Metaheuristics Algorithms for Complex Disease Prediction

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1 Introduction

Medical technology has improved illness identification and patient analysis, increasing life expectancy. Data helps diagnose and predict illnesses. Several medical communities gather health data for the diagnosis of diseases. Using algorithms and procedures, this data can provide important information. Data is often ambiguous or inaccessible to humans. Consequently, information exploration requires various methods. Data mining and machine learning assist analyze data. These methods may identify certain illnesses [1]. With more data, machine learning is evolving. Machine learning can understand large amounts of data, which is difficult or impossible for humans [2]. With its predicting, proactive, and lifesaving capabilities, every health system requires machine learning (ML). Artificial intelligence covers machine learning, reasoning, and automation. Artificial intelligence systems can filter, arrange, and search for patterns in large databases from diverse sources to make rapid, informed judgments. Machine learning is used in illness detection and prediction, biomedicine, medical imaging, polypharmacology, drug repurposing, biomedical event extraction, and system biology [3].

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1.1 Nature Inspired Algorithms

Algorithms inspired by nature—animals, flowers, plants, microbes, the environment, and humans—can be used to optimize a problem utilizing the meta-heuristic method. Nature-inspired algorithms employ randomization and local search. Population-based genetic algorithms and trajectory-based algorithms are meta-heuristics (MH) algorithms. Finding the appropriate nature-inspired algorithm for a problem is a major challenge. Particle swarm optimization (PSO), Ant and Bee algorithm, simulated annealing, Genetic algorithm (GA), Cuckoo search, Particle swarm optimization (PSO), Bat algorithm and others are meta-heuristic and heuristic algorithms. The nature-inspired algorithm is used in healthcare, energy conservation, healthcare, gaming, and other domains [4, 5].

1.2 Machine Learning in Disease Prediction and Detection

Machine learning has been used to anticipate or diagnose an illness early so that treatment is simpler and the patient is more likely to be recovered (As illustrated below in Table 1). These methods have recognized several illnesses, although accuracy depends on the algorithms, training dataset, feature set, etc. Ongoing experiments should determine the algorithm's feature subset. Testing, training, and validation are the three processes of using a machine learning algorithm. An Ideal machine learning algorithm should optimize the bias-variance trade-off. During validation, the validation dataset is used to evaluate the resultant machine learning algorithm. As an initiation studying about machine learning methodologies and algorithms used for clustering and classification.

Table 1 Various machine learning approaches and algorithms

(i) Supervised learning	(ii) Unsupervised learning
K-Nearest Neighbour(KNN)	Partition Clustering
Support Vector Machine(SVM)	Graph-Based Clustering
Decision Trees(DTs)	Hierarchical Clustering
Classification and Regression Trees(CARTs)	Density-Based Clustering
Model-Based Clustering	
Logistic Regression (LR)	
Random Forest Algorithm (RFA)	
Naive Bayes (NB)	
Artificial Neural Network (ANN)	
(iii) Active Learning	
(iv) Deep Learning and (v) Reinforcement Learning	

To make this chapter appealing from the start, it is advantageous to identify several biomedical applications of machine learning after describing numerous machine-learning algorithms. Neuroscience uses machine learning classifiers to explore brain function and structure. Cancer prognosis uses machine learning. SVM classifiers detect prostate cancer. Alzheimer's disease research uses hierarchical clustering. ANN classifies psychogenic nonepileptic seizure subtypes. With the information gained on numerous machine learning methodologies and algorithms, major contributors to biomedicine computational biology, it is time to investigate deeper and uncover the possibilities of these algorithms in diverse domains [6].

2 Meta-heuristics (MH) Algorithms for Complex Disease Prediction

Metaheuristic algorithms generate optimum solutions using random algorithms. Metaheuristic algorithms solve difficult optimization issues successfully. Metaheuristics are estimated optimization algorithms that can assist engineers to avoid the local optimum [7]. In several categories, metaheuristic algorithms are used [8–10].

2.1 MH Algorithms for Heart Disease Prediction

Heart disease is a global concern with a remarkable mortality rate. The heart didn't pump enough blood to other organs. Coronary artery blockages cause heart failure. Weakness, breathlessness, swollen feet, and fatigue are heart illness symptoms, poor diet, smoking, high blood pressure, inactivity, high cholesterol, increases heart disease risk. Compared to existing machine learning languages, an imperial competing algorithm with a meta-heuristic method was used to select major heart disease characteristics for the optimum response and approaches as illustrated in Table 1. The classification was performed with the k-nearest neighbour algorithm. An imperialist competitive algorithm optimized feature selection for genetic and other optimization approaches. Following feature extraction, KNN classifies the features. The two methods improved heart disease diagnostic and categorization accuracy. The designed algorithm reduced features and improved classification accuracy. Imperialist Competitive Algorithm (ICA) was selected for heart disease diagnostic characteristics. To improve heart disease diagnostic accuracy, features were evaluated. The test's chosen features matched the different data sets. The early population started an imperialist competitive algorithm. Each population member has hypothesized a country. Colony-subordinated countries and colonialist countries were divided. Each colonial power controlled its colonies. The imperialist competitive method used the k-nearest neighbour algorithm with an observer to classify specified characteristics. The algorithm designed has two objectives: namely to determine. Patient data is used to predict heart disease to start the experimentation. Discussed parameters improve heart disease prognosis. Cardiac Disease Experiments use UCI Machine Learning Repository data. The URL is https://www.kaggle.com/sulianova/cardiovascular-disease-dataset. It has 70,000 instances and 12 features. The patient data set includes age, weight, gender, cholesterol, height, glucose, alcohol use etc. The quantitative investigation is equated with different parameters like,

- Prediction accuracy
- Prediction time and
- Error rate

2.1.1 Analysis of Prediction Time (P_{Time})

P_{Time} is the product of a number of patient data and the time used up to predict the absence or presence of cardiac disease in one data. The prediction time, P_{Time}, is determined as

$$P_{Time} = \text{Number of patient data time consumed for predicting one data} \tag{1}$$

From (1), the prediction time (P_{Time}) is determined.

Subsequently, the prediction time intelligent computational predictive system is 18% lower than ICA with a metaheuristic method and 27% lower than the selection of feature. As seen from the below Fig. 1.

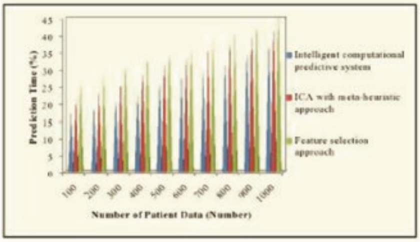
2.1.2 Analysis of Prediction Accuracy (PA_{cc})

Prediction accuracy is the ratio of the number of patient-data that accurately predicted the absence or presence of cardiac disorder to the sum of the number of patients as the input data. Hence, prediction accuracy, PA_{cc}, is determined in terms of percentage (%) as,

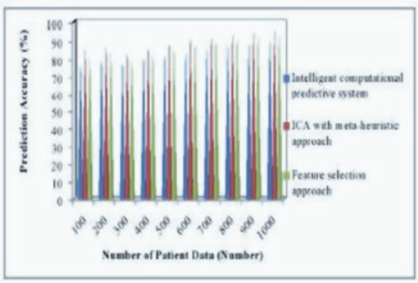
$$PA_{cc} = \left(\begin{array}{l} \text{Number of patient} \quad \text{data that accurately} \\ \text{predicted heart disease / Number of patient data} \end{array} \right) \times 100 \tag{2}$$

Imperialist competitive algorithm (ICA) and Intelligent computational predictive systems with the meta-heuristic method, and feature selection techniques are compared for PA_{cc}. The imperialist-competitive algorithm (ICA) with metaheuristic methodology outperforms the intelligent computational-predictive system and technique feature selection. This is because performing the classification challenge uses the KNN method. KNN, an imperialist competitive algorithm with an observer, classified selected characteristics.

Tabulation for Prediction Time	Prediction Time (%)		
	Intelligent computational predictive system	ICA with meta-heuristic approach	Feature selection approach
100	17	21	26
200	18	23	28
300	20	25	30
400	22	28	32
500	25	31	34
600	27	33	35
700	29	35	38
800	31	37	40
900	34	39	42
1000	36	41	45



Number of Patient Data (Number)	Prediction Accuracy (%)		
	Intelligent computational predictive system	ICA with meta-heuristic approach	Feature selection approach
100	75	84	80
200	78	86	83
300	76	82	78
400	79	85	81
500	81	87	84
600	82	90	86
700	84	91	88
800	86	93	90
900	87	94	91
1000	89	95	92



Number of Patient Data (Number)	Error rate (%)		
	Intelligent computational predictive system	ICA with meta-heuristic approach	Feature selection approach
100	20	18	12
200	22	20	14
300	23	23	15
400	25	25	18
500	27	22	16
600	30	21	15
700	31	23	17
800	33	25	18
900	35	27	20
1000	38	29	22

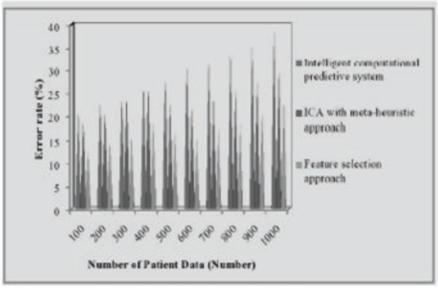


Fig. 1 The above table and graphs represent the prediction time, prediction accuracy, and error rate respectively. (Table reproduced from Ref. [11])

2.1.3 Analysis on the Error-Rate ($\mathbf{Error_{Rate}}$)

The $\text{Error}_{\text{Rate}}$ is the percentage of predicted patient data incorrectly that is absence or presence of cardiac disorder to the total quantity of patient data collected. Therefore, the error rate, $\text{Error}_{\text{Rate}}$, is computed in terms of percentage (%) as

$$\text{Error}_{\text{Rate}} = \left(\begin{array}{l} \text{Number of patient data that} \\ \text{are predicted incorrectly / Number of patient data} \end{array} \right) \times 100 \quad (3)$$

The imperialist competitive algorithm (ICA), an intelligent-computational predictive system, using meta-heuristic and feature selection approaches, compares error rates. The imperialist competitive algorithm (ICA) and intelligent computational predictive system with a meta-heuristic approach have higher error rates than the feature selection methodology. This is because of the applicable properties of the NB classifier proficient with optimum features designated using optimization methods and feature selection.

The optimal variable size n-gram features for a supervised method of learning were generated using the feature optimization technique. Hence, feature selection reduces mistakes. Eventually, the feature selection strategy has 41% less error than the intelligent computational predictive system and 29% less than ICA with the metaheuristic approach. With fewer false alarms, the designed approach recognized heart disease risk in patient records [11]. Few Researchers evaluate machine learning algorithms utilizing precision, accuracy, f1-score, recall etc. The optimized model from Fast Correlation-Based Feature Selection (FCBF), PSO and ACO achieves 99.65% classification accuracy. Age, Sex, Resting Blood pressure, Blood sugar, Heart rate, Slope, Serum cholesterol level, peak, Major vessel, and class attributes were employed [12]. Some researchers use genetic algorithms in health systems to predict heart disease according to the law of genetics, which states that crossover and mutations in chromosomes (features) generate individuals of the second generation with more diversified characteristics [13]. Another research provided dimensionality reduction and feature extraction and proposed ensemble-based classification to develop a novel heart disease prediction system. Higher order statistics (degree of dispersion and qualitative assessment) and Statistical (central tendency) characteristics are extracted initially during the anticipated phase of feature extraction. Unfortunately, the "curse of dimensionality" appears to be the primary problem in this case, therefore the higher-dimensionality characteristics have to be reduced to lower ones. PCA-based feature reduction was applied. The anticipated ensemble classifier received as input factors these reduced-dimensional characteristics, which include RF, SVM and KNN. Afterward, the categorized results of all three-classifiers were sent to the optimized NN as input, where the training is done by a novel S-CDF optimization algorithm and an enhanced sea lion algorithm by adjusting the ideal weights. The results from optimized NN are more correct. M8's accuracy (=0.957152) is 17.11, 8.5, 17.11, 2.6, 17.11, 2.6, and 13.7% superior to M_1, M_2, M_3, M_4, M_5, M_6, and M_7 respectively. The suggested study has more sensitivity, specificity, and accuracy than previous efforts. Future data dimensionality can be increased to evaluate the heart disease prediction system's performance and optimize prediction algorithms to increase the prediction rate [14]. Normal sinus rhythm and 40 components of ECG signal analysis are used to diagnose six forms of cardiac arrhythmia. The proposed Computer-aided diagnosis (CAD) technology might enable physicians to enhance clinical decision-making accuracy. This study extracts frequency, morphological and nonlinear indices, combines them, identifies the most correlated features using a meta-heuristic multiobjective optimization technique, and classifies them using various algorithms for machine learning. The suggested technique is efficient, automated, low computing complexity, and rapid in diagnosing heart illnesses using ECG signal processing. The experimental findings show an improvement in cardiac anomaly detection precision. Using the FF net classifier, yields the greatest accuracy among the seven classes, validating the reliability of this phrase. The presented method has been shown to be useful in classifying different types of cardiac arrhythmias, with a high degree of accuracy when compared to other approaches using comparable datasets [15].

2.2 MH Algorithms for Breast Cancer Diagnosis

Diagnostic ultrasound imaging methods are useful in identifying breast cancer. CAD is a model that can assist physicians to make precise judgment calls. Using a wavelet neural network (WNN) and the grey wolf optimization method, the authors of this research suggest a computer aided diagnosis (CAD) model for the diagnosis of breast cancer. Images were enhanced with a sigmoid filter for more contrast, and speckle noise was eliminated with IDAD in this setup. The ROI taken from the pre-processed picture was used to obtain a region of interest, after which the texture and morphological characteristics were extracted and merged. Principal component analysis (PCA) was employed to decrease the feature dimensions. The classification challenge was finally performed using grey wolf optimization (GWO)—wavelet neural network (WNN). Classical WNN necessitates more time invested in optimizing and training the parameters. The training and computational periods were shortened since GWO was used to fine-tune the WNN parameters in this suggested strategy. When compared to its contemporaries in terms of classification accuracy, the proposed CAD model system significantly excelled in the simulation results. GWO-WNN robustness, shorter training data, and convergence speed are its main benefits. The GWO algorithm outperforms other bio-inspired algorithms because of its nature-inspired leadership ability mechanism. Most feature selection approaches used meta-heuristic algorithms. The suggested CAD system tuned WNN parameters using the meta-heuristic approach to decrease computing cost and to prevent the local minima problem, improving performance. Cat swarm optimization, ant lion optimization, and other meta-heuristic techniques will be researched to increase classification accuracy [16].

2.3 MH Algorithms for Parkinson's Diagnosis

The novel metaheuristic algorithm was developed to identify Parkinson's disease early, and the findings demonstrate that it predicts the illness with 100% accuracy. Hence, the optimized crow search algorithm (OCSA) facilitates early therapy. The optimized OCSA was designed to detect Parkinson's disease and 20 benchmark datasets using KNN, Decision Tree models, and Random Forest to minimize features, accuracy, and computing time. Using the Random Forest model with the innovative optimized crow search algorithm yields improved results. For 20 benchmark datasets, the proposed algorithm selected less features with a precision of 88.2% and a computational time of 0.20 s compared to the original chaotic crow search algorithm's precision of 84.2% and 0.40 s computational time. The rate of convergence shows the robustness of the suggested algorithm's fitness function. Several study fields can use the proposed algorithm like Handwriting-exam-based Parkinson's diagnostic. Researchers and practitioners can use the algorithm for various PD diagnoses [17].

2.4 MH Algorithms for Prediction of Alzheimer's Disease

Several applications now prioritize image segmentation optimization. The whale optimization algorithm (WOA) solves numerous real-time issues and finds the global optimal solution, is an MH-optimized algorithm. WOAs may choose local optima over global optima as issue complexity rises. This may impair optimal solution finding. This research offers a hybrid algorithm that combines WOA and GWO to segment brain subregions such as the grey matter (GM), white matter (WM), ventricles, corpus callosum (CC), and hippocampus (HC). WOA and GWO comprise this hybrid combination. The hybrid WOA and GWO approach segments brain subregions (SRs) to diagnose Alzheimer's disease (AD) (H-WOA-GWO, which is denoted as HWGO). The segmented region has 92% accuracy after validation with a different measure. After segmentation, the deep learning classifier classified normal and Alzheimer's disease pictures. WOA/GWO accuracy is 90%. So, the recommended strategy is extremely effective for selecting the best solution and is combined with a deep learning algorithm for classification [18].

2.5 MH Algorithms for Prediction of Chronic Kidney Disease and Bone Disorders

Chronic kidney disease, mineral and bone disorders (CKD-MBD) cause vascular and cardiac calcification, which compromises blood pressure compensation. The researcher used BSWEGWO_KELM, a feature selection framework based on an optimized GWO algorithm and kernel extreme learning machine (KELM), to examine 1940 data from 178 Haemodialysis (HD) sufferers. The BSWEGWO_KELM method was evaluated using global optimization and feature selection tests on HD and public datasets. The BSWEGWO_KELM can be capable to screen out critical markers including dialysis vintage, intact parathyroid hormone (iPTH), mean arterial pressure (MAP) and alkaline phosphatase (ALP), according to experimental data. Hence, BSWEGWO_KELM can forecast intradialytic hypotension (IDH) accurately and practically [19].

2.6 MH Algorithms for Immunity Based Ebola Optimization Search Algorithm for Feature Extraction Minimization and Digital Mammography Reduction Using CNN Models

The novel revolutionary biology-dependent metaheuristic algorithm Ebola optimization search algorithm (EOSA) solved deep learning issues rapidly and precisely in recent research. The current EOSA metaheuristics use the spread of the Ebola virus and related sickness to explore by what means exploitation and exploitation stages of optimization may assist solve specific medical optimization challenges.

Researchers created SEIR-HVQD by improving the SIR model of Ebola. The model arises from incorporating into the basic SIR (Susceptible, Infected, Recovered) model the concepts of Exposed (E), Hospitalized (H), Quarantined (Q), Vaccinated (V) and Dead (D) [20].

2.7 MH Algorithm for Classification of White Blood Cells in Healthcare Informatics

In this procedure, blood is examined through blood count using manual and/or automatic procedures. In the search for medical innovations, this necessitated a Deep Learning framework for categorizing white blood cell subtypes in digital images, achieving effectiveness and dependability while attempting to make the methodology more accessible to underprivileged populations. Given this, systems that enable reliable, low-cost medical report procurement are important. For this, it was developed in python utilizing Jupyter notebook and analysis was done using a dataset of 12,500 digital photos of human blood smear fields with nonpathological leukocytes. The approach's accuracy was 85.72%, confirming its excellent dependability. So, the proposal is an accurate, reliable, and economical approach that may be used as a third-practicable blood count procedure among impoverished populations in undeveloped and developing nations [21].

2.8 MH Algorithm for EMG Classification Utilizing PSO Optimized SVM for Neuromuscular Diseases Prognosis

SVM is widely utilized for biological signal classification. This work developed a novel PSO-SVM model to improve EMG signal categorization accuracy by combining PSO and SVM considerably affecting the accuracy of classification. This optimization strategy involves setting kernel parameters in the SVM training method, which affects the accuracy of classification. EMG signals classified the research as neurogenic, normal, or myopathic. The suggested technique divided EMG signals into frequency subbands employing the discrete wavelet transform (DWT) and generated statistical characteristics to reflect wavelet coefficient distribution. The results demonstrate that the SVM approach outperforms standard machine learning methods and that the planned PSO-SVM classification system may increase classification accuracy. The PSO-SVM had 97.41% accuracy on 1200 signals of EMG from 27 subject records, against 96.75%, 95.17%, and 94.08% for the SVM, KNN, and RBF classifiers, respectively. PSO-SVM uses several SVMs as its core to diagnose neuromuscular diseases [22].

2.9 MH Algorithm Using Hybrid Case-Based Reasoning and Particle Swarm Optimization (PSO) Approach to the Detection of Hepatitis Disease

Physicians struggle to diagnose diseases. Misdiagnosis can lead to fatalities. In this context, expert systems and artificial intelligence approaches are used to decrease errors. The diagnoses of serious hepatitis use a combination of Case-Based Reasoning (CBR) and PSO. The CBR approach pre-processes the data and extracts each field's weight that has an influence on diagnosis, followed by PSO clustering. Each record's categorization and patient record are determined by PSO. The CBR-PSO technique outperformed FDT, KNN, SVM, PSO, and NB in hepatitis illness diagnosis with 94.58% accuracy. Comparatively, this technique works better when compared to different algorithms. This approach and fuzzy logic will be used in medical data by future researchers [23].

3 Meta-Heuristic Algorithms in Medical Image Segmentation

Recently, academics have focused on soft computing methods for medical data issue resolution. Similarity measurements are used to segment images. Medical image anomalies volumetric analysis is used for illness detection. Meta-heuristic algorithms support segmentation approaches recently. Highlights of meta-heuristic methods are presented. Meta-heuristic stochastic algorithms such as cellular automata, Memetic algorithms, ant colony optimization, particle swarms, evolutionary computation, Tabu search, and simulated annealing [24] (Fig. 2).

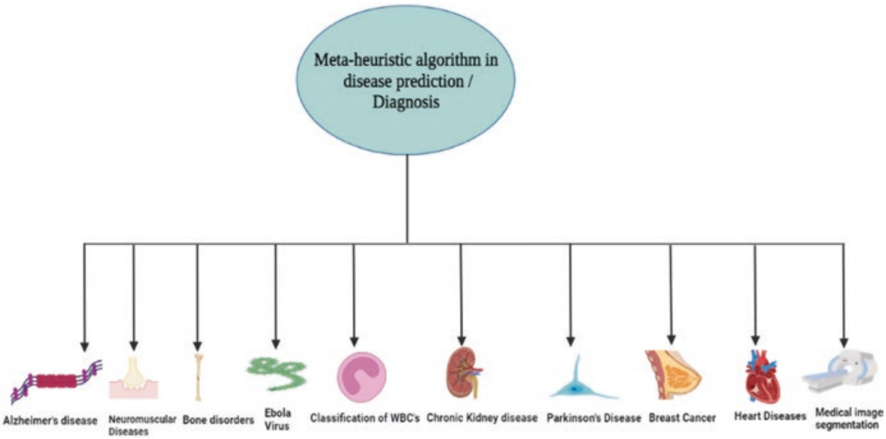


Fig. 2 Meta-heuristic algorithm helps in the prediction/diagnosis of diseases

4 Conclusion

Meta-heuristics algorithms rapidly explore the enormous solution space of candidate characteristics and models to predict diagnose and complicated diseases. Genetic algorithms, particle swarm optimization, and simulated annealing can optimize feature and model parameter selection to improve prediction. Meta-heuristics may become more important in illness prediction as healthcare data grows in volume and complexity. As processing power and machine learning improve, metaheuristics algorithms will become more complex and accurate, making them a vital tool for healthcare practitioners.

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