International Journal of Current Engineering and Technology
E-ISSN 2277 – 4106, P-ISSN 2347 – 5161

Available at http://inpressco.com/category/ijcet

Research Article

Congestive Heart Failure Detection through ANN and Dempster Shafer Reasoning

Shreya B. Yadav Prof. M.S.Takalikar

Computer Engineering PICT, Pune, India

Received 10 Nov 2020, Accepted 10 Dec 2020, Available online 01 Feb 2021, **Special Issue-8 (Feb 2021)**

Abstract

There have been large scale advancements in the medical field that have contributed to reduced infant mortality and increased life expectancy. The increased life expectancy has had a double-edged effect, where there has been a sharp increase in the number of elderly individuals in the populous. This largescale increase in elderly individuals corresponds to a similar increase in the Heart Failure scenarios. Congestive Heart Failure or CHF is characterized by decreased blood flow which is due to the inability of the heart to provide enough blood to the various parts of the body due to extensive aging. The diagnosis of a heart failure condition is highly complex as there is no one definitive cause of this ailment rather a combination of different conditions. Therefore, the analysis technique that is used mostly for this purpose is the ECG or Electrocardiogram, through which the RR intervals that indicate the significant signs of Congestive Heart Failure. Therefore, for the purpose of automatic Heart failure prediction, the methodology described in this paper utilizes, Kmeans Clustering, Linear Regression, Artificial Neural Networks (ANN) and Dempster Shafer rules for the purpose of effective and accurate predictions.

Keywords: *Congestive Heart Disease, K means clustering, Artificial Neural Network, Dempster Shafer Theory.*

Introduction

Heart Disease has been one of the chief causes of death in recent years. This has been noticed significantly all over the world. The significant increase in the number of Heart Disease occurrences in the population can be attributed to the increase in the number of elderly people. As humans get older the risks related to heart disease and heart failure increase substantially. The elderly people generally tend to be weak and have a compromised blood circulatory symptom which is highly susceptible to heart disease or heart failure cases very easily. The majority of Heart failure patients, therefore, are elderly individuals requiring utmost care and protection.

Over the years, there have been large advances in the medical treatments and facilities that have been attributed to extensive research in the medical paradigm. This continuous research has been going on for centuries where the researchers develop on the works done by the previous scientists. The gradual improvements led to the treatment of various common as well as highly debilitating diseases. The advancements in modern medicine resulted in a large-scale decrease in infant mortality and a significant increase in the life expectancy of humans. This also contributed to a large number of elderly individuals and created a lot of more aging-related issues. These issues were largely unnoticed due to the lower life expectancy that was prevalent earlier.

Therefore, a lot more research should be done on this paradigm to enable a better approach towards the prevention and the treatment of the various different ailments. There have been significant improvements in the elderly patient care in the hospitals and effective treatment has also resulted in improved patient survival statistics. This inadvertently increases the frequency of diabetes, obesity and cardiovascular disease risk exponentially. Most of the approaches towards heart failure have been targeted towards its treatment; there is a need for the implementation of a prevention technique that can be utilized extensively to reduce the risks related to heart failure.

The heart failure assessment is one of the most archaic processes that have been utilized to analyze the risk that a particular symptom possesses to result in a heart failure scenario for the patient. The heart failure disease diagnosis must be validated to make sure that the assessment is accurate. The heart disease paradigm is one of the most complex approaches and is being governed by a large number of individual risk factors and a combination of the prevalence of certain

different types of diseases such as valvular disease, Congestive Heart Disease, hypertension and elevated blood pressure, all of these factors contribute to the heart failure substantially.

Therefore, heart failure conditions are highly complex and can happen at any time unannounced. Hence, there is a need for a heart failure disease prediction for a patient to help ensure that the patient receives timely care. This is due to the fact that a heart failure disease is very time-sensitive and every second count when confronted with such a scenario. Therefore, it is compulsory that a prediction mechanism can foretell the actual heart failure scenario as it would help prepare for the scenario which would save valuable time and eventually has the capabilities to save a patient's life.

The prediction of heart failure scenarios can also help the doctors decide if the patient is supposed to be discharged or not. As most of the elderly people are living alone and identifying any imbalances in their body while at home is very difficult and the time taken after an episode to get the patient to a medical professional for treatment could be highly fatal for the patient and the time could mean life or death. In this situation, if a scenario like this is being predicted, then the doctors won't discharge the patient so that he/she remains under medical care when the event does take place to achieve a swift and accurate treatment.

Machine learning is one of the leading techniques that are used for the purpose of prediction of a heart failure disease. Machine Learning is a technique that utilizes a collection of past data for the purpose of prediction of future events. The predictions are based on the recurring patterns of other information that would allow the algorithms to identify and elaborate on them to perform accurate predictions. The algorithms are designed solely for the purpose of identifying the trends in the data that are then utilized for the purpose of providing efficient predictions. The past data is a necessity for the algorithms to work as intended and help infer future events based on the insight provided by the past data.

Heart Failure prediction requires a lot of data containing the various different parameters and information about the patient's vital stats and other heart-related data. The data has a large number of attributes; an increase in the number of attributes corresponds to the increasing inaccuracy of the prediction. The Machine Learning paradigm is an excellent choice for this as it has the capability to achieve highly accurate predictions. This paradigm assesses the potential hazards and other indicators that can accurately assess the condition of the patient and provide appropriate results.

The Heart disease failure prediction allows the doctors and professionals to save a lot of time that would be spent on analyzing the various reports and the past history of the patients that would take a lot of time. Also, the attributes and diseases that are the root cause of the heart failure are plenty and various different attributes can affect the results drastically. A large number of attributes also add to the complexity of the prediction which would further increase the workload on the medical professional in charge of the patient. This increase in complexity combined with the increasing workload on the medical professionals makes the implementation of automatic prediction through the use of Machine Learning highly plausible and a viable alternative to the platform.

The Dempster Shafer theory is a Machine Learning algorithm that was defined by A. Dempster and his student G. Shafer in the late 1970s. This technique was designed due to various limitations in the Bayesian Model that was unable to describe the ignorance as well as the Bayesian probability only utilized single evidence for its application. Therefore, the Dempster Shafer theory overcomes this limitation through the combination of all the different outcomes of an event to provide solutions and predictions to various different problems. The Dempster Shafer theory is an appropriate implementation of the Heart Failure Prediction paradigm as it allows for a much accurate prediction and the implementation of a plausibility that will make the outcomes highly efficient.

The Dempster Shafer is used in conjunction with Artificial Neural Networks or ANN to further enhance the prediction system and handle the increasing complexity of the heart failure prediction. The ANN is a computational network that has been modeled according to the human brain. The ANN tries to emulate the human thinking process through the use of a similar taxonomy. This allows for a human-like thinking process that is highly useful where human-like decision making is desired. The heart failure prediction requires the implementation of an Artificial Neural Network to allow for the effective computation of the accurate prediction that help save countless lives.

In this paper, section 2 is dedicated for literature review of past work and finally section 3 concludes this paper.

Literature Review

This section of the literature survey eventually reveals some facts based on thoughtful analysis of many authors work as follows.

A. Naniwal states that the main diagnosis of Congestive Heart Failure is done through an ECG scan which is extracted from the patient [1]. The authors in this paper design a technique for the detection of morphological changes in an ECG; this is used to

indicate that the morphological changes are in fact an accurate depiction of a Congestive Heart Disease. The major drawback of this technique is that the authors have only considered a narrow set of features that provide sub-optimal performance.

G. Valenza explains that the Heart Rate Variability (HRV) spectral analysis is one of the most widely used techniques that is utilized for the purpose of the characterization of the heart. But this technique does have its drawbacks that need to be eliminated for an accurate diagnosis of Congestive Heart Disease. Therefore, the authors have presented a technique that utilizes the PAI or Parasympathetic Activity Index and SAI or Sympathetic Activity Index for identifying the dynamics of a healthy heart [2]. The results indicate that the presented technique is quite reliable. The major drawback of this technique is that the authors have not evaluated other applicative setting such as physical activity and other parameters in their methodology.

S. Potturu elaborates on the concept of utilizing the nervous system along with the respiratory system to identify the Congestive Heart Failure disease. For this purpose, the authors have designed a system with two states that utilize a non-linear space model, where the variables that are utilized are partial carbon-di-oxide and oxygen pressures in the alveoli. The system identifies the delay in the feedback control loop which is used to classify according to the length of the delay [3]. If the delay is large it is an indicator of a Congestive Heart Failure condition. The experimental results indicate that the proposed technique has produced an accurate analysis. The main limitation of the proposed technique is the authors have not utilized the no negativity theories for the analysis of this model.

A. Khayyat present a technique for the diagnosis of heart failure condition using the decision support tool that can reduce or estimate the probabilities of the patient being readmitted for the same ailment (CHF) [4]. The researchers have demonstrated the effectiveness by thorough experimentation and yielded satisfactory results. The major drawback of this technique is that the authors have not adapted the decision support tool to increase its accuracy for a much detailed approach.

W. Pan introduces the paradigm of the utilization of a Heart Rate Variability index for the purpose of diagnosing a Congestive Heart Failure disease. The authors state that the Autonomic Nervous System is also an accurate indication of a person suffering from Congestive Heart Failure. Therefore, the authors devise a technique for the purpose of CHF identification using the HRV and multi-frequency components Entropy through the HHT paradigm [5]. The experimental results indicate increased accuracy over the traditional techniques. The major drawback of this technique is that the authors have not considered the limitations of the algorithm when implementing the system which further decreases the accuracy.

E. Mbazumutima explains that there is a possibility of the prediction of the various different variables in an Exercise test designed for determining the severity of the Congestive Heart Failure condition of the patient. The researchers proposed a methodology that utilizes Linear Regression (LR) for the purpose of predicting the accurate peak heart rate and oxygen values for the patient. The experimental results indicate that the proposed methodology is highly accurate and can be used for prediction purposes [6]. The main limitation of this paper is that the technique shows the accurate peak heart rate but the predictions of the peak oxygen consumption are highly inaccurate.

H. Wendt states that there have been various different indices that are designed to statistically characterize a large number of Heart Rate Variability variables and their temporal dynamics. The authors have devised a technique that utilizes non-Gaussian multi-scale representations on wavelet p leaders that utilized the apriori framework and identifies the difference between a healthy heart and a heart suffering from Congestive Heart Failure [7]. The framework was analyzed and experimented for its performance analysis which indicated a satisfactory performance. The main drawback of this technique is that the authors have not utilized the different combinations of higher-order cumulants in the framework which can increase the performance metrics.

B. Hu elaborates on the topic of identification of the Congestive Heart Failure in patients and claims that identification with relative accuracy requires the use of Heart Rate Variability measures using the ECG or Electrocardiogram. The authors present a framework for the utilization of multiple time scales in the analysis of the patient that increases the accuracy of the prediction. The proposed technique has included time-based features for the analysis purpose and the experimental results indicate a high-level accuracy obtained in comparison to the popular techniques [8]. The main drawback of this paper is that the time complexity is higher than the other traditional techniques.

A. Windmon introduces the concept of a smart phone application that can be used for the purpose of identification of cough increase in the patients suffering from congestive heart failure as they are one of the earliest indicators of a Chronic obstructive pulmonary disease that is usually caused due to CHF. The authors have devised a technique called TussisWatch that is used to identify episodes of cough and correlated it with the other results for the diagnosis of the CHF condition [9]. The experimental results indicate an increase in CHF identification by a

large margin in comparison to the popular techniques. The main drawback of this technique is that the classification accuracy has not been improved leading to irregularities in the results.

D. Destiani explains that the Congestive Heart Failure is a condition of the heart that is related to a heart muscle abnormalities and other related diseases of the heart muscle. The Congestive heart failure condition can be diagnosed using an ECG scan of the heart and its beats. The authors in this paper devise a technique for the purpose of prediction of a Congestive Heart failure condition through the use of PolakRibiere conjugate and the Artificial Neural Networks on the Discrete Wavelet Decomposition [10]. The proposed technique has been tested extensively and produces exceptional results. The major drawback of this technique is the increased Computational complexity of the system.

M. Alex discusses the paradigm of diagnosis and prediction of various heart-related diseases. There is an increase in the number of Heart failure-related deaths in recent years. This is due to the fact that the diagnosis of the condition takes time which then the damage is already done. Therefore, the authors devise a technique for the prediction of various different heart ailments with the use of Artificial Neural Networks and K nearest Neighbors for the purpose of accurate predictions of heart disease at an early stage which can help save a lot of lives in a timely manner [11]. The authors have utilized a Data Mining approach that has a very large space complexity which is the only drawback of this technique.

A. Massaro states that there have been a large number of Smart health platforms that have been on the rise in recent years. These systems are capable of producing a large number of predictions based on the data collected by the various different sources. The authors have devised a framework for the utilization of a Multilayer perceptron along with Artificial Neural Networks for the accurate predictions of a Congestive Heart Failure conditions in the patients beforehand [12]. This allows for an efficient diagnosis that can help alleviate the pain of the patient and also gives time to the doctors to perform accurate treatment at an early stage. The major drawback of this approach is the general approach that is very limiting for the framework.

B. Tarle explains that the accurate prediction of the various different heart diseases is one of the most important aspects of Machine Learning that can greatly help the elderly patients in the accurate and early treatment of their Heart Ailments. The authors proposed a technique for the accurate classification and prediction of medical data that can help identify various diseases before time to help increase the chances of the survival of the patient [13]. The authors utilize Artificial Neural Networks and a back-propagation algorithm to increase the prediction accuracy of the system by a large margin. The major drawback of this technique is that it has not been used to provide consistent results and needs some improvements.

M. Jazi elaborates on the topic of medical data prediction that can help in early diagnosis of various different conditions, especially the conditions involving heart abnormalities as it takes a long time for the diagnosis through traditional means and could lead to a decrease in the patient's life expectancy. Therefore, the researchers have implemented a technique for the purpose of prediction of different abnormalities of the heart using Artificial Neural Networks on the ECG data of the patient for accurate predictions of Congestive Heart Failure [14]. The proposed technique produced excellent results that have been highly accurate. The main drawback of this technique is that the algorithm has only been trained for heart abnormalities specifically.

L. Wang [15] states that the use of Heart Rate Variability measure for the prediction of Congestive Heart Failure can lead to highly accurate results. The temporal feature extraction technique has been highly useful for this purpose and has been used extensively for the prediction of the Congestive Heart Failure condition. Therefore, the authors have designed a technique that utilizes the RR intervals in an ECG of the patient to perform Deep Ensemble detection of the Congestive heart failure condition. The technique has been implemented on various datasets and has produced highly accurate results. The main drawback of the proposed technique is that the authors have not solved the issue of data imbalance that decreases the prediction accuracy.

III PROPOSED METHODOLOGY

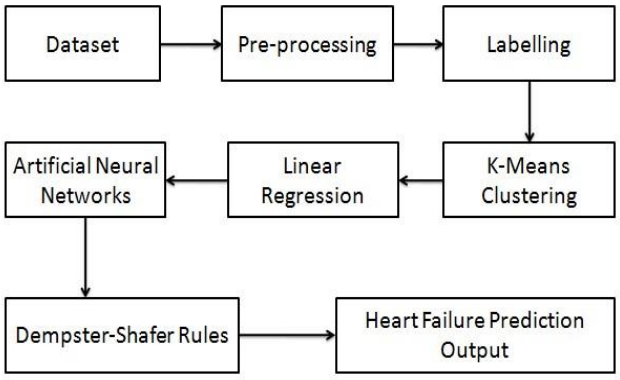

Figure 1: System Overview

The proposed model of congestive heart failure prediction is developed according to the steps shown in the above figure 1. And these steps are detailed below.

Step 1: Dataset Collection and Preprocessing - This is the initial step of the proposed model where a model dataset s collected for the process of congestive Heart failure prediction from figshare website.

This dataset is enriched with some of the attributes like personid, ecgdate, ecgdept, ecgsource, RR, PR, QRS, QT, QTc, P_wave_axis, QRS_axis, T_wave_axis and ACCI. In this step of the proposed model where a dataset in the form of a worksheet is being fed to the system for the purpose of learning. Where a required attribute positions are estimated and they are selected to form a preprocessed list of attributes. By doing this proposed model is get rid of the unwanted attributes on the dataset that are eventually increases the time complexity of the process.

Step 2: K-Means Clustering - In this step most important attributes are identified based on the frequency and then they are labeled numerically for the cluster process. This Cluster process contains some steps as explained below.

Distance Evaluation - Once the labeled double dimension is formed then it is subjected to estimate the Euclidean distance as mentioned in equation (1). This distance is measured for each and every row with all other rows of the list. Then the measured Euclidean distance is appended at the end of each row and they are referred as R_D. Then the Average Euclidean A_{ED} is evaluated for the complete list by using equation (2).

$$RD = \sqrt{(x1 - x2)^2 + (y1 - y2)^2} \quad (1)$$

$$A_{ED} = \sum_{k=0}^{n} RD \quad (2)$$

Where,

RD- Euclidean distance of a specific row.

x1,x2,y1, and y2 are the gas sensor reading values.

A_{ED} = Average Euclidean Distance

n= Number of Rows

Centroid Evaluation - Once the distance is evaluated, this list is sorted in ascending order based on the appended row distance using Bubble sort technique. This sorted list is used to evaluate the data points depend on the required number of the clusters. Data points are decided based on the random integers, which are normalized to the size of the sorted list. Data points are used to fetch a row and then its row distance R_D in a list, to call it as the centroid list.

Cluster Formation - Each of the centroid from centroids list is used to estimate the boundary of the cluster as $C_i - A_{ED}$ to $C_i + A_{ED}$. Then these estimated boundaries of each cluster are used to collect the respective data based on the Row distance R_D. After adding the outlier data this eventually yields the more matured clusters which are semantically segregated.
The cluster formation can be shown in the below algorithm 1.

ALGORITHM 1: K Means Cluster Formation

// Input: Mean Euclidean Distance E_D, Centroid List C_L, Data
List D_L
// Output: Cluster Set C_{SET}
1: Start
2: **For** I = 0 to size of C_L
3: Ci = CL [i]
4 Min = C_i-E_D
5: Max = C_i+E_D
6: Single Cluster S_C = NULL
7: **For** j = 0 to size of D_L
8: **IF**(($D_{L[i]CENT}$ >=Min) AND($D_{L[i]CENT}$<=Max),**THEN**
9: ADD $D_{L[i]}$ into S_C
10: **End IF**
11: **End For**
12: ADD S_C into C_{SET} 13: **End For**
14: **return** C_{SET}
15: End

Step 3: Linear Regression - Here in this step a regression is analyzed based on the most effective predictive values as shown in the equation (3).

$$Y = mx+b \quad (3)$$

Where, y = how far up x = how far along
m = Slope or Gradient (how steep the line is) b = the Y Intercept (where the line crosses the Y axis)

This regression analysis provides a prediction parameter for the important attributes of the clustered data. And these important attributes are segregated from each of the clusters to form a list which used in the next step of ANN.

Step 4: Artificial neural network - Once the regression list is received the neurons are created based on the hidden factors of the relationship attributes. These attributes are subjected for the cost estimation process of artificial neural network that is further used by the Dempster Shaffer theory to yield the Classification factor list for the heart failure prediction. This process of neural learning is deployed using the following equation (4) and (5).

$$f(AN) = \sum_{0}^{n} (ATi)(ATj) \quad (4)$$

Where,
A_N =Neurons
A_{Ti}=Attribute at i.
A_{Tj}=Attribute at j.

$$f(HL) = \int AT \Rightarrow PR \sum^{n_0}(ATi)(ATj) \quad (5)$$

Where,
H_L =Hidden Layer
A_T=Attributes
P_R=Protocol Set

Step 5: Dempster Shafer Reasoning - This theory is evaluating the reasoning for the estimated prediction reasons. This is done by setting a protocol for the belief network that are eventually helping to identify the proper prediction of heart failure conditions.

$$K = \sum_{B \cap C = \emptyset} m1(B)m2C \quad (6)$$

Where,
K=Effect of Coefficient m_1,m_2=Set of Module B, C=Belief Set

The whole proposed system is expressed mathematically with the below model.

Mathematical Model

1. S = { } be as system for Heart Failure Prediction

System

2. Identify Input as D_S

Where, D_S = Dataset

3. S = { D_S }
4. Identify H_{FP} as Output i.e. Heart Failure Prediction

S = { D_S, H_{FP} }

5. Identify Process P S= { D_S,P,H_{FP} }

P= { K_M, L_R ,A_{NN}, D_R }

Where,
P=Preprocessing
L=Labeling
K_M =K-Means
L_R = Linear Regression
A_{NN} = Artificial Neural Network
D_R = Dempster Shafer Rules

6. So the Complete system for heart failure prediction, S = { D_S, P,L,K_M, L_R ,A_{NN}, D_R, H_{FP} }

Results and Discussions

The methodology proposed in this paper has been coded in the python programming language on the Spyder development environment. The development machine is running on the Microsoft Windows operation system with a basic configuration of an Intel i5 processor with 4 GB of physical memory and 500 GB of storage. The methodology performs accurate predictions of a heart failure condition by implementing K-means clustering, Linear regression along with Artificial Neural Networks and Dempster Shafer rules.

The presented technique has been analyzed for its performance in cluster formation. Extensive experimentation has been performed for evaluation of the Heart Failure sample extraction accuracy of the technique.

Precision and Recall are the parameters used to evaluate the performance of the system below.

Performance Evaluation based on Precision and Recall :

Precision and Recall are the best parameters to ascertain the performance of the system. Precision extracts the relevant accuracy of the system through the extraction of the exact values of the level of accuracy.

Precision in this methodology has been defined as the ratio of accurate Heart Failure samples clustered and the combined sum of all the clusters that have been analyzed. Hence, the parameters in precision allow for a thorough evaluation of the relative effectiveness of the system as a whole.

The Recall parameters, on the other hand, generate the absolute accuracy of the system. This is due to the fact that recall is a ratio of the number of accurate Heart Failure samples clustered versus the total number of inaccurate heart failure samples clustered. Therefore, the recall generates the absolute accuracy of the system. Precision and Recall are elaborated mathematically in the equations given below.

Precision can be more effectively explained as below

A = The number of accurate Heart failure samples clustered for the given cluster

B= The number of inaccurate heart failure samples clustered for the given cluster

C = The number of Heart failure samples that are not clustered for the given cluster

So, precision can be given as

Precision = (A / (A+ B)) *100
Recall = (A / (A+ C)) *100

A collection of experiments detailed in the presented system has been performed with utmost scrutiny and tabulated in the table below.

Table 1: Precision and Recall Measurement Table

No of Data Samples (in a cluster)	Samples Extracted (in the cluster) (A)	Samples Extracted (in the cluster)	Samples not Extracted (in the cluster) (C)	Precision	Recall
100	87	3	10	96.66667	89.690722
50	45	1	3	97.82609	93.75
125	121	2	4	98.37398	96.8
25	24	1	2	96	92.307692
75	88	2	7	97.77778	92.631579

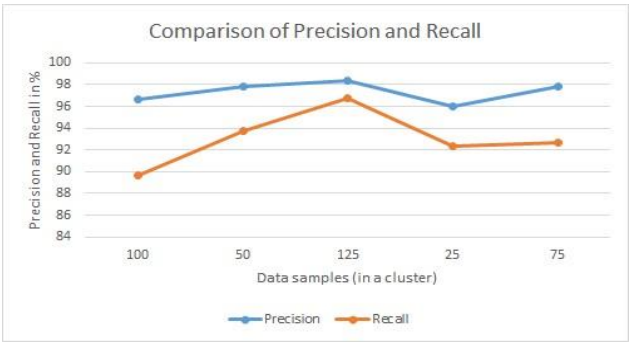

Figure 2: Comparison of Precision and Recall

The accuracy of the K means clustering has been demonstrated in the graph of Figure 2. The proposed model achieves the average of 97.3% precision and Recall of 93.03 % in quality cluster formation.

Conclusion and Future Scope

Due to the increase in the life expectancy of humans, there has been a sharp increase in the number of elderly individuals. This is a problem as there is also a significant increase in the number of Heart Failure incidences in the elderly population due to the ill effects of aging. Therefore, the past works on the paradigm of Heart Failure prediction have been analyzed in detail by this research article to learn their strength as well as their flaws. However, this paper presents an innovative technique that utilizes K Means Clustering, Linear regression along with Artificial Neural Networks and Dempster Shafer Rules to improve Heart Failure Prediction rate. The cluster formation has been extensively evaluated that has produced excellent results for the precision and recall parameters. For future implementation, the live ECG stream can be utilized as an input to the system to achieve accurate and realtime Heart Failure Prediction.

References

[1] A. Naniwal, Y. Kumar and B. Jha, "Morphological Changes in Congestive Heart Failure ECG", 2nd International Conference on Advances in Computing, Communication, & Automation (ICACCA), 2016.
[2] G. Valenza et al, "ECG-Derived Sympathetic and Parasympathetic Nervous System Dynamics: A Congestive Heart Failure Study", IEEE Computing in Cardiology, 2018.
[3] S. Potturu, T. Pal and S. Maka, "Modelling and Analysis of Respiratory System with Congestive Heart Failure", Fifth Indian Control Conference (ICC), 2019.
[4] A. Khayat et al, "Decision Support Tool to Estimate and Reduce the Probability of Readmission for Congestive Heart Failure Patients", IEEE Access, 2019.
[5] W. Pan et al, "Multi-Frequency Components Entropy as Novel Heart Rate Variability Indices in Congestive Heart Failure Assessment", IEEE Access, 2019.
[6] E. Mbazumutima et al, "A Study of the Possibility of Predicting Main Parameters of a Cardiopulmonary Exercise Testing in Patients with Congestive Heart Failure", IEEE Access, 2019.
[7] H. Wendt, P. Arby et al, "Wavelet p-Leader Non-Gaussian Multiscale Expansions for Heart Rate Variability Analysis in Congestive Heart Failure Patients", IEEE Transactions on Biomedical Engineering, 2018.
[8] B. Hu et al, "Multiple Time Scales Analysis for Identifying Congestive Heart Failure Based on Heart Rate Variability", IEEE Access, 2019.
[9] A. Windmon et al, "TussisWatch: A Smart-phone System to Identify Cough Episodes as Early Symptoms of Chronic Obstructive Pulmonary Disease and Congestive Heart Failure", IEEE Journal of Biomedical and Health Informatics, 2018.
[10] D. Destiani, Adiwijaya and D. Utama, "Study of Wavelet and Line Search Techniques on Modified Backpropagation Polak-Ribiere Algorithm for Heart Failure Detection", 6th International Conference on Information and Communication Technology (ICoICT), 2018.
[11] M. Alex et al, "Prediction and Diagnosis of Heart Disease Patients using Data Mining Technique", International Conference on Communication and Signal Processing, April 4-6, 2019.
[12] A. Massaro et al, "Neural Networks for Automated Smart Health Platforms oriented on Heart Predictive Diagnostic Big Data Systems", AEIT International Annual Conference, 2018.
[13] B. Tarle et al, "An Artificial Neural Network Based Pattern Classification Algorithm for Diagnosis of Heart Disease", Third International Conference on Computing, Communication, Control and Automation (ICCUBEA), 2017.
[14] M. Jazi et al, "Detection of Heart Abnormalities via Artificial Neural Network: An Application of Self Learning Algorithms", IEEE Canada International Humanitarian Technology Conference (IHTC), 2017.
[15] L. Wang et al, "Deep Ensemble Detection of Congestive Heart Failure Using Short-Term RR Intervals", IEEE Access, 2019.