neural network (back propagation), Fuzzy Inference System (FIS) and Adaptative Neuro-Fuzzy System (ANFIS) are considered for the design of the prediction system. The systems are designed using data sets. The data sets contain 1319 samples that includes 8 input attributes and one output. The output refers presence of a heart attack in the patient. For comparative analysis, the simulation results of the ANFIS model is compared with the simulation results of the neural network-based prediction model. The ANFIS model has shown better performance and outperformed NN based model. The obtained simulation results demonstrate the efficiency of using ANFIS model in the identification of heart attacks.

Keywords: Artificial neural network; adaptive neuro-fuzzy inference system; fuzzy inference System (FIS); neural network (back propagation); heart attack
I. Introduction

Present time, data has been scattered as Statistics, Reports, and Forms and so forth. It as a vast benefit which allows the creation of result in real time situations. Despite that, a lot of research has been conducted in various areas, health care has a wide extension to utilize officially accessible information and determine results which will be available to the world. Heart attack often occurs when a blood clot prevents blood course in the coronary artery - the blood vessel that connects blood to the heart muscle Fig.1. Blocking blood run to the heart may hurt the of the heart muscle, or even ruin it completely Long ago, heart attacks often ended in death. Now, the common of people with heart attacks they stay of live, thanks to the improved wakefulness of symptom of heart attacks and the development and improvement of treatment. The generally daily life, the food we eat the pace of physical doings we exercise and the way we face stress and stress - all play a significant function in improving from a heart attack. In addition, a healthy daily life can help to ban a first heart attack, or a heart attack, by decrease peril factors that help tight the coronary arteries, which are answerable for supplying the heart with blood.

Heart attack diseases are the major reason of death at an average level worldwide. In 2015, 17.7 million deaths which are caused from cardiovascular disease are estimated to be approximately 31% worldwide, according to the World Health Organization. According to this report, 82% of them are in low and middle-income countries, 17 million are under 70 years of age which are prone to non-communicable diseases, 6.7 million due to stroke and 7.4 million were due to coronary heart disease[XVI].When a heart attack happens, we have to quicken medical attention to prevent heart damage and to maintain the life of a patient with a heart attack. These days, the utilization of computer technology for medicine is very high. In order to realize our goals in this complex phase, active hybrid fuzzy expert systems that the doctor may need and that can prophecy the probability of a patient getting a heart illness problem and being able to assist in embodying the illness. The purpose of classification is to look for a pattern to predict the category of objects whose classification is unknown and depicts them in distinguishing data categories or concepts.
The concept of this paper is to style an architecture contain of fuzzy system and neural network to symbolize the knowing in an interpretable way and the learning capacity to optimize parameters. This paper is different with the utilize of fuzzy logic, neural network (back propagation) and Neuro-fuzzy (ANFIS) algorithms in an integrative technique to prophesy heart attacks with highest amount of rigor. This paper aims at developing a dynamic, intelligent and accurate system for diagnosis heart attack and we utilize these algorithms to determine which model gives the elevate proportion of correct foretelling for the diagnose between these algorithms.

II. Literature Review

Research conducted in [I] a fuzzy expert system for the diagnosis of heart illnesses. The researchers have utilized many variables which utilized 11 variables as input. The condition of patients either healthy or ill has been utilized as output which 4 kinds of illness have been utilized as output. Research conducted in [XII] discussed a methodology for how to analyze the life style parameters of individual with an adaptive neuron fuzzy inference system that acts as a resolution prop system for the physician to prophesy the hazard of heart illness and helping the patient to define their scale of hazard from heart illness with the possibility of avoiding the aggravation of the illness by changing the life style with medications, sound diet and exercise.

Authors in [III] presented Particle Swarm Optimization system (PSO) and feed forward neural network. In the first stage, this system partitions the orders set into two sets of sick and healthy people. In the second phase, 8192 partial groups of gross lineaments were extracted at an obvious cost. In the third stage, the PSO algorithm is applied for all the subsets to discover the better subset with the time, thoroughness, low cost and highest accessibility. The rigor was amended by 2.38% and 9.94% rigor.

Research conducted in [XIII] proposed Genetic Algorithm had task pivotal turn and active on prognostication of heart illness and one should look at that Genetic Algorithm necessarily to get extra applicable outcomes. A tests of dataset concerning with
heart illness indicative that people in age collection between 40 to 60 years should be afraid of heart illness signs because this age collection load hazards of heart disease more. Men have bigger hazards of heart illness than women. Research conducted in [XIV] depicts the prototype utilizing weighted associative classifier (WAC) and gullible qualities to prophesy the prospect of patients drawing heart attacks. There is a notable rise in the number of people hurting from heart illness. As an outcome, there is a rising in the unavailability of medical practitioners and also errors or inexactness in the diagnosis of the illness due to the rise in the growth of people over the years.

Research performed in[X] introduced a fuzzy rule-based classifier for diagnosis heart illness which decides structural and functional. The Researchers utilized weighted vote strategy and single victor technique. The outcome has demonstrated that the weighted vote technique by and large has expanded the characterization precision of congenital heart illness.

III. Research Algorithms

There is an increase in solicitude for intelligent systems throughout the last years and are being utilized to different problems in various fields especially medicine. In this work, we utilized three algorithms for diagnosing a heart attack and compared between them and determined the best for diagnosing a heart attack. The substantial concepts, for Neural Network, Fuzzy logic and Neuron-Fuzzy are illustrated in this part.

**Neural Network (NN)**

A neural network is a system developed for information processing generally, it was depend on the human brain where it is an exemplification of the human brain, which is capable of processing information, where it has a samemethod with the features of organic neural systems artificially sophisticated which attempts to spur the operation of learning. Traditionally the neural term pointed to a Nervous system which has biological neuron in it which transfers necessary information Fig.2. Also pointed to as Artificial Neural Network (ANN) is a computational paradigm where its ways and functions are depend on the build of the brain. Generally, they are intricate, nonlinear, and have able to work in parallel, distributed, adaptability and local processing [IV].

![Figure2: Schematic of neurons biological](image)
Fuzzy logic

One of the prediction algorithms used in this paper is a fuzzy logic. Fuzzy logic (FL) is a multi-valued logic that has been utilized to disband numerous intricate defies such as medical diagnostics [XVII]; [XVIII]. where in FL instead of fixed and accurate values, the values are approximated. In the mid - the 1960s Professor Lotfi A. Zadeh first Suggested the expression “fuzzy logic” and “fuzzy sets”. The classic logic is called fuzzy logic according to Zadeh.where the information is either true or false and it is based on Boolean logic. In classical logic, the membership represented by 0 if it does not belong to the set and 1 if it is in the set, i.e. {0, 1} furthermore, in fuzzy logic, this set is protracted to the interval of [0, 1]. Fuzzy logic is a way to calculate the analysis based on their accuracy, which is done to utilizing Boolean logic of 0s and 1s. Where Based on mysterious, inaccurate, uncertain, noisy, or missing input information where the idea of fuzzy logic serves a process that can achieve a distinct Fig.3.

![Fuzzy inference system](image)

**Fig 3: Fuzzy inference system**[VII]

Adaptive Neuron-Fuzzy Interference System (ANFIS)

The combined of two soft-computing methods of ANN and fuzzy logic together is refer to Modify network-based fuzzy inference (ANFIS)[IX]. Fuzzy logic has the capability to alteration the insights into the method of exact quantitative analysis and qualitative aspects of human knowledge. However, fuzzy logic takes more time to modify the membership functions (MFs) and also it doesn't have a defined style that can be utilized as evidence in the human thought and operation of conversion into rule-based fuzzy inference system (FIS). In contrast ANN, it has a bigger ability in the learning operation to adapt to its circumference. Thus, the ANN can be utilized to reduce the average of faults in the determination of basics in fuzzy logic and automatically adjust the MFsas in figure 4.
Data preparation

In this paper we described dataset that we got from the (Surgical Specialty Hospital-Cardiac Centre "Directorate of Health-Erbil" Kurdistan Regional Government Iraq, 2018). This dataset is used to diagnose the existence or nonexistence of heart attack obtained from different medical tests done out on the patients. This dataset include 1319 cases,(females 449 —, males —870, mean age: between 14 to 103 years). The dataset contains 9 traits which will be utilized in the study,eight input fields and one output field which indicate the existence of heart attack of the patient.We utilized 8traits for input and one trait for output. Input traits are age, sex, heart rate, systolic BP, diastolic BP, blood sugar,CK-MB and test-Troponin, and output trait indicate to the presence of heart attack which has two assort (0 and1): 0 refers to the nonexistence of heart attack and 1refers to the existence of heart attack. We utilized MATLAB framework for the dataset to be utilized in order and the data were normalized between 0 and 1.The detailed information about ingredients variables is presented in Table.1.

Table1: Dataregarding input ingredients

| Description          | Number of MF IN (FIS) | Number of MF IN (AFIS) | Max  | Min  | Variable Name |
|----------------------|-----------------------|------------------------|------|------|---------------|
| Age in years         | 3                     | 2                      | 103  | 14   | Age           |
| Sex                  | 2                     | 2                      | 1    | 0    | Sex           |
| maximum heart rate   | 3                     | 2                      | 135  | 20   | Heart Rate    |
| systolic BP          | 3                     | 2                      | 223  | 42   | SBP           |
| diastolic BP         | 3                     | 2                      | 154  | 38   | DBP           |
| blood sugar          | 3                     | 2                      | 541  | 35   | FBS           |
| CK-MB                | 2                     | 2                      | 300  | 0.321| CK-MB         |
| test-troponin        | 2                     | 2                      | 10.3 | 0.001| test-troponin |

Copyright reserved © J. Mech. Cont.& Math. Sci.
Sozan Sulaiman Maghdid et al
Data Normalization and Performance Evaluation

To guarantee equivalent consideration is given to all inputs and output, and to dispose of their measurements, the data utilized in this paper were scaled in the range of 0 and 1. There are two fundamental points of data normalization before the utilization of intelligence system models. The first is the evasion of utilizing properties in greater numeric extents that eclipse those in littler numeric reaches. The second is to dodge numerical challenges in the calculation. In this manner, the data utilized in this paper were normalized using the following equation:

\[ E_n = \frac{E_i - E_{\text{min}}}{E_{\text{max}} - E_{\text{min}}} \quad i = 1, 2, \ldots, n \]

Where \( E_n, E_i, E_{\text{min}}, E_{\text{max}} \) signify the normalized values, real values, least values, and highest values, respectively.

IV. Experiments and Results

A data set that includes the symptoms of 1319 patients are utilized in this study. The data set is split into two sections - the training and testing sets. Using identical inputs and output variables, the design of the models has been carried out. Eight input features are age, sex, heart rate, systolic BP, diastolic BP, blood sugar, CK-MB and test-Troponin. We have utilized three models Back Propagation Neural Network, the fuzzy inference system, and ANFIS. Each model has only one output to predict the heart attack of the Patient. Each model utilized the same domain of data sets. Matlab toolbox is utilized to design the models including Back Propagation Neural Network, the fuzzy inference system, and ANFIS. As follows the simulations of models are expounded:

**Back Propagation Neural Network**

In the test, we have utilized 1060 training styles to train the Back Propagation Neural Network, 259 testing and validation Patients are utilized to see the performance of the model and the best validation performance with 100 neuron 200 epoch is 0.081708 as shown in figure 5.
Fig. 5 and Table 2 highlights the training, testing, and validation accuracy; the accuracy of training is 0.94927 and it's fair enough but not perfect. The testing accuracy was 0.76559. The validation accuracy is 0.8086.

**Table 2:** Training, testing and validation by BP for 1319 patients

| Patients | neurons | epoch | Inputs                      | output            | Function | Training | testing | validation |
|----------|---------|-------|-----------------------------|-------------------|----------|----------|---------|------------|
| 1319     | 100     | 200   | age, sex, heard rate, SBP   | Heart attack      | Trainlm  | 0.94927  | 0.76559 | 0.8086     |
|          |         |       | , DBP, BS, CK-MB, Troponin. |                   |          |          |         |            |
Figure 7: Back propagation Gradient, Mu, Validation checks state

Fig. 7 the Gradient at 200 epochs which is 0.013266, Mu is 0.0001 and validation checks is 96.

Fuzzy Inference System

In the test, we have utilized 1060 training styles to train the fuzzy inference system model, 259 testing and validation Patients are utilized to see the performance of the model. The Mamdani technique is utilized for this model as shown in Fig. 8.
The Mamdani technique is used for fuzzy inference system.

We have specified the range of input variables from the data sets the range is set as follows: the age was in between 14-103, the sex was in between 0-1, the heart rate was in between 135-20, the systolic blood pressure was in between 42-223, the diastolic blood pressure was in between 38-154, the blood sugar was in between 35-541, the CK-MB was in between 0.321-300, the Troponin was in between 0.001-10.3 and one output which was the diagnosis heart attack in between 0-1 for example Fig.9 and Fig.10 shows the membership function for the age variable and the membership function for diagnosis heart attack output.
Figure 9: The membership function for the age variable

Figure 10: The membership function for diagnosis heart attack output

Beneath a perfect conception to our data set, and the domain of the different input variables and the output variable, we come up with some rules. The rules were as follows:

1. If (age is young) and (sex is woman's) and (heart rate is least) and (systolic is least) and (diastolic is highest) and (blood sugar is least) and (CK-MB is natural) and (Troponin is highest) then (output is positive).
2. If (age is old) and (sex is woman's) and (heart rate is natural) and (systolic is highest) and (diastolic is least) and (blood sugar is least) and (CK-MB is highest) and (Troponin is natural) then (output is positive).
3. If (age is old) and (sex is woman's) and (heart rate is least) and (systolic is least) and (diastolic is highest) and (blood sugar is least) and (CK-MB is natural) and (Troponin is highest) then (output is positive).
4. If (age is middle age) and (sex is woman's) and (heart rate is least) and (systolic is least) and (diastolic is highest) and (blood sugar is least) and (CK-MB is natural) and (Troponin is highest) then (output is positive).
5. If (age is young) and (sex is man's) and (heart rate is least) and (systolic is least) and (diastolic is highest) and (blood sugar is least) and (CK-MB is natural) and (Troponin is highest) then (output is positive).
The results are shown in Figures 11 and 12.

**Figure 11:** The rules in fuzzy logic

**Figure 12:** The eight variables input
Adaptive Neuron-Fuzzy Interference System (ANFIS)

In the trial, the Sungo technique is utilized as shown in Fig. 14. A gauss2mf membership function for the eight inputs utilized and a linear function utilized for the output as shown in Fig. 15.

Figure 13: The surface of the model in fuzzy logic

Figure 14: The Sungo technique is used for fuzzy inference system. A gauss2mf membership function for the eight inputs utilized and a linear function utilized for the output as shown in Fig. 15.
Figure 15: How to select the functions for both inputs and output
1060 Patients was the training set and 259 Patients is utilized as a testing set. Hybrid is the way options available for FIS training in the ANFIS parameter optimization ways. The hybrid is executed. Error toleration is utilized to make a coaching cessation norm, which is linked to the fault size. After the coaching data error remains within this toleration where the coaching will stop. If we were not sure how our coaching error would behave this is best left set to 0. The test set is done, and the outcome were outstanding compared to the FIS model and the Back Propagation Neural Network, see Fig.16.

Figure 16: The testing session for the ANFIS model.

Table 3: Training, testing and validation by ANFIS for 1319 patients

Copyright reserved © J. Mech. Cont. & Math. Sci.
Sozan Sulaiman Maghdid et al
Patients | MF type | neurons | epoch | Inputs | output | Function | Error tolerance | Obtained error
---|---|---|---|---|---|---|---|---
1319 | Linear MF | 10 | 100 | Age, sex, heard rate, SBP, DBP, BS, CK-MB and Troponin. | Heart attack | gauss2mf | 0.00 | 0.28509

The five layers that were expounded in portion 2 presently for the ANFIS model are drawn as shown in Fig.17.

**Figure17:** The ANFIS model

Fig.18 and Fig.19 show the results that produced by ANIS.
Comparison of the three algorithms

We utilized the Root Mean Square Error (RMSE) evaluation method for Comparison of the three algorithms. RMSE is the criterion perversion of the residuum (foretelling errors). Residuum is a gauge of how away from the regression streak data points are; RMSE is a gauge of how prevalence out this residuum is. In other words, he informs you how centered the data is about the streak of the better. Root mean square error is generally utilized in foretelling, regression analysis, and climatology to prove experiential results. The formulation is:

\[ \sqrt{(f-o)^2} \]

Where:
- \( f \) = prediction (unknown results or predictable values),
- \( o \) = observed values (known results).

Table 4: Root-mean-square-error (RMSE) after training and testing

| Number of patients | Number of neurons | RMSE     | Accuracy   |
|--------------------|-------------------|----------|------------|
|                    | BPNN              | ANFIS    | BPNN       | ANFIS      |
| 1319               | 0.597605          | 0.28509  | 74.343866  | 91.250607  |
Table 4 is Root-mean-square-error (RMSE) after training and testing for BPNN and ANFIS and compare between them where the ANFIS is the best because the error rate is less compared to BPNN which is 0.28509 and BPNN is 0.597605.

As for the fuzzy logic where the fuzzy logic is a design pattern which can be joined with algorithms to predict based on Fuzzy Rules. For example, ANFIS is using Fuzzy Logic Rules and train Neural Network with it. It also can predict alone by itself one by one.

V. Conclusion

We utilized MATLAB circumference normalization and processing of data set. In this study, three techniques- neural networks (back propagation), fuzzy inference system (FIS) and ANFIS models are utilized to predict the heart attack of the patients. The simulation results of three techniques are compared. Mathlab software was utilized to implement all techniques FIS, ANFIS and neural network (back propagation) for identification of heart attack. The ANFIS has shown good performance.

References

I. Adeli, A., & Neshat, M. (2010, March). A fuzzy expert system for heart disease diagnosis. In Proceedings of International Multi Conference of Engineers and Computer Scientists, Hong Kong (Vol. 1).

II. American Heart Association (2015). Heart.org/answers by heart National Center 7272. Greenville Ave. Dallas, TX 75231 Customer Service 1-800-AHA-USA-11-800-242-8721 from https://www.heart.org/en/health-topics/consumer-healthcare/answers-by-heart-fact-sheets/answers-by-heart-fact-sheets-lifestyle-and-risk-reduction/

III. Feshki, M. G., & Shijani, O. S. (2016, April). Improving the heart disease diagnosis by evolutionary algorithm of PSO and Feed Forward Neural Network. In Artificial Intelligence and Robotics (IRANOPEN), 2016 (pp. 48-53). IEEE.

IV. Haykin S (2009) Neural network and machine learning. 3rd ed Copyright © 2009 by Pearson Education, Inc., Upper Saddle River, New Jersey 07458. Pearson Prentice Hall, New York ISBN-13: 978-0-13-147139-9 ISBN-10: 0-13-147139-2.

V. Teng, H., Liu, X., Liu, A., Shen, H., Huang, C., & Wang, T. (2018). Adaptive transmission power control for reliable data forwarding in sensor based networks. Wireless Communications and Mobile Computing, 2018.

VI. Narcisse, M. R., Rowland, B., Long, C. R., Felix, H., & McElfish, P. A. (2019). Heart Attack and Stroke Symptoms Knowledge of Native Hawaiians and Pacific Islanders in the United States: Findings From the National Health Interview Survey. Health promotion practice, 1524839919845669.

Copyright reserved © J. Mech. Cont.& Math. Sci.
Sozan Sulaiman Maghdid et al
VII. Takdastan, A., Mirzabeygi, M., Yousefi, M., Abbasnia, A., Khodadadia, R., Soleimani, H., ...&Naghan, D. J. (2018). Neuro-fuzzy inference system Prediction of stability indices and Sodium absorption ratio in Lordegan rural drinking water resources in west Iran. Data in brief, 18, 255-261.

VIII. Nicole, O., Bell, D. M., Leste-Lasserre, T., Doat, H., Guillemot, F., &Pacary, E. (2018). CaMKIIβ regulates nucleus-centrosome coupling in locomoting neurons of the developing cerebral cortex. Molecular psychiatry, 23(11), 2111.

IX. Jang, J. S. (1993). ANFIS: adaptive-network-based fuzzy inference system. IEEE transactions on systems, man, and cybernetics, 23(3), 665-685.

X. Kaya, E., Oran, B., &Arslan, A. (2011). A diagnostic fuzzy rule-based system for congenital heart disease. World academy of science, Engineering and technology, 78, 253-256.

XI. Patil, S. B., &Kumaraswamy, Y. S. (2009). Intelligent and effective heart attack prediction system using data mining and artificial neural network. European Journal of Scientific Research, 31(4), 642-656.

XII. Shanithi. S (February 2017). Customized Prediction of Heart Disease with Adaptive Neuro Fuzzy Inference System International Journal of Advanced Research in Computer and Communication Engineering, SO 3297:2007 Certified

XIII. Shinde, P. P., Oza, K. S., &Kamat, R. K (2016). An Analysis of Data Mining Techniques in Aggregation with Real Time Dataset for the Prediction of Heart Disease. InternationalJournal of Control Theory and Applications, 9(20), 327-336.

XIV. Sundar, N. A., Latha, P. P., & Chandra, M. R. (2012). Performance analysis of classification data mining techniques over heart disease database. IJESAT] International Journal of engineering science & advanced technology ISSN, 2250-3676.

XV. Vipul, A. S. (2009). Adaptive Neuro-Fuzzy Inference System for Effect of Wall Capacitance in a Batch Reactor. Advances in Fuzzy Mathematics ISSN, 69-75.

XVI. WHO (2015). Cardiovascular diseases. Retrieved August 28, 2015 from http://www.who.int/ media centre/factsheets/fs317/en/.

XVII. Zadeh, L. A. (1965). Fuzzy sets. Information and control, 8(3), 338-353.

XVIII. Zadeh, L. A. (1973). Outline of a new approach to the analysis of complex systems and decision processes. IEEE Transactions on systems, Man, and Cybernetics, (1), 28-44.