Engineering and Technology Journal e-ISSN: 2456-3358

Volume 08 Issue 11 November -2023, Page No.- 2985-2993

DOI: 10.47191/etj/v8i11.07, I.F. – 7.136

Application of Artificial Neural Networks in the Identification of Heart Abnormalities Based On ECG: Literature Review

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ABSTRACT: In recent years, a lot of research on Biomedicine is mainly related to heart defects. The recognition and detection of heart defects using an electrocardiogram (ECG) is numerous. This article aims to explain ECG research trends using the artificial neural networks (ANN) approach in the last twelve years. We reviewed journals with the keyword title "ANN ECG" and published from 2011 to 2022. Articles classified by the most frequently discussed topics include: data sets, case studies, pre-processing, feature extraction, and classification/identification methods. Data collection from articles obtained some of them use data banks such as PhysioNet, European Society of Cardiology (ESC), UCI Repository, as well as data collection directly from patients. The pre-processing stage of the total number of journals used 23% uses this stage, while in characteristic extraction almost 25% of papers are used. This research is very interesting because only a few researchers focus on researching about it. This article will provide further explanation of the most widely used algorithms for ECG research with the ANN approach. At the end of this article, critical aspects of ECG research can be carried out in the future, and the use of deep learning becomes a huge opportunity for researchers.

KEYWORDS: electrocardiogram, ANN, dataset, pre-processing, feature extraction, identification

I. INTRODUCTION

Cardiovascular disease is the biggest killer in Europe, accounting for 4 million deaths per year (47% of all deaths) and costing the EU economy around €196 billion per year [1]. The diagnosis of heart defects is established through the collection of data on symptoms, medical and family history and the results of supporting examinations performed. One examination technique that is often used to diagnose cardiovascular disease is to analyze an electrocardiogram (ECG) [2]. An electrocardiogram is used to measure the rate and regularity of the patient's heartbeat. ECG can be used to identify abnormal heart rate speeds, heart rhythm disturbances, and heart muscle damage. The doctors find it difficult in diagnosing abnormal heart behavior, but early and precise detection of heart defects helps in providing proper treatment to the patients [3]. Manual extraction in ECG readings is very less efficient Computer systems can help identify the electrical condition of the heart [4]. Research related to ECG on heart defects is a challenge in today's technological developments. Several studies have been published in matters relating to computer-based ECG.

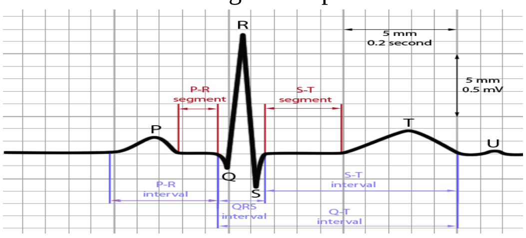

Fig 1. ECG Illustration [5]

Because it is very important for us to maintain the condition of the heart to stay healthy and function properly, many studies have case studies using the heart. Several approaches are used in order to obtain excellent results. Therefore, with the correct method of detecting heart defects, it is possible to apply more targeted treatment [6]. One approach that is often used is to use the neural network method. The ANN method is widely used at the identification and classification stages. According to [3] an effective technique uses Artificial Neural Network (ANN) in performing classification. Similarly [7] states that Artificial Neural Networks are an invaluable tool when classifying ECG in patients. This study tried to review the literature related to ECG using an artificial neural network approach within twelve years (2011-2022). With this literature review, it is hoped that it can obtain a road map related to future researches.

II. METHODS

Research on ECG from several published scientific publications is very much. From the researchers' search, ECG research was conducted by Pan and Tompkins in 1985 [8]. While the use of artificial neural networks has also been done in identifying heart defects carried out by Özbay and Karlik [9]. Furthermore, many researchers who conduct ECG studies as well such as [10], examine ECGs with artificial neural networks in detecting normal and abnormal heartbeats, with the Levenberg-Marquardt training algorithm used to provide the best training results. Application to MLP neural networks for ECG pulse classification [11]. Various method approaches are used to obtain good end results, such as SOM (Self-Organization Maps), BP (Back-Propagation) and LVQ (Learning Vector Quantization) [12]. The neural networks used in his research are Multi-Layered Perceptron (MLP) and Back-propagation algorithm for his training [13].

Modeling of heart disease diagnosis using ECG with verified neural network method has been done [14]. In the same years [15], [16], [17], [18] and [19] conducted ECG-related neural network research. The following years [20], [21], [22], performed a merger between fuzzy logic and artificial neural networks. Next [23], examined ECG with, neural networks and the Hidden Markov model. In the same year there were also many studies related to ECG and artificial neural networks, such as [24], [25], and [26].

In this study, researchers tried to conduct research in terms of literature studies related to electrocardiogram (ECG). Researchers began to search literature studies related to journals that discuss ECG and use artificial neural network methods. The search was conducted on several publication database sites published from 2011 to 2022 with the keyword "Artificial Neural Network ECG", and was limited to the field of Computer Science.

In the first stage of the results of the document search collected as many as 63 that the researcher got. The second stage of 63 documents that match the criteria sought (ECG by wavelet method) there are 43 documents (Table 1).

Table 1. Article Search

No.	Search	Information
1	63 Article	Collected articles
2	43 Article	Appropriate articles

The distribution of the corresponding article search results (43 articles) can be seen in figure 2.

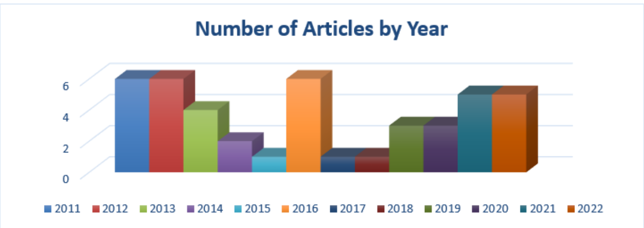

Fig 2. Number of Articles by Year

So at this last stage, the researcher analyzes the content of each document based on a predetermined classification scheme.

III.RESULT & DISCUSSION

In order to be seen thoroughly from previous studies using the same domain, namely identifying heart defects using ANN based on ECG, this study will be divided into three subsections, namely pre-processing, feature extraction and classification. As well as systematically focused on 43 journals starting from 2011 to 2022.

A. *Dataset*

In this study, we see several related journals ("ANN ECG") whose data collection uses data from PhysioNet, European Society of Cardiology, UCI repository and some are taking data independently.

a. Physionet

When referring to its website, Physionet is one of the research resources for Complex Physiologic Signals established in 1999 under the auspices of the National Institutes of Health (NIH). Its main objective is to catalyze research and education in the biomedical field, by offering free access to physiological and clinical databases. Pshysionet also organizes the Computing in Cardiology conference, as well as the annual series of challenges, which focus its research on unsolved problems in the fields of basic and clinical science. PhysioNet is managed by members of the MIT Laboratory for Computational Physiology. Some of the databases provided include MIT-BIH, Europe ST-Database, Fantasia Database, St-Petersburg, Creighton University database (CUDB), PTB diagnostic ECG database, and others.

Fig 3. Website PhysioNet [27]

b. European Society of Cardiology (ESC)

ESC is a non-profit medical society led by volunteers. Members and decision makers are made by scientists, doctors, nurses, and professionals working in all areas of cardiology. ESC brings together heart communities from around the world. This network is very unique which allows us to understand the impact of cardiovascular disease and how we can better reduce its burden. All activities undertaken to advance the prevention, diagnosis, and management of heart and blood vessel diseases. ESC disseminates its evidence-based scientific knowledge to cardiovascular professionals so that they can better care for patients.

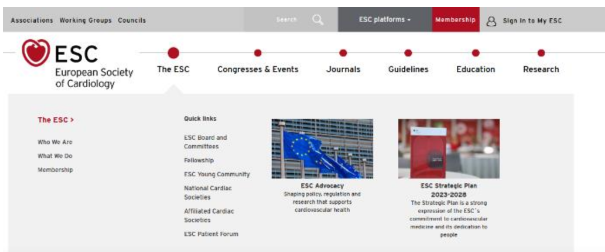

Fig 4. Website European Society of Cardiology [28]

c. UCI Repository

The UCI Machine Learning Repository is a collection of databases, domain theories, and data generators used by the machine learning community for empirical analysis of machine learning algorithms. The archive was created as an ftp archive in 1987 by UCI PhD student David Aha. Since then, it has been widely used by students, educators, and researchers around the world as the primary source of machine learning datasets. UCI currently has 624 datasets as a service to the machine learning community.

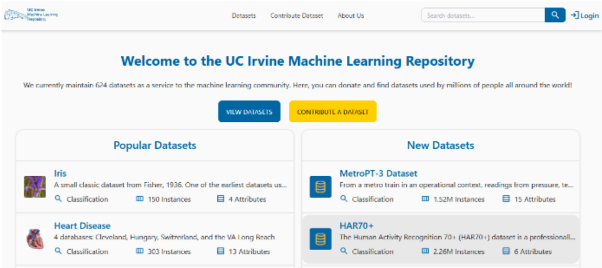

Fig 5. Website European Society of Cardiology [29]

d. Idependent

The purpose of independent here is that they are mainly researchers in terms of data collection carried out independently. From several researchers who took data independently as in table 2.

Table 2. Independent Data Retrieval

Year	Author	Collect Data
2013	[55]	Named the data Z-Alizadeh Sani
2016	[60]	Taking data from Hospital Clínic in Barcelona between 2011–2012
2020	[66]	Using CODE (Clinical Outcomes in Digital Electrocardiology)
2021	[38]	Data collection in hospitals Sardjito Yogyakarta
2022	[72]	From Cardiovascular Department of Azienda Sanitaria Universitaria Giuliano Isontina (ASUGI) in Trieste, Italy

B. Pre-processing

As mentioned above, most of the research related to ECG using Neural Networks goes through several stages, namely pre-processing, feature extraction and classification / identification. While in this pre-processing stage, out of 43 journals used, there are several methods used in this pre-processing stage (Table 3).

Table 3. Use of Pre-Processing

Pre-Processing	Year	Author
Koefisien *Auto Regresif* (AR) and *Entropi Spektral* (SE)	2011	[30]
QRS Complex identification	2011	[31]
Analisis Spektral and Baseline Wander Removing	2012	[32]
Analyze PQRST	2012	[33]
Deteksi QRS	2013	[34]
Noise Filtering	2016	[35]
Normalized and Standard Deviation	2016	[36]
Wavelet Transform	2021	[37]
Segmentation, Morfology and Transformation to the Spatial form	2021	[38]
Filtering and Normalization	2022	[39]

C. Feature Extraction

The second stage is feature extraction, where from several journals used there are several journals that use characteristic extraction with different methods. Regarding the literature review of this study, almost 25% of the papers used all used the characteristic extraction stage. Some researchers who use the method at the trait extraction stage as shown in Table 4.

Table 4. Feature Extraction Method

Feature Extraction	Year	Author
Fuzzy C-Means (FCM)	2011	[30]
RR Interval	2011	[31]
Transformasi Wavelet	2012	[32]
Continuous Wavelet Transform (CWT)	2012	[40]
Fast Fourier Transform (FFT)	2012	[33]
Feature PQRST	2014	[41]
Interval RR, dan PVC	2014	[42]
Determination of a Feature Vector From a Pattern Vector	2016	[36]
Global Shape and Local Statistical	2016	[35]
Wavelet	2016	[43]
R-R Interval	2019	[44]
Decomposition Wavelet Symlet orde 4 (Sym4)	2021	[38]

D. Identification & Performance

This last stage is mostly related to classification or identification. These classification stages all use the neural network method. Some of the methods used include: Probabilistic Neural Network, Backpropagation, Multi Layer Perceptron (MLP), Basis Radial Function (RBF), Convolution Neural Network (CNN) and others. Researchers in choosing the method used are usually based on the use of data. The use of the data used will affect the selection of methods at this stage. The classification and identification stages are some researchers looking for performance. Performance that is often used by researchers includes accuracy, sensitivity and specificity [45]. In finding the level of accuracy, sensitivity and specificity using the Confusion Matrix [46]. The use of Confusion Matrix is one of the methods used to obtain evaluation results based on matrix tables [47]. From the explanation above, research related to ECG with an artificial neural network approach can be presented in Table 5.

CONCLUSIONS

Discussions related to ECG are very diverse to be used as studies in research. The use of data used from several researchers is also very diverse, ranging from utilizing data banks such as PhysioNet, European Society of Cardiology (ESC), UCI Repository, as well as taking data directly from patients. The pre-processing stage of 43 journals used 23% used this stage. Including trait extraction, there are also very various methods used such as finding the R-R interval, finding PQRST peaks, or using wavelets. While at the identification stage, everything uses artificial neural network methods such as Probabilistic Neural Network, Backpropagation, Multi Layer Perceptron (MLP), Basis Radial Function (RBF), Convolution Neural Network (CNN) and other artificial neural network methods. Future work is very wide open related to electrocardiogram (ECG), and may be an opportunity to combine the same discussion, namely ECG with Deep Learning methods, so this is a very big opportunity for researchers to examine ECG both in the form of direct research and research with a literature review approach.

Table 5. Identification & Performance

Year	Author	Approach	Performance	Source Data
2011	[48]	Multi-Layer Perceptron (MLP) Backpropagation		
2011	[49]	Multi Layer Perceptron Basis Radial Function		PhysioNet
2011	[50]	Multi Layer Perceptron (MLP) Adaptive Neuro Fuzzy Inference System (ANFIS)		*European Society of Cardiology*.
2011	[30]	Probabilistic Neural Network Multi Layered Feed Forward Network	Accuracy PNN: 99,05% Accuracy MLFFN:97,14 %	PhysioNet
2011	[51]	Self-Organizing Maps Radial Basis Function	Accuracy: 93 % Accuracy:87,5 %	PhysioNet
2011	[31]	Feed Forward Network	Accuracy: 98,48 %	PhysioNet
2012	[52]	Modular Neural Network (MNN) Generalized Feed Forward Neural Networks (GFFNN) Multilayer perceptron (MLP)		UCI
2012	[33]	Multi-Layer Feed-Forward	Accuracy: 98,6 %	PhysioNet
2012	[32]	Backpropagation	Accuracy: 95.45 %	PhysioNet
2012	[53]	Radial Basis Function	Accuracy: 98,7 %	PhysioNet
2012	[54]	Fused Hierarchical Neural Networks (FHNNs)		
2012	[40]	Backpropagation	Accuracy: 87,04 %	PhysioNet
2013	[55]	SMO (Sequential Minimal Optimization), Naïve Bayes Bagging Simulated Neural Network (SNN).	Accuracy: 94,08 %	Z-Alizadeh Sani
2013	[56]	Backpropagation		PhysioNet
2013	[57]	multi-layer feed-forward Backpropagation	Accuracy: 93 %	PhysioNet
2013	[34]	Multi-Layer Perceptron	Accuracy: 91,8 %	PhysioNet
2014	[41]	ANN		PhysioNet
2014	[42]	ANN	Accuracy: 99,38 % Sensitivity: 99,82 % Specificity: 99,48 %	PhysioNet
2015	[58]	Backpropagation	Accuracy: 94,49 % Sensitivity: 94,63 % Specificity: 93,94 %	PhysioNet
2016	[35]	Backpropagation	Accuracy: 97,8 %	PhysioNet
2016	[59]	ADALINE NN	Accuracy: 99 %	PhysioNet
2016	[60]	ANN		Hospital Clínic in Barcelona

				between 2011–2012
2016	[7]	ANN	Accuracy: 96 %	PhysioNet
2016	[43]	Backpropagation	Accuracy: 93,3 % Spesifity: 100 %	PhysioNet
2016	[36]	Backpropagation		PhysioNet
2017	[61]	Bayesian Regularization Levenberg Marquard Backpropagation	Accuracy: 93,19 % Accuracy: 92,88 % Accuracy: 88,63 %	PhysioNet
2018	[62]	CNN	Accuracy: 99,1 %	PhysioNet
2019	[63]	Feed Forward NN Convolutional NN	Accuracy: 86,4 % Accuracy: 97,6 %	PhysioNet
2019	[64]	Backpropagation	Accuracy: 76,9 %	PhysioNet
2019	[44]	Bayesian Regularization Levenberg Marquard Backpropagation		PhysioNet
2020	[65]	Multilayer Perceptron Convolutional NN Spiking NN	Accuracy: 95 % Accuracy: 76 % Accuracy: 90 %	PhysioNet
2020	[66]	DNN (Deep Neural Networks)	Sensitivity: 99 %	CODE (Clinical Outcomes in Digital Electrocardiolog y
2020	[67]	Backpropagation	Accuracy: 99,82 %	
2021	[37]	CNN	Accuracy: 97,35 % Sensitivity: 97,05 % Specificity: 99,35 %	PhysioNet
2021	[38]	Backpropagation	Accuracy: 92,94 % Sensitivity: 90 % Specificity: 94,55 %	
2021	[68]	ANN (Levenberg–Marquardt)		PhysioNet
2021	[2]	ANN		
2021	[69]	Multilayered Perceptron	Accuracy: 98,89 %	PhysioNet
2022	[3]	ANN	Accuracy: 92,47 %	UCI
2022	[70]	Backpropagation	Accuracy: 87 %	
2022	[71]	Multi-Layer Perceptron		PhysioNet
2022	[39]	CNN	Accuracy: 92 %	PhysioNet
2022	[72]	Convolution Neural Networks		Cardiovascular Department of Azienda Sanitaria Universitaria Giuliano Isontina (ASUGI) in Trieste, Italy

ACKNOWLEDGMENT

The author would like to thank the IAIN Syekh Nurjati Cirebon for its support in its research.

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