Fuzzy Logic and Hybrid based Approaches for the Risk of Heart Disease Detection: State-of-the-Art Review

Jagmohan Kaur[1] · Baljit S. Khehra[2]

Abstract Artificial Intelligence, Machine Learning, Fuzzy Logic, Neural Network, Genetic Algorithm and their hybrid systems play vital role in the medical sciences to diagnose various diseases efficiently in the patients. The problems related to the heart are widely comon in today's world. The risk of heart failure develops due to the narrowness and blockage in the coronary arteries of the heart as excess cholesterol deposits in the arteries and blood vessels that results in fatigue, chest pain, dyspnoea, sleeping difficulties and depression. This research aims to explore diverse work done on FL and Hybrid-based techniques to identify the risk of heart disease among the patients. The present study reveals publications along with the strength, operating system, accuracy rate and other specifications used in the identification of heart disease based on FL and Hybrid-based approaches since 2010. This survey contributes motivation for research scholars to generate more innovative ideas and continue their research work in the respective field. Moreover, the future model for direct service of the patients from old age homes to the Intensive Care Unit through ambulance services is also presented in this paper.

Keywords Artificial intelligence (AI) ·
Machine learning (ML) · Fuzzy logic (FL) ·
Neural network (NN) · Genetic algorithm ·
Intensive care unit (ICU)

✉ Jagmohan Kaur
mohnideep1234@gmail.com

1   IK Gujral Punjab Technical University, Jalandhar, Punjab, India

2   BBSB Engineering College, Fatehgarh Sahib, Punjab, India

Introduction

The heart disease involves many risks like gender, age, obesity, high blood pressure, high cholesterol, diabetes, family history, drinking alcohol and smoke. Apart from these, there are many other threats like underemployment industrialization, stress due to over work, physical inactivity, depression, stress, diet/routine changes and distressed sleep have increased in this technical and modern world. In addition to this, change in life style, egoism, greed and narcissistic approach of people have triggered the occurrence of chronic diseases in patients.

Heart diseases are categorized into distinct types like congenital heart disease, coronary heart disease (CHD), arrhythmia, dilated cardiomyopathy, heart failure, myocardial infarction (MI), hypertropic cardiomyopathy and mitral regurgitation. The patient having heart problem may feel chest pain, faintness or coolness in arms and legs. However, controlling blood pressure, eating a well-balanced nutritious diet, regulating exercise regime, limited usage of alcohol, tobacco, smoking and gazettes can treat illness and malfunction of the heart.

The mortality rate of the heart patients is the highest in two countries namely: Africa and India, which is 34% and 23%, respectively, and it is the lowest in France, Japan and Hong Kong. Both developed and underdeveloped countries have been facing this chronic disease since four decades due to the excess consumption of alcohol, smoking and tobacco. Nowadays, the most of the deaths occur due to coronary heart disease. However, in some European countries, death rate due to heart failure has declined as they are followed by better health/education services and other preventive measures. According to the report of WHO [1], near 17.8 million older and adults face this deadly disease. In fact, the death rate in adults is greater

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than that of the aged people. Centers for Disease Control and Prevention (CDC) [2] have announced that ratio of death rate in Americans is 1:4 that means one out of every four is dead due to heart stroke and 1 out of each 5 people doesn't know that they are affected by silent attack. One more description from British Heart Foundation (BHF) [3] revealed that the panic of pandemic COVID-19 (coronavirus disease) in the year 2020 has become the reason of people dying with heart stroke due to psychological stress and social distancing. All this has even affected the economy of the world as well as of other countries.

With the advancement of power of computer applications can make drastic changes in the medical field by predicting disorder of tumors, lungs, thyroids and heart at very early stage in the patients. Computer-aided heart disease risk diagnose system has many features:

(a) Modern technique
(b) Time saving
(c) Independent from medical experts
(d) Minimize expenditure
(e) Minimal errors
(f) Less human effort
(g) Diminish mortality rate

This era of artificial intelligence comes up with another invention made by the scholars of the Oxford University [4], well known as "fingerprint" a biomarker named as FRP (Fat Radiomic Profile) which is helpful in diagnosing future stroke via scarring and inflammation of blood vessels. The British Heart Foundation (BHF) and the National Institute of Health Research (NIHR) are providing funds for the same.

Research Methodology

The selection and collection of papers in journals and international conferences have been chosen from state-of-the-art and well-recognized publishers that ensures the quality of this review paper. Total 53 papers are summarized in this paper, out of which 4 revealed the status of heart disease patients in the world by WHO, BHF, NIHR and CDC and rest 49 papers bring forward current approaches and algorithms of AI being used for the identification of heart risk since 2010. In the Fig. 1, pie chart shows 73% of area of publications is covered by hybrid system and 27% belongs to FL.

Further, references of 21 IEEE, 13 Springer, 9 Elsevier and 4 ACM papers are provided to bring forward the distinct techniques and their combinations being used in heart disease detection along with their data bases, approaches, accuracy and other specifications. Collection of research papers per year and per publication is presented in Figs. 2
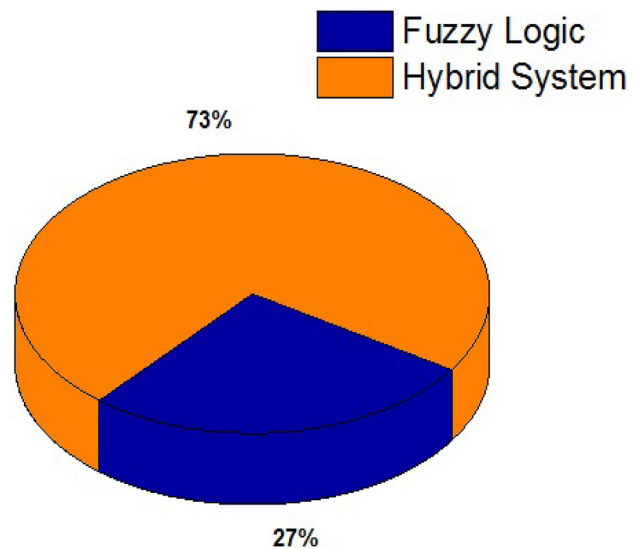

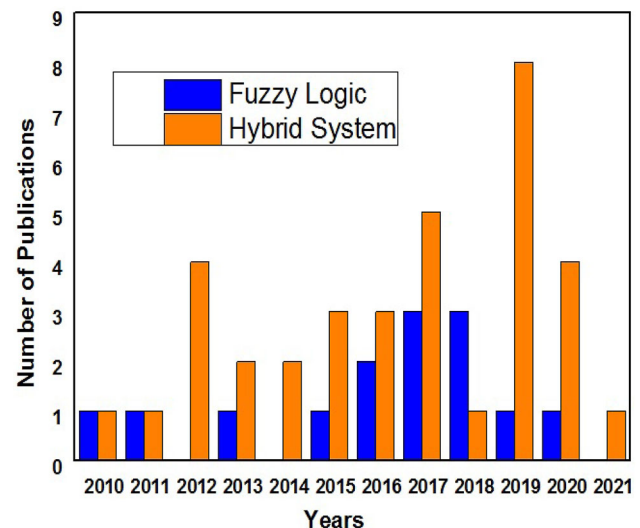**Fig. 1** Publications of fuzzy logic and hybrid system

Fig. 2 Collection of research papers per year

and 3, respectively. The Table 1 reveals total number of publications of SCI Index.

Table of Abbreviations of Symptoms and Heart Disease Database

The following Tables 2 and 3 give the information of abbreviations used for symptoms and heart disease database throughout the paper.
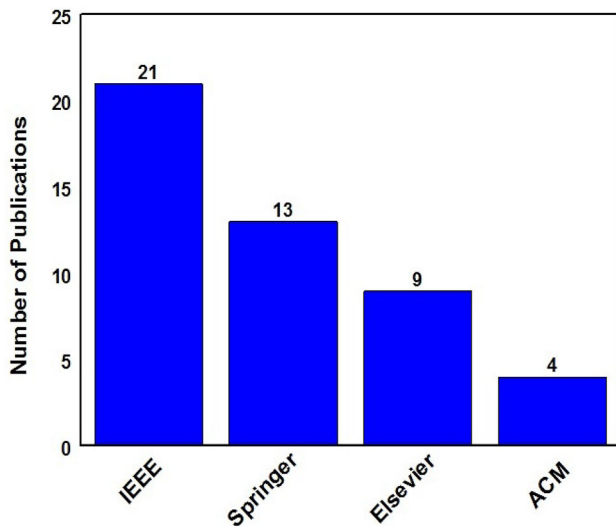
Fig. 3 Collection of research papers per publisher

Table 1 Total no. of publications of SCI index

Publisher	Research paper	No. of researches
IEEE	[5–25]	21
Springer	[26–38]	13
Elsevier	[39–47]	9
ACM	[3, 48, 49, 51]	4

Review of FL and Hybrid-Based Approaches for the Risk of Heart Disease Detection

A mathematical discipline in which the structure of human behavior in the form of uncertainties, true or false forms the basis of FL. FL has following features:

(a) Fascinating area of research
(b) Computational approach
(c) A matter of degrees of truth
(d) A limiting case of estimated reasoning
(e) Performs decision-making with approximate values

The flow chart of algorithm of Fuzzy logic-based approach for the risk of heart disease is shown in the Fig. 4. The combination of two or more than two technologies to find the solution of the peculiar problem, overcome the deficiency of one technique and strengthen the system are known as hybrid systems. In this study, hybridization of techniques has been described as, FL [8, 9, 11, 12, 14, 15, 19, 20, 25–32, 35, 36, 38–41, 45, 48, 50, 52, 53], GA [5, 7, 10, 14, 18, 26, 27, 36, 44], Artificial Neural Network (ANN) [5, 7, 10, 13, 35, 42–44, 51], Particle Swarm Optimization (PSO) [13, 33, 41], Ant Colony Optimization (ACO) [37], Naive Bayes (NB) [16, 18, 23, 29, 34], Decision Tree (DT)

[8, 18, 20, 22, 23, 28, 41, 48, 51], K-means Clustering Algorithm [22], Logistic Regression (LR) [23, 42], Multivariate Adaptive Regression Splines (MARS) [42], Rough Set (RS) [3, 42], Support Vector Machine (SVM) [33, 34], Random Forest (RF) [21, 23], K-Nearest Neighbourhood (K-NN) [18, 30, 37, 46], Logistic Regression SVM (LR SVM) algorithm in [23], has been summarized.

Review of Research Papers from 2010–2013 of FL and Hybrid-Based Approaches

Adeli et al. [52] demonstrated the fuzzy expert system (2010) using 11 input attributes from database of CCF, LBF and V.A medical Center: AG, CP, CHL, MHR, RBS, RECG, THR, BP, OP, GR, EXANG and 1 output attribute with 5 features: sick (s1-s4) and healthy. Fuzzification was structured in trapezoidal, triangular, R and L membership functions. Implementation of Mamdani inference system was made with rule-based system of 44 rules. 'COG' technique was used for defuzzification and yielded 94% accuracy. Design of the system was implemented in MATLAB. Explanation of hybrid fuzzy-evidential inference engine (2010) was made by Vahib Khatibi et al. [39] using fuzzy sets and Demster–Shafer theory of evidence. The hybrid system achieved 91.58% accuracy from the data set of patients from V.A medical Center, CCF, HIC and UHS.

An article (2011) by Anooj in [40] revealed the system based on self-received information from the database. Extension in a clinical decision support system was made by using triangular membership functions along with Mamdani fuzzy inference system in programming language MATLAB 7.10. Defuzzification technique 'COA' was utilized to achieve 62.35% of accuracy rate. CCF, V.A medical center and UHS were the main sources of database. E. P. Ephzibah in the paper [26] presented a hybrid system (2011) based on GA and FL in MATLAB 7.3.0 for the smooth work in healthcare field. CCF data set was used for the implementation of the work. Due to GA, 14 selected attributes were reduced to 6 attributes: CP, RBP, EXANG, MHR, OP and CA. Trapezium and triangular membership functions were used in the strategy of fuzzification. Another development in the framework of fuzzy expert system (2012) was initiated by Bhuvaneswari Amma [5] to demonstrate an adaptable disease diagnosis system using hybridization of GA along with NN. It consisted of 13 input variables AG, CP, GR, CHL, RBP, FBS, THS, RECG, MHR, EXANG, OP, CA, SLOPE and 1 output variable for the data base of UIC, Irvine. Accuracy rate was obtained 94.17% which was evaluated through Root Mean Square Error. The system (2012) described by Ephzibah et al. [27] made use of GA to select salient and 6 prime features responsible for the rapid and error free diagnosis

Table 2 Table of abbreviations of symptoms

| Sr. No	Symptoms	Units	Abbreviation	Limit
1	Age		AG	30–86
2	Chest pain (typical angina, atypical angina, non- anginal pain, asymptomatic)		CP	Yes, no
3	Cholesterol	mg\dL	CHL	125–200
4	Serum cholesterol	mg\dL	Serum CHOL	Less than 200
5	Low density lipoprotein	mg\dL	LDL CHOL	18–232
6	High density lipoprotein	mg\dL	HDL CHL	15–111
7	Resting blood pressure\Blood pressure	mm\Hg	RBP\BP	75–120
8	Diastolic blood pressure	mm\Hg	DBP	80-greater than 120
9	Systolic blood pressure\High blood pressure	mm\Hg	SBP\HBP	130-greater than 180
10	Blood pressure	mm\Hg	BP	90–190
11	Elecrocardiogram\Resting elecrocardiogram	ms	ECG\R ECG	120–200
12	Maximum heart rate\Maximum heart rate achieved during exercise	bpm	MHR\THALACH	Varies
13	Resting heart rate	bpm	Thal rest	60–100
14	Gender		GR	Yes, no
15	Old peak (ST depression)		OP	Variable
16	Slope of the peak-exercise ST-segment		SLOPE	Upsloping, flat, downsloping
17	Blood creatinine level	mg\dL	BCL	0.5–2.2
18	Blood uric acid level	mg\dL	BUAL	2.4–6.0 (female), 3.4–7.0 (male)
19	Blood sodium level	.125, .129, .141mEq/L	BSL	135–145
20	Height	Feet	HT	
21	Weight	Kg	WT	
22	Pulse rate	ppm	PR	50–110
23	Fasting blood sugar	mg\dL	FBS	62–400
24	History of hypertension		HTN	Yes, no
25	Family history of coronary artery disease		FAMHIST	Yes, no
26	History of diabetes		DM	Yes, no
27	Number of major vessels colored by fluoroscopy		CA	0–3
28	Exercise-induced Angina		EXANG	Yes, no
29	Obesity		OBES	Yes, no
30	Thallium scan		THAL	Normal, fixed defect, reversible defect

of disease and then implemented FL. MATLAB was used as programming language for the data base taken from UCI ML respository. Akhil jabbar et al. [6] revealed the methodology (2012) of association rules which were generated by using hybrid feature subset selection. The paper consisted of mainly 11 input variables: AG, GR, THALACH, LDL CHL, HDL CHL, CHOL, Rural/Urban, BP Systolic, BP Diastolic and Serum Triglycerides. Approach was implemented in the database of Andra Pradesh which yielded 95% accuracy.

The another system (2012) designed by Muthukaruppan [41] was based on DT and PSO containing 13 input variables: AG, CHOL, BP, GR, THALACH, CP, RECG, OP, EXANG, SLOPE, THAL, CA and 1 output variable. The phenomenon of 'if-then' rule in fuzzy rule-base was applied. The system was designed in MATLAB 7 and yielded accuracy of 93.27%.

The demonstration of another fuzzy expert system (2013) was presented by Sanjeev Kumar et al. [53]. It explained 6 input variables: CP, BS, BP, CHL, MHR, OP and one is decision variable with 5 features. Mamdani

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Table 3 Table of abbreviations of heart disease database

Sr. No	Heart disease data base	Country	Abbreviation
1	Cleveland Clinic Foundation	Ohio, US	CCF
2	The Veterans Health Administration	US	V. A. medical center
3	Hungarian Institute of Cardiology	Budepast, Hungary	HIC
4	University of California	Irvine, California	UCI
5	Unified Medical Language System	US	UMLS
6	Massachusetts Institute of Technology, Boston's Beth Israel Hospital	US	MIT-BIH
7	Long Beach Foundation	Long Beach, California	LBF
8	The University Hospital	Zurich, Switerzland	UHS
9	Cleveland Clinic Foundation and Hungarian Institute of Cardiology	US and Hungry	CH
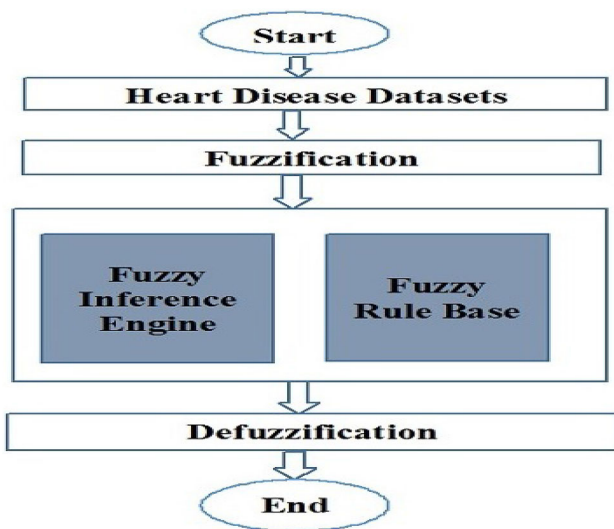
Fig. 4 Flow chart of algorithm of FL-based approach for the risk of heart disease detection

inference system was implemented with rule-based system (22 rules). Rule base was characterized by 'if-then' rules using logical combinations of inputs with AND operator in MATLAB. Center of Gravity (COG) approach was applied for defuzzification, and database was taken from Smt. Parvati Devi hospital, EMC hospital, medical center, Amritsar with accuracy of 92%. The demonstration of another fuzzy expert system (2013) was presented by Syed Umar Amin et al. [7] using a hybrid system of ANN along with GA for prediction of heart disease. Total 12 input variables: GR, AG, CHL, BP, FAMHIST, SMOKE, alcohol intake, physical activity, DM, diet, OBES, stress and 1 output variable were used. The article used input (12), hidden (10) and output (2) nodes, respectively. Implementation was done in MATLAB R2012a. Accuracy of 92% was measured by applying least mean square error (MSE). Jae-Kwon Kim et al. [28] represented prediction model (2013) of heart disease in MATLAB to overcome

the uncertainty received from the medical experts by using FL and GA with an accuracy of 69.22%. The fuzzy rule base generated 'if-then' rules by making use of C4.5 algorithm of the DT. Experiment was conducted on 299 patients of Gill medical center, Korea by taking 7 input variables GR, AG, CHL, HDL CHL, RBP, DM and SMOKE. The Table 4 presents the list of research papers from 2010–2013 of FL and Hybrid-based approaches.

Review of Research Papers from 2014–2017 of FL and Hybrid-Based Approaches

Explanation of hybrid model (2014) was made by Yuehjen E. Shao et al. [42] consisted of many hybrid approaches MARS, LR, RS and ANN techniques. Input variables: AG, CP, GR, RBP, FBS, Serum CHOL, RECG, EXANG, THALACH, OP, CA, THAL were used in this hybrid model and attained 83.93% accuracy evaluated by Root Mean Square Error in RESE software. Jan Bohacik et al. [8] applied cumulative application of FL Controller and DT in heart disease diagnosis (2014). Coding was developed in weka tool with a data base from Hull York medical school and University of Hull, England with sensitivity and specificity 34.23% and 91.01% respectively.

Again Jan Bohacik et al. [9] developed an Algorithmic Model (2015) for heart disease patients by employing the same on 2032 patients of Hull York medical school and University of Hull, England with an accurate rate 64.41% and specificity 63.27%. The system considered 9 input variables: BCL, BUAL, GR, BSL, AG, WT, PR, HT and NT-proBNPlevel. Software tool Java was implemented in fuzzy inference system. The hybrid technique (2015) designed by Ankita Dewan [10] evolved a prototype to find and execute unknown information from the database of heart disease. Genetic Algorithm was hybrid with back propagation method. The study used 20, 10 and 10 as input, hidden and output nodes, respectively. MATLAB R2012a was used for the implementation of the task. The proposed

methodology achieved nearly 100% with least error but being stiffen in local minima, the system was unable to achieve the desired outcome. The focus of Hui Yang et al. [29] was to construct a hybrid model (2015) for the heart failure identification by combining FL and NB in MAL-LET operating system. The system made use of 7 main risk factors responsible for heart stroke extracted from UMLS database and yielded 91.5% accuracy with precision 88.4%. Krishnaiah et al. [30] developed a robust system (2015) using data mining techniques: FL Controller and K-NN algorithm with a capability of reducing uncertainty available in the medical data. Weka 3.6.6 was used in the system which got 91% accuracy. Mainly 13 input attributes : AG, CR, CP, RBP, CHOL, RECG, FBS, THALACH, EXANG, OP, SLOPE,CA, THAL were considered and testing was conducted on 550 patients of heart disease databases of CCF and Statlog.

The design of fuzzy expert engine (2016) was developed by Wiga Maulana et al. [11]. The system made use of 13 input variable: AG, CP, CHL, MNR, RBS, RECG, THAL, BP, OP, GR, EXANG, SLOPE, CA and 1 output variable: the status of angiography. The system used C4.5, CART and RIPPER in MATLAB (7.12 R2011a). The membership functions were optimized by imperialist competitive algorithm (ICA). The designed method was experimented on data sets from CCF and HIC, Budapest with an accuracy of 81.82%. Assemgul Duisenbayeva et al. [12] revealed more adaptable and compatible fuzzy inference system (2016) that assist doctors and physicians in their decision-making for CAD disease. CP, BP, LDL CHL, BS, GR, MHR and AG were 7 input and 1 output variable having 5 features: sick (s1–s4), healthy. The given approach was implemented in MATLAB. Coronary heart disease prediction system (2016) was developed by Mokeddem et al. [48] hybrid with SIPINA Decision Tree algorithm and Fuzzy logic. The system used 13 input features from the well-known CCF, HIC, LBF and UCI heart disease data sets using triangular, trapezoidal, R and L membership functions. 'if-then' rules were used in rule-base using logical combinations of inputs with AND operator. Centroid method was used for defuzzification. This new approach has yielded an accuracy of 94.05%. Feshki et al. [13] proposed the system of diagnosis (2016) that yielded results in less time and cost with an accuracy of 91.94%. AG, CP, RBP upon admission in hospital, GR, CHL, FBS, CA, RECG results, EXANG, MHR, OP, SLOPE and thalassemia were 13 attributes considered in this paper. The Particle Swarm Optimization was implemented to extract 8 features. Further, Feed Forward Back-Propagation Neural network (FFBPNN) was applied to optimize the PSO algorithm. Cleveland Clinic Foundation (CCF) data set was used. Fuzzy Decision Support System (2016) to predict heart disease was applied by Animesh Kumar Paul et al.

[14] to pre-process data set, select effective attributes and then to make a strategy of fuzzy rule base. Accuracy of this approach is very close to near 80%. CCF, HIC, UHS and V. A. medical center heart disease datasets from the UCI ML repository were used in this system. C++ was used to implement the system.

An overview of fuzzy logic controller (2017) for coronary heart disease with 9 input variables: AG, CHL, BS, CP, ECG, HR,EX, GR, SMOKE and 1 output variable with 5 features was proposed by Mohammad Alqudah [31]. Trapezoidal, triangular, R, and L membership functions were used for all variables. Mamdani inference system with rule-based system (66 rules) using logical combinations of inputs with 'AND' operator was implemented on patients' records in Jordan'. Coding was done in Visual Studio 2010 C which accomplished the diagnosis by yielding high accuracy. Tanmey Kasbe et al. [15] designed fuzzy expert system (2017) with 10 input variables: CP, CHOL, SBP, FBS, MHR, ECG, THAL, OP, AG, GR and 1 output variable with 5 parameters. Mamdani inference mechanism was implemented with rule-based system (86 rules) characterized by 'if-then' rules using logical combinations of attributes with AND/OR operator. Fuzzification was accomplished using triangular and trapezoidal membership function. MATLAB R2008 tool was used as programming language and Center of Gravity (COG) approach was applied for defuzzification and finally achieved 93.33% accuracy. V.A medical center, CCF and LBF were data set sources. Coronary illness framework (2017) was applied by Purushottam Sharma et al. [32] considered 13 input attributes: AG, GR, CP, FBS, RBP, RECG, THALACH, EXANG, OP, SLOPE, CA, THAL and CHOL from the data set of Hungary, Switzerland and U.S. The paper made use of very common combination of FL and GA, and brought 88.11% accuracy. Creation of accurate rule set was the main theme of this article. With a purpose of improvement in accuracy and reduction in computational time Kanika Pahwa and Ravinder Kumar [16] proposed prediction method of heart disease (2017) by hybridization of techniques NB and RF. Both these techniques yielded 84.15% and 84.16% accuracy, respectively. Kaan Uyar et al. [43] presented diagnosis of heart disease model (2017) using 13 input attributes: AG, GR, CP, RBP, CHOL, FBS, RECG, THALACH, EXANG, OP, SLOPE, CA and THAL. GA-based Recurrent Fuzzy Neural Network (RFNN) involved 13 input, 7 hidden and 1 output neurons. An accuracy of 97.78% was yielded by experimentation on CCF patients' data set which was further evaluated by RMSE (Root Mean Square Error). Programming Languages Ubuntu and Java were used for the implementation of the system. Utilization of hybrid data mining techniques (2017) was demonstrated by Meenal Saini et al. [17] using 13 attributes AG, GR, CP, RBP,

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Table 4 List of research papers from 2010–2013 of FL and Hybrid-based approaches

Year and paper	Author	Title	Application Software	AI approach	Strength
2010 [52]	Ali Adeli, Mehndi Neshant	A Fuzzy Expert System for Heart Disease Diagnosis	MATLAB	FL	Simulation of the expert and doctor with presentation of definite output in an undefinate term
2010 [39]	Vahib Khatibi, Gholam Ali Montazerac	A Fuzzy -Evidential Hybrid Inference Engine for Coronary Heart Disease Risk Assessment	–	Demster-Shafer theory of evidence and fuzzy sets theory (DFT)	Requisite of a precise, certain and firm decision-making to formulate a model in various problems of engineering
2011 [40]	P. K. Anooj	Clinical Decision Support System: Risk Level Prediction of Heart Disease using Weighted Fuzzy Rules	MATLAB (7.10)	FL	Development of a medical decision support system based on fuzzy rule engine in order to classify training and testing database depending on risk level
2011 [26]	E. P. Ephzibah	A Hybrid Genetic-Fuzzy Expert System for Effective Heart Disease Diagnosis	MATLAB 7.3.0	FL and GA	Implementation of the diagnosis model dependant upon knowledge-based expert system for the smooth work in the healthcare industries
2012 [5]	Bhuvaneswari Amma NG	Cardiovasular Disease Prediction System using Genetic Algorithm and Neural Network	–	GA and NN	Analysis of nonlinear functions and attribute selection to construct a compatible model
2012 [27]	E. P. Ephzibah, V. Sundrapandian	A Fuzzy Rule Based Expert System for Effective Heart Disease Diagnosis	MATLAB	FL and GA	Selection of the salient and prime features responsible for the rapid and error free diagnosis of disease
2012 [6]	M. Akhil jabbar, Priti Chandra, B. L. Deekshatulu	Prediction of risk score for heart disease using associative classification and hybrid feature subset selection	WEKA	Association rules generated by hybrid feature subset selection	Associative classification rules and feature subset selection. Discovery of a new rule set through extraction of important information from knowledgeable data base of UCI to detect risk score in Andhra Pradesh
2012 [41]	S. Muthukaruppan, M. J. Er	A Hybrid Particle Swarm Optimization Based Fuzzy Expert System for the Diagnosis of Coronary Heart Disease	MATLAB 7	Fuzzy Expert System, DT and PSO	Potentiality in the interpretation of the judgement through fuzzy expert engine based on PSO
2013 [53]	Sanjeev Kumar, Gursimranjeet Kaur	Detection of Heart Disease using Fuzzy Logic	MATLAB	Fuzzy expert system	Itself usage by the patients and less scope of redundancy and conflicts in the generation of fuzzy rules
2013 [7]	S. U. Amin, K. Agarwal and R. Beg	Genetic Neural Network based Data Mining in Prediction of Heart Disease using Risk Factors	MATLAB R2012a	GA and NN	Insurance of early prediction of the disease and hence insurance of reduction in the expenditure during clinical tests and treatments of the disease
2013 [28]	Jae-Kwon Kim, Jong-Sik Lee, Dong-Kyun Park, Yong-Soo Lim, Young-Ho Lee, Eun-Young Jung	Adaptive mining prediction model for content recommendation to coronary heart disease patients	MATLAB	FL Controller and DT	Importance of linking medical expert knowledge and information with data mining approaches and reducing uncertainty in the prediction framework using information and knowledge from medical resource persons

CHOL, FBS, RECG, CA, THAL, EXANG, THALACH, OP and SLOPE. This approach has considered hybridization of 9 classifiers classifiers: SVM, Decision tree, Neural Network, Bayesian regularized NN, Generalized linear model, Lasso, MARS, Classification and Regression Tree and come out with an accuracy of 82.54%. Arabasadi et al.

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[44] presented an adaptive and affordable technique (2017) for the enhancement of accuracy and finally achieved 93.85%. The system combined together GA and NN, and involved 22 input, 5 hidden and 1 output neurons. Experimentations were done on 303 patients with data set from HIC, CCF and LBF. The identification of heart disease diagnosis (2017) was derived by Abhishek Rairikar et al. [18] using hybridization of GA, DT and KNN. The use of 13 vital clinical attributes was considered to achieve considerable accuracy rate. The Table 5 presents the list of research papers from 2014–2017 of FL and Hybrid-based approaches.

Review of Research Papers from 2018–2020 of FL and Hybridbased Approaches

Explanation of a mediative fuzzy logic system (2018) given by Ion Iancu [45] has considered 11 input variables: CP, CHL, BP, MHR, BS, RECG, EX, THAL, OP, AG, GR and 1 output variable with 5 features. Mamdani inference system was implemented with rule-based system (44 rules) using 'single input-single output' phenomenon. Software MATLAB was used for the implementation of experimental work from the data base of CCF, V. H. medical center and LBF. Defuzzification was done using 'Middle of maxima and middle of minima' approach. Hasan Kahtan et al. [49] proposed a FL system with 4 inputs variables: AG, BS, BP and CHL. Fuzzification was done using trapezoidal membership function for all variables. A rule-based system (96) was implemented in JAVA (using Net Beans IDE 8.2 in Java) with an accuracy of 98%. The Fuzzy Inference System (2018) designed by Vishu Madaan et al. [19] has resolved a peculiar problem of diagnosis by making use of 6 input parameters: AG, BP, CP, CHL, HR and DM. The rule base set contained 162 rules (if-then rule) with the implementation in MATLAB tool. The proposed model has acquired 82.65% accuracy. Another hybrid system (2018) based on FL controller and DT was described by Oumaima Terrada et al. [20] using 14 clinical input parameters: Total CHL, HDL, LDL, HBP, SMOKE, OBES, DM, GR, BMI, SBP, TRIG, AG, FAMHIS and sedentary lifestyle. Software MATLAB was used the experiments of diagnosis for the rule base consisting of logical combinations of AND operator and gave 63.24% accuracy.

The study developed by Prerna Jain et al. [50], displayed the system (2019) considering 8 input variables: AG, CHL, GR, OBY, HTN, DM, FAMHIS, SMOKE and 1 output variable with 3 parameters. Fuzzification was done using triangular and trapezoidal membership functions for each and every all input variable. Mamdani approach was used in rule base system (44 rules) using if-else statements. The system was designed in programming language MATLAB

and achieved 91% of accuracy. J. Vijayashree et al. [33] presented ML framework (2019) using 11 input attributes: AG, GR, CP, RBP, FBS, CHOL, CA, OP, RECG, SLOPE and THALACH. Hybridization of PSO-SVM was utilized and compared with other classifiers and using the data base of staLog heart disease set and yielded 88.22% accuracy results and implementation was done in MATLAB. The Hybrid system (2019) was expanded by M. Tarawnah et al. [34] for heart disease identification. The system comprised of 11 input variables from the data base of CCF and UCI ML respository. Implementation of classification techniques NB, SVM, J4.8, NN, GA and RF was shown and compared with the hybrid approach of all techniques. Accuracy obtained was 89.2% and it was achieved by hybrid approach which was better than all other approaches. Senthil kumar Mohan et al. [21] used hybrid ML techniques (RF and Linear Model (HRFLM)) to demonstrate an effective heart disease prediction framework (2019) with an accuracy of 88.7%. The study made use of 13 attributes: AG, GR, CP, RBP, CHOL, FBS, RECG, OP, SLOPE, CA, THAL, MHR and EXANG. Classification of heart disease was done in R Studio Rattle software tool using the data of 297 patients obtained from CCF data set. Heart disease detection hybrid classifier (2019) was represented by Yukti Sharma [22] using hybridization of DT and K-Means Clustering. The study considered 14 attributes namely: AG, GR, CP, BP, CHL level, BS, ECG, THAL, CA and SLOPE obtained from CCF data base. Classifier K-Means Clustering and Decision Tree obtained 49% and 52% accuracy, respectively, and the proposed work of hybrid classifier yielded 62% accuracy which was greater than that of individual classifiers. Saba Bashir et al. [23] gave an emphasis on approaches and algorithms of attribute selection in datasets of heart disease diagnosis system (2019) using 4 classifiers. Logistic Regression SVM yielded 84.85% accuracy which is the highest among the accuracies obtained using DT (82.22%), LR (82.56%), RF (84.17%) and NB (84.24%) algorithms on UCI database in Rapid Miner Studio software tool. Presentation of a fuzzy-based framework (2019) was proposed by Padmavathi Kora et al. [46] for valvular heart disease detection by considering 7 clinical input variables: AG, BP, CHL, DM, BMI, SMOKE and physical activity with 1 output variable having 3 features. After training the dataset using NN, Mamdani inference framework was implemented with rule set system (44 rules) 'if-then' rules using logical combinations of inputs with AND operator. The source of dataset was CCF and HIC. Parameter ROC Curve (Receiver Operator Characterstic) was used to check the accuracy of 99.3% in MATLAB R2019b. The another proposal (2019) using Imperialist Competitive Algorithm (ICA) to select optimal features and K-nearest neighbor approach (KNN) was used to classify heart disease by J. Nourmohammad-

Table 5 List of research papers from 2014–2017 of FL and Hybrid-based approaches

Year and paper	Author	Title	Application software	AI approach	Strength
2014 [42]	Yuehjen E. Shaoa, Chia-Ding Houa, and Chih-Chou Chiu	Hybrid Intelligent Modeling Schemes for Heart Disease Classification	RESE software	LR, MARS, RS and NN techniques	Enlargement of a hybrid model using least input variables and having distinct classification capability
2014 [8]	Jan Bohacik, C. Kambhampati, Darryl N. Davis, J. G. F. Clevland	Use of Cumulative Information Estimations for Risk Assessment of Heart Failure Patients	Weka	FL Controller and DT	An algorithmic as well as intelligent home tele-monitoring model based on cumulative system of Fuzzy Logic and Decision Tree
2015 [9]	J. Bohacik, K. Matiasko, M. Benedikovic, I. Nedeljakova	Algorithmic Model for Risk Assessment of Heart Failure Patients	Java	Fuzzy Expert System	Challenged a task by using AI or computer aided technology to develop an effective and intelligent biomedical diagnosis system
2015 [10]	Ankita Dewan and Meghna Sharma	Prediction of Heart Disease using a Hybrid Technique in Data Mining Classification	MATLAB R2012a	NN with back propagation method and GA	A promising, feasible, supportive and suitable system concluding smart medical decisions
2015 [29]	Hui Yang and Jonathan Garibaldi	A Hybrid Model for Automatic Identification of Risk factors for Heart Disease	MALLET	Rule -based methods and NB	A robust knowledge extraction system with less human effort for automatic detection of heart disease
2015 [30]	V. Krishnaiah, G. Narsimha and N. Subhash Chandra	Heart Disease Prediction System Using Data Mining technique for Fuzzy K-NN Approach	Weka 3.6.6	FL Controller and K-NN algorithm	Capability to eliminate uncertainty available in the medical data using data mining techniques
2016 [11]	Wiga Maulana Baihaqi, Noor Akhmad Setiawan and Igi Ardiyanto	Rule Extraction for Fuzzy Expert System to Diagnose Coronary Artery Disease	MATLAB 7.12 (R2011a)	FL contoller	Development of a new prototype along with the comparison of performance with other models and classification of overall error rate of the data
2016 [12]	Assemgul Duisenbayeva, Lyazzat Atymtayeva, Iskander Beisembetov	Using Fuzzy logic concepts in creating the decision making expert system for cardio-vascular diseases (CVD)	MATLAB	Fuzzy inference system	Assistance to the physicians and practitioners by taking decisions, reducing time period to determine disease and producing error-free results
2016 [48]	Sidahmed Mokeddem and Baghdad Atmani	Assessment of Clinical Decision Support Systems for Predicting Coronary Heart Disease	–	FL and SIPINA DT	Necessity of the application of attribute selection technique for the removal of the irrelevant and redundant factors available in the database of heart disease
2016 [13]	M. G. Feshhki and O. S. Shijani	Improving the Heart Disease Diagnosis by Evolutionary Algorithm of PSO and Feed Forward NN	–	NN Feed Forward Back Propagation and PSO	Utilization of artificial intelligence and mining of data to extract cognizant output to mark the improvement in the framework
2016 [14]	Animesh Kumar Paul, Pintu Chandra Shill, Md. Rafiqul Islam Rabin and M. A. H. Akhand	Genetic Algorithms Based Fuzzy Decision Support System for the Diagnosis of Heart Disease	C++	Fuzzy Decision Support System (FDSS) and GA	Consumption of only relevant and irredundant features to achieve admissible exactness from the generalization of FDSS
2017 [31]	Ali Mohammad Alqudah	Fuzzy Expert System for Coronary Heart Disease Diagnosis in Jordan	Visual Studio 2010	Fuzzy Logic Contoller	Demonstration of the method which is easily applicable on the patients' clinical data and construct a mobile-based web or application for e-health support system
2017 [15]	Tanmay Kasbe and Ravi Singh Pippal	Design of Heart Disease Diagnosis System using Fuzzy Logic	MATLAB	Fuzzy Logic Controller	A competent, reasoning and powerful approach in order to manage variability of the available data

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Table 5 continued

Year and paper	Author	Title	Application software	AI approach	Strength
2017 [32]	Purushottam Sharma and Kanak Saxena	Application of fuzzy logic and genetic algorithm in heart disease risk level prediction	–	Fuzzy Logic Controller	Efficient and logical engine with the capability of replicating human decisions
2017 [16]	Kanika Pahwa, Ravinder Kumar	Prediction of Heart Disease using hybrid Techniques for selecting features	–	Naive Bayes (NB) and Random-Forest (RF)	Optimization of the classification problem by adopting hybrid technique of attribute selection that helps in removing irrelevant and redundant attributes
2017 [43]	Kaan Uyar and Ahmet Ilhan	Diagnosis of heart disease using genetic algorithm-based trained recurrent fuzzy neural networks	Ubuntu and Java	ANN and RFNN	Determination and extraction of the unrevealed information about heart disease
2017 [17]	Meenal Saini, Niyati Baliyan, Vineeta Bassi	Prediction of Heart Disease Severity with Hybrid Data Mining	–	Hybrid Classifier with Weighted Voting	Demonstration of favorable outcomes with the utilization of hybrid data mining techniques
2017 [44]	Zeinab, Roohallah Alizadehsani, Mohamad Roshanzamir, Hossein Moosaei, Ali Asghar Yarifard	Computer aided decision making for heart disease detection using hybrid neural network-Genetic algorithm	–	GA and NN	Affordable and adaptive technique to enhance accuracy and increase the execution of NN
2017 [18]	Abhishek Rairikar, Vedant Kulkarni, Vikas Sabale, Harshavardhan Kale and Anuradha Lamgunde	Heart disease prediction using data mining techniques	–	Genetic Algorithm, NB, DT and K-NN	Consumption of only relevant and irredundant features to achieve admissible exactness from the generalization of FDSS

Khiarak et al. [35]. The system was user-friendly in the strategy of feature selection as well as training and testing of data set and yielded accuracy of 88.25%. Testing was conducted on 303 patients with 13 clinical parameters of heart disease databases from UCI ML respository and T. S. Rajaei hospital. An intelligent medical heart diagnose system (2019) was designed by L. Ali et al. [24]. Data set was extracted from CCF which considered 13 input attributes out of 76 attributes: AG, CHOL, CA, CP, FBS, EXANG, RECG, THAL, THALACH, RBS, OP. After extracting noisy and redundant features using Chi-square statistical model, the proposed method used Deep Neural Network (DNN) to avoid underfitting and overfitting of network and achieved 93.33% accuracy.

A hybrid approach (2020) to predict heart disease was proposed by G. Thippa Reddy et al. [36] considering together adaptive GA with FL. The first step followed the selection of features through rough set theory and the implementation of hybrid AGAFL classifier is made in second step. The membership functions were designed in trapezoidal functions. The system consisted of 13 input variables, namely AG, RBP, GR, CHL, MHR, OP, CA, RECG, FBS, CP, SLOPE, THAL and EXANG. Experimental work was done with data base from CCF, HIC and

UCI ML respository which obtained 90%, 91% and 89% accuracy, respectively. Preethi Krishnan et al. [25] proposed a novel clinical based and intuitive model (2020) for heart disease detection using fuzzy expert system whose accuracy, specificity and sensitivity were 96.6%, 96.8% and 95.6%, respectively, using MIT-BIH heart disease data base in Physionet. Better outcomes were generated to detect PVC beats in electrocardiogram signals [57-63]. Fuzzification was done using Gaussian and triangular membership functions. Explanation of another classical model (2020) was described by Anna Karen et al. [47] using 6 ML classifiers out of which maximum accuracy was achieved by (CHI-PCA) with RF where the data were derived from CH datasets [54-56] . The paper also revealed clear comparative study other classifiers using CCF, HIC and CH datasets in Apahe Spark 2.2.0. The prediction model (2020) of hybrid approach using ACO and Hybrid K-NN (HKNN) was designed by Sowmiya et al. [37]. Utilization of feature selection was made by ACO, and then another hybrid classifier was implemented in Netbeans IDE. Experiments were conducted in Netbeans IDE with an accuracy of 99.2% using data obtained from CCF. Comparison with other classifiers along with their accuracies was presented in this study. Mohammad Ali Hassani

Table 6 List of research papers from 2018–2021 of FL and Hybrid-based approaches

Year and paper	Author	Title	Application Software	AI approach	Strength
2018 [45]	Ion Iancu	Heart Disease Diagnosis based on mediative Fuzzy Logic	MATLAB	FL	Resolvement of contradictory situations by dealing with inconsistent data in order to calculate mediate output
2018 [49]	Hasan Kahtan, Kamal Z.Zamli, Wan Nor Ashikin, Wan Ahmed Fatthi, Azma Abdullah, Noor Shahaiyusniezam	Heart Disease Diagnosis using Fuzzy Logic	JAVA	FL Controller	Exhibition of a promising, feasible and suitable system to assist peculiar diagnosis process
2018 [19]	Vishu Madaan, Anjali Goyal	X-Cardio: Fuzzy Inference System to Diagnose Heart disease	MATLAB	FL Controller	Solution to resolve a peculiar problem of diagnosis by dealing with incomplete and vague medical records. Moreover, presentation of an error-free and user-friendly interface of toolbox
2018 [20]	Oumaima Terrada, Bouchaib Cherradi, Abdelhadi Raihani and Omar Bouattane	A fuzzy medical diagnostic support system for cardiovascular diseases diagnosis using risk factors	MATLAB	FL Contoller and DT	Suitable solution based on Fuzzy Logic and further on DT due to more count of rules to improve results
2019 [50]	Prerna Jain and Amandeep Kaur	A Fuzzy Expert System for Coronary Artery Disease Diagnosis	MATLAB	FL Controller	Provision of an easy-to-use graphical presentation of the dataset along with working environment resulting in constructing predictive analytics
2019 [33]	J. Vijayashree, H. Parveen Sultana	A machine learning framework for feature selection in heart disease Classification using Improved Particle Swarm Optimization with S.V.M classifier	MATLAB	SVM and PSO	Requirement of an effective and powerful system in order to trace the essential features that contribute towards the diagnosis of disease
2019 [34]	Monther Tarawnah, Ossama Embarak	Hybrid Approach for Heart Disease Prediction using Data Mining Techniques	–	NB and SVM	Analysis of hidden patterns, information and relationships available in the clinical data of the patients
2019 [21]	Senthil kumar Mohan, Chandrasegar Thirumalai, Gautam Srivastava	Effective Heart Disease Prediction Using Hybrid Machine Learning Techniques	R Studio Rattle	HRFLM	A novel approach with high discriminative power to develop and frame a model resulting in the improvement of medical awareness and reduction in the expenditure of the treatment
2019 [22]	Yukti Sharma, Rikku Veliyambara and Rajshree Shettar	Hybrid Classifier for Identification of Heart Disease	–	Decision Tree (DT) and K-means clustering algorithm	Framework of a model that has ability to generate high accuracy by hybridism classifiers rather than single individual classifier
2019 [23]	Saba Bashir, Zain Sikander Khan, Farhan Hassan Khan, Khurram Bashir and Aitzaz Anjum	Improving Heart Disease Prediction using Feature Selection Approaches	Rapidminer Studio	LR, DT, LR SVM, RF and NB	Prerequisite of a system that eliminates unnecessary and irrelevant factors present in any data base of heart patients
2019 [46]	Dr. Padmavathi Kora, Dr. K Meenakshi, Dr. K Swaraja, Dr. A Rajani and Md. Kafiul Islam	New hybrid method for heart disease diagnosis utilizing optimization algorithm in feature selection	–	Imperialist Competitive Algorithm (ICC) and K-NN	A boosting and compatible approach with acceptable accuracy by using efficient and reliable classifier

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Table 6 continued

Year and paper	Author	Title	Application Software	AI approach	Strength
2019 [35]	Jalil Nourmohammadi-Khiarak, Mohammad-Reza Feizi-Derakhshi, Khadijeh Behrouzi, Samaneh Mazaheri, Yashar Zamani-Harghalani and Rohollah Moosavi Tayebi	Detection of Cardiac Arrhythmias using Fuzzy Logic	MATLAB R2019b	FL Controller and ANN	Automatic prediction with the application of determination strategies which are PC based followed by artificial intelligence
2019 [24]	Liaqat Ali, Atiqur Rahman, Aurangzeb Khan, Mingyi Zhou, Ashir Javeed and Javed Ali Khan	An Automated Diagnostic System for Heart Disease Prediction Based on χ Statistical Model and Optimally Configured Deep Neural Network	Python	χ^2 Statistical Model and DNN	Removal of noisy and irrelevant attributes from feature space along with automation and improvement in the accuracy of disease diagnosis
2020 [36]	G. Thippa Reddy, M. Praveen Kumar Reddy, Kuruva Lakshmanna, Dharmendra Singh Rajput, Rajesh Kaluri and Gautam Srivastava	Hybrid genetic algorithm and a fuzzy logic classifier for heart disease diagnosis	MATLAB 7.12	FL Controller and GA	Application of t-test to show the existence of significant difference between proposed algorithm and present one in MATLAB R2014a
2020 [25]	Preethi Krishnan, Viswanathan Rajagopalan, Bashir I. Morshed	A Novel Severity Index of Heart Disease from Beat-wise Analysis of ECG Using Fuzzy Logic for Smart-Health	PhysioNet	FL Controller	Real time applicable clinical based and intuitive model which is computationally efficient to generate better outcomes to detect PVC beats in electrocardiogram signals
2020 [50]	Anna KarenGarate-Escamila, Amir Hajjam El Hassani,Emmanuel Andresb	Classification models for heart disease prediction using feature selection and PCA	Apahe park 2.2.0	CHI-PCA and RF	Application of feature selection method and dimensionality reduction technique after tracing the features of the risk of heart disease
2020 [37]	C. Sowmiya, P. Sumitra	A Hybrid Approach for Mortality Prediction for Heart Patients using ACO-HKNN	Netbeans IDE	ACO and HKNN	Design of an innovative hybrid approach with various classifiers by selecting necessary attributes from the data set
2020 [51]	Mohammad Ali Hassani, Ran Tao, Marjan Kamyab, Mohammad Hadi Mohammadi	An Approach of Predicting Heart Disease Using a Hybrid Neural Network and Decision Tree	–	DT and NN	Noteworthy approach that deals with combination of unique dataset i.e. CCF and Stalog heart disease dataset, UCI ML repository
2021 [38]	L. J. Muhammad, Ebrahem A. Algehyne	Fuzzy-based expert system for diagnosis of coronary artery disease in Nigeria	MATLAB	FL and Improved C4.5 algorithm	Requirement of a affordable, capable, reliable and relatively unique technology

et al. [51] used hybrid ML techniques (NN and DT) to demonstrate a prouctive heart disease detection model (2020) with an accuracy of 98.7%. The study made use of 13 input attributes: AG, GR, CP, RBP, CHOL, FBS, RECG, OP, SLOPE, CA, THAL, THALACH and EXANG. Classification of heart disease was done in Weka software tool using the data of 227 patients obtained from CCF and StaLog heart disease data set. A new and unique hybrid technique (2021) using Fuzzy Logic along with Improved C4.5 algorithm was designed and implemented by Muhammad et al. [38]. The system consisted of 11 input variables, namely AG, RBP, glucose, LDL CHOL, HDL CHOL, triglycerides, BCL, BMI, MHR, CP and CHL. Mamdani approach was applied in the fuzzy inference engine of 87 rules, and defuzzification was completed by centroid method. The proposed technique was designed and implemented in the MATLAB tool. Experimental work was done with data base from State Ministry of health, Kano, Nigeria which obtained 94.55% accuracy. Testing dataset was of 100 patients implemented in MATLAB software. The Table 6 presents the list of research papers from 2018–2021 of FL and Hybrid-based approaches.

Table 7 Summary of accuracy rate of heart disease detection based on FL and Hybrid-based approaches

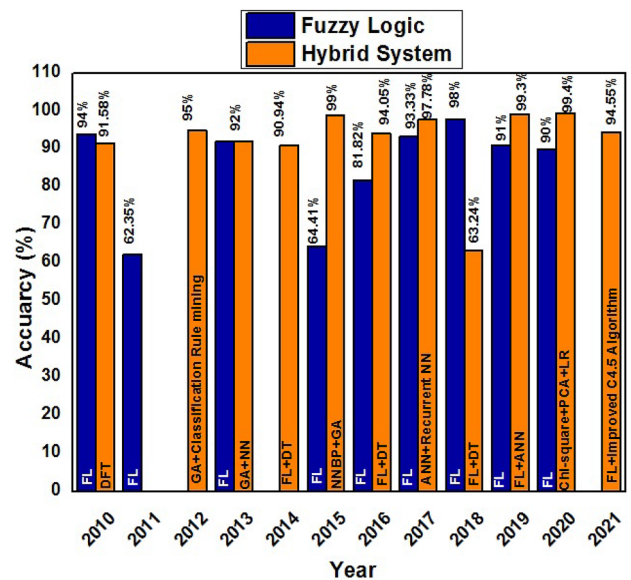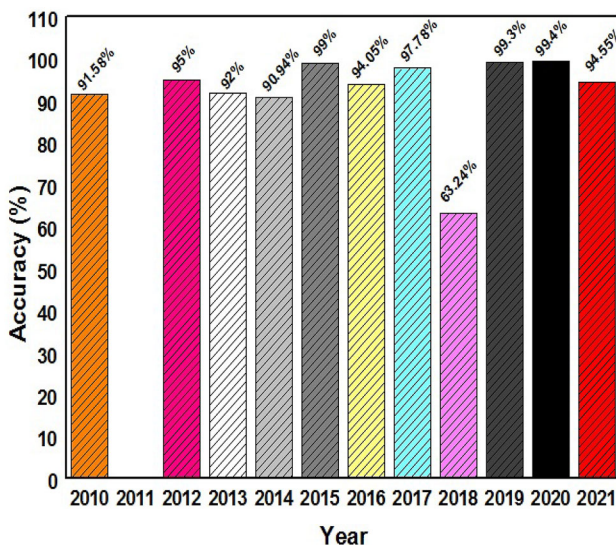| References	Research methodology	Accuracy	Evaluation parameters
[52]	FL	94%	–
[39]	Demster–Shafer theory of evidence and fuzzy sets theory	91.58%	–
[40]	FL	a) 62.35% (CCF) b) 46.9% (HIC) c) 51.3% (UHS)	K = 10 fold cross validation (CCF, HIC), K = 8 fold cross validation (UHS)
[26]	FL + GA	–	–
[5]	GA + NN	94.17%	Confusion matrix
[27]	FL + GA	–	–
[6]	GA + Association classification rule mining	95%	Confusion matrix
[41]	FL + DT	93.27%	Confusion matrix
[53]	FL	92%	–
[7]	GA + NN	92%	Mean square error (MSQ)
[28]	FL + DT	69.22	–
[42]	LR + MARS + RS + ANN	83.93	Type-I/Type-II error
[8]	FL + DT	90.94%	K = 10 fold cross validation
[9]	FL	64.41%	K=10 fold cross validation
[10]	NNBP + GA	Near 100%	
[29]	NB + Rule based methods	91.5%	F-measure
[30]	FL+K-NN	91% (k = 1)	Confusion matrix
[11]	FL	81.82%	F-measure
[12]	FL	–	–
[48]	FL+DT	94.05%	K=10 cross validation
[13]	NNFFBP + PSO	91.94%	K = 10 cross validation
[14]	GA + FL	Near 80%	Confusion Matrix
[31]	FL	–	–
[15]	FL	93.33%	–
[32]	FL	88.11%	K=10 cross validation
[16]	NB + RF	84.16%	K = 10 cross validation, ROC Curve
[43]	ANN + Recurrent NN	97.78%	F-measure, Root Mean Square Error (RMSE)
[17]	Hybrid classifier with weighted voting	82.54%	
[44]	GA + NN	93.85%	ROC Curve
[18]	GA + NB + DT + K-NN	–	–
[45]	FL	–	–
[49]	FL	98%	–
[19]	FL	82.65%	–
[20]	FL+DT (C4.5 Algorithm)	63.24%	–
[50]	FL	91%	–
[33]	SVM + PSO	88.22%	ROC Curve
[34]	NB + SVM + ANN+DT (J4.8)+GA	89.2%	F-measure
[21]	RF + Linear Model	88.7%	F-measure
[22]	DT + K-means clustering algorithm	62%	K-fold cross validation
[23]	LR, DT, LR SVM, RF, NB	a) DT-82.22% b) LR-82.56% c) RF-84.17% d) NB-84.24% e)LR SVM-84.85%	K=5 fold cross validation
[46]	FL + ANN	99.3%	ROC Curve

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Table 7 continued

| References	Research methodology	Accuracy	Evaluation parameters
[35]	K-NN + ICA	88.25%	Confusion matrix
[24]	K-NN + CHI model	93.33%	ROC curve, AUC, MCC
[36]	AGAFL	a) 90% (CCF) b)91% (HIC) c)89% (UHS)	K = 10 fold cross validation
[25]	FL	96.6%	Confusion matrix
[47]	Chi-square+PCA+RF	a) 98.7% (CCF) b) 99.0% (CCF, HIC) c) 99.4% (HIC)	F1-score
[37]	HKNN + ACO	99.2%	Precision/recall
[51]	DT + NN	98.7%	F-meaasure/ROC
[38]	FL+ Improved C4.5 algorithm	94.55%	ROC
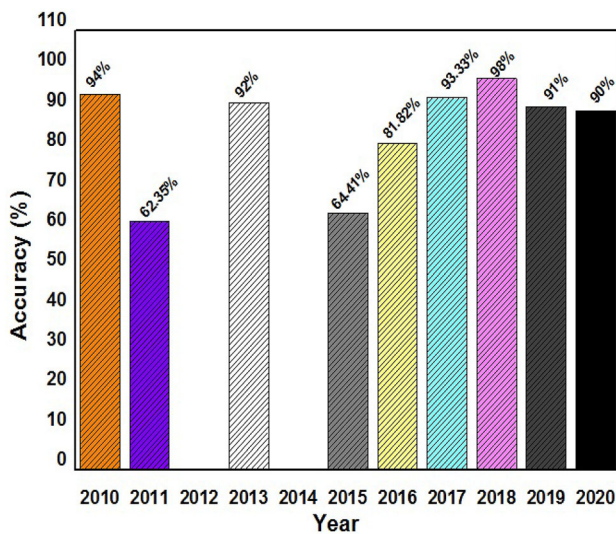
Fig. 5 Year-wise accuracy rate using FL

Fig. 6 Year-wise accuracy rate using hybrid system

Fig. 7 Year-wise accuracy rate using FL and hybrid system

Comparative Analysis of Accuracies/Techniques

Accuracy of all respective years for FL and Hybrid System is considered and shown in Table 7 along with evaluation parameters. In the Figs. 5 and 6, higher accuracy in that respective year is shown and further, comparative analysis of both system's accuracies is presented in Fig. 7 along with technique used in that particular paper. All the papers come up with distinct techniques to improve the accuracy in the diagnosis system of heart. The highest accuracy (99.4%) is achieved by using **Fuzzy Logic hybrid with Improved C4.5 algorithm** in the current year 2021 [38]. Existence of uncertainty is always there in the detection of any disease. An extensive amount of research has been carried out by various researchers using FL on heart disease detection as FL has enough capability to diagnose heart disease. Therefore, to handle FL is more suitable but the only challenge in FL system is the optimization of rules. If rules are more, complexity of the system increases and if rules are less, system accuracy decreases. Hence,
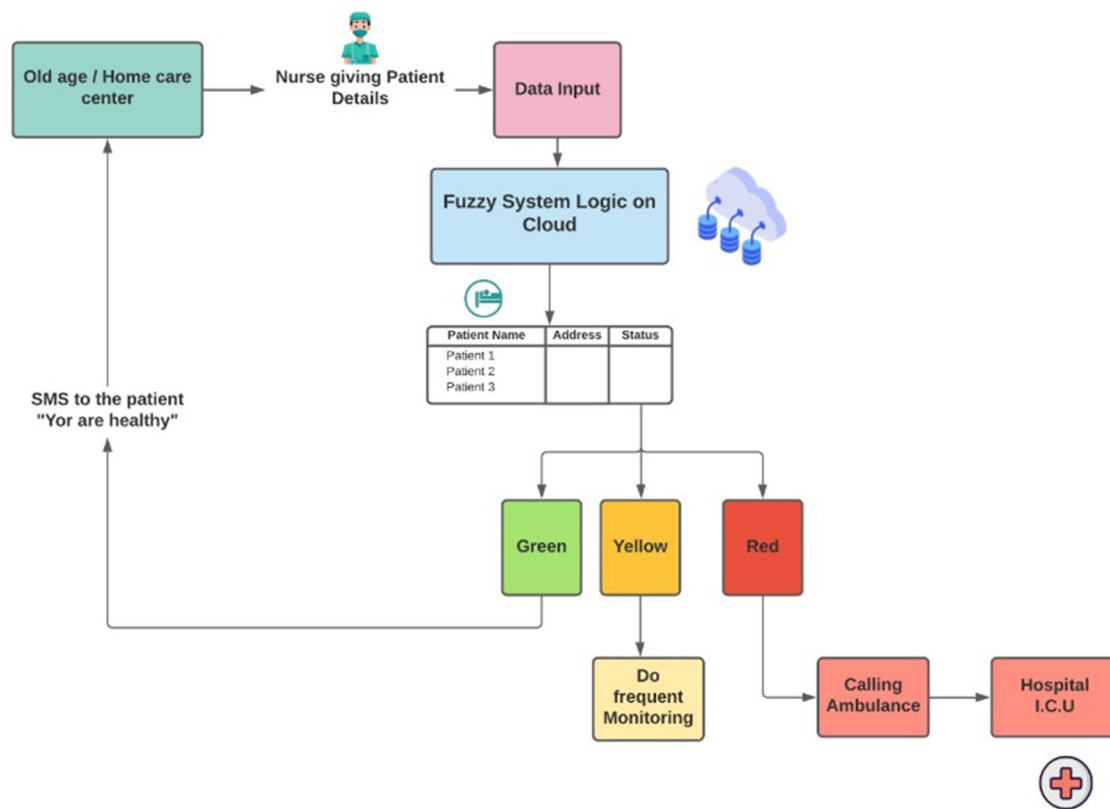
Fig. 8 Future framework of fuzzy logic

selection of optimal rules is a major problem in FL. After that the next and the most used techniques are ANN, GA and DT. ANN is indeed a robust and powerful algorithm still it faces the challenge of the implementation of the automatic detection of the disease due to the complex and complicated structure of the network. Though GA and DT are easy and simple to understand, yet GA is time-consuming algorithm and DT leads to overfitting of the data.

Conclusion

The paper presents concise information about the diverse work done by various scholars in the field of developing a heart disease detection algorithm and software using soft computing techniques. The paper is the result of in-depth study and analysis of various papers published year-on-year in various renowned journals on this subject. Key finding is that maximum publications are based on FL and FL Hybrid Systems to improve the accuracy using genetic fuzzy logic, fuzzy neural, Adaptive Neuro-Fuzzy, Genetic Neuro-Fuzzy and PSO with FL as FL has enough capability to diagnose the heart disease. Comparison of accuracy of various approaches has been presented graphically, and the best approach is also recommended. The paper also

motivates young researchers and scholars to identify the gaps in existing work and take-up the work to create new models and optimize existing models. The efforts should be made to make cost-effective real-life software and tools which can be used by health institutions on a day-to-day basis helping to improve heart disease diagnostics.

Future Model of Fuzzy Logic

In future, model for direct service of the patients from the old age homes or other home care centers to the Intensive Care Unit (ICU) through ambulance services can be planned. An artificially intelligent system will take the data of clinical parameters from old age homes or other care centers. Fuzzy Logic system will be implemented to get the single output that will reveal distinct stages of patients in terms of healthy, first/second stage of sickness and critical stage. The system will show green color if the status of the person is healthy, and the respective person will be informed via SMS that you are 'Healthy'. Otherwise, if the person is at the first/second stage of sickness, then a SMS 'Do frequent monitoring' will be sent to his/her mobile number. Furthermore, if the patient is at chronic stage of any disease, the system will show red color and the patient

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will be directly brought to the hospital. The Fig. 8 represents the future framework of the fuzzy logic system in any type of disease.

Declarations

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