Machine Learning

Classification of Arrhythmia by Using Deep Learning with 2-D ECG Spectral Image Representation.

Amin Ullah Syed Muhammad Anwar, Muhammad Bilal, and Raja Majid Mehmood (2020)

The electrocardiogram (ECG) is one of the most extensively employed signals used in the diagnosis and prediction of cardiovascular diseases (CVDs). The ECG signals can capture the heart's rhythmic irregularities, commonly known as arrhythmias. A careful study of ECG signals is crucial for diagnosing patients' acute and chronic heart conditions. In this study, we propose a two-dimensional (2-D) convolutional neural network (CNN) model for the classification of ECG signals into eight classes; namely, normal beat, premature ventricular contraction beat, paced beat, right bundle branch block beat, left bundle branch block beat, atrial premature contraction beat, ventricular flutter wave beat, and ventricular escape beat. The one-dimensional ECG time series signals are transformed into 2-D spectrograms through short-time Fourier transform. The 2-D CNN model consisting of four convolutional layers and four pooling layers is designed for extracting robust features from the input spectrograms. Our proposed methodology is evaluated on a publicly available MIT-BIH arrhythmia dataset. We achieved a state-of-the-art average classification accuracy of 99.11%, which is better than those of recently reported results in classifying similar types of arrhythmias. The performance is also significant in other indices, including sensitivity and specificity, which indicates the success of the proposed method.

Jagdeep Rahul Lakhan Devi Sharma (2022)

Atrial fibrillation (Afib) is a heart arrhythmia that is linked to a number of other cardiac-related issues. The incidence of Afib increases with age, causing high risks of stroke. Accurate and reliable detection of Afib remains a challenge and is valuable for clinical diagnosis. This work presents a novel approach for the detection of Afib using both 1-D electrocardiogram signal and its time-frequency representation as an image (2D). The signal was pre-processed utilising a 2-stage median filter and least-square filter followed by normalisation before applying it to artificial intelligence–based models for classification. Bi-directional long short-term memory network was trained and tuned to attain high accuracy. Our proposed method shows favourable performances applying ECG segment as short as 4 s. And it has achieved an accuracy of 98.85% in the 2-D time-frequency representation. Better classification accuracy and use of short-duration ECG signal compared to existing state-of-art methods make this method suitable for an automated, reliable, and timely detection of Afib.

Fatma Murat, Ozal Yildirim, Muhammed Talo, Ulas Baran Baloglu, Yakup Demir, U Rajendra Acharya (2020)

Deep learning models have become a popular mode to classify electrocardiogram (ECG) data. Investigators have used a variety of deep learning techniques for this application. Herein, a detailed examination of deep learning methods for ECG arrhythmia detection is provided. Approaches used by investigators are examined, and their contributions to the field are detailed. For this purpose, journal papers have been surveyed according to the methods used. In addition, various deep learning models and experimental studies are described and discussed. A five-class ECG dataset containing 100,022 beats was then utilized for further analysis of deep learning techniques. The constructed models were examined with this dataset, and results are presented. This study therefore provides information concerning deep learning approaches used for arrhythmia classification, and suggestions for further research in this area.

Kurniawan, I Ketut Eddy Purnama, Mpu Hambyah Syah Bagaskara Aji (2021)

Cardiovascular disease is part of global death's main cause. It is the term for all types of diseases that affect the heart or blood vessels. Heart disease is a type of cardiovascular disease. It can be detected early by examining the arrhythmia presence. Arrhythmia is an abnormal heart rhythm that is commonly diagnosed and evaluated by analyzing electrocardiogram (ECG) signals. In classical techniques, a cardiologist/ clinician used an electrocardiogram (ECG) to monitor the heart rate and rhythm of patients then read the journal activity of patients to diagnose the presence of arrhythmias and to develop appropriate treatment plans. However, The classical techniques take time and effort. The development of arrhythmias diagnosis, toward computational processes, such as arrhythmias detection and classification by using machine learning and deep learning. A convolutional neural network (CNN) is a popular method used to classify arrhythmia. Dataset pre-processing was also considered to achieve the best performance models. MIT-BIH Arrhythmia Database was used as our dataset. Our study used the EfficientN et- V2 which is a type of convolutional neural network to perform the classification of five types of arrhythmias. In pre-processing, the ECG signal was cut each 1 second (360 data), signal augmentation is applied to balance the amount of data in each class, and then the Continues Wavelet Transform (CWT) is employed to transform the ECG signal into a scalogram. The dataset is then distributed into subsets by using modulo operation to get variants of data in each subset. The colormap is applied to convert scalograms into RGB images. By this scheme, our study achieved superior accuracy than the existing method, with an accuracy rate of 99.97%.

Rui Hu, Jie Chen, Li Zhou (2022)

Recently, much effort has been put into solving arrhythmia classification problems with machine learning-based methods. However, inter-heartbeat dependencies have been ignored by many researchers which possess the potential to boost arrhythmia classification performance. To address this problem, this paper proposes a novel transformer-based deep learning neural network, ECG DETR, which performs arrhythmia detection on continuous single-lead ECG segments. The proposed model simultaneously predicts the positions and categories of all the heartbeats within an ECG segment. Therefore, the proposed method is a more compact end-to-end arrhythmia detection algorithm compared with beat-by-beat classification methods as explicit heartbeat segmentation is not required. The performance and generalizability of our proposed scheme are verified on the MIT-BIH arrhythmia database and MIT-BIH atrial fibrillation database. Experiments are carried out on three different arrhythmia detection tasks including 8, 4, and 2 distinct labels respectively using 10-fold cross-validation. According to the results, the suggested method yields comparable performance in contrast with previous works considering both heartbeat segmentation and classification, which achieved an overall accuracy of 99.12%, 99.49%, and 99.23% on the three aforementioned tasks.

Faezeh Nejati Hatamian, Nishant Ravikumar, Sulaiman Vesal(2020)

Cardiovascular diseases are the most common cause of mortality worldwide. Detection of atrial fibrillation (AF) in the asymptomatic stage can help prevent strokes. It also improves clinical decision making through the delivery of suitable treatment such as, anticoagulant therapy, in a timely manner. The clinical significance of such early detection of AF in electrocardiogram (ECG) signals has inspired numerous studies in recent years, of which many aim to solve this task by leveraging machine learning algorithms. ECG datasets containing AF samples, however, usually suffer from severe class imbalance, which if unaccounted for, affects the performance of classification algorithms. Data augmentation is a popular solution to tackle this problem. In this study, we investigate the impact of various data augmentation algorithms, e.g., oversampling, Gaussian Mixture Models (GMMs) and Generative Adversarial Networks (GANs), on solving the class imbalance problem. These algorithms are quantitatively and qualitatively evaluated, compared and discussed in detail. The results show that deep learning-based AF signal classification methods benefit more from data augmentation using GANs and GMMs, than oversampling. Furthermore, the GAN results in circa 3% better AF classification accuracy in average while performing comparably to the GMM in terms of f1-score.

Rashidah Funke Olanrewaju, S. Noorjannah Ibrahim, Ani Liza Asnawi, Hunain Altaf (2021)

According to World Health Organization (WHO) report an estimated 17.9 million lives are being lost each year due to cardiovascular diseases (CVDs) and is the top contributor to the death causes. 80% of the cardiovascular cases include heart attacks and strokes. This work is an effort to accurately predict the common heart diseases such as arrhythmia (ARR) and congestive heart failure (CHF) along with the normal sinus rhythm (NSR) based on the integrated model developed using continuous wavelet transform (CWT) and deep neural networks. The proposed method used in this research analyses the time-frequency features of an electrocardiogram (ECG) signal by first converting the 1D ECG signals to the 2D Scalogram images and subsequently the 2D images are being used as an input to the 2D deep neural network model-AlexNet. The reason behind converting the ECG signals to 2D images is that it is easier to extract deep features from images rather than from the raw data for training purposes in AlexNet. The dataset used for this research was obtained from Massachusetts Institute of Technology-Boston's Beth Israel Hospital (MIT-BIH) arrhythmia database, MIT-BIH normal sinus rhythm database and Beth Israel Deaconess Medical Center (BIDMC) congestive heart failure database. In this work, we have identified the best fit parameters for the AlexNet model that could successfully predict the common heart diseases with an accuracy of 98.7%. This work is also being compared with the recent research done in the field of ECG Classification for detection of heart conditions and proves to be an effective technique for the classification.

Ozal Yildirima, MuhammedTaloa, BetulAybUlas BaranBalogluc, GalipAydinbU, RajendraAcharya (2020)

In this study, a deep-transfer learning approach is proposed for the automated diagnosis of diabetes mellitus (DM), using heart rate (HR) signals obtained from electrocardiogram (ECG) data. Recent progress in deep learning has contributed significantly to improvement in the quality of healthcare. In order for deep learning models to perform well, large datasets are required for training. However, a difficulty in the biomedical field is the lack of clinical data with expert annotation. A recent, commonly implemented technique to train deep learning models using small datasets is to transfer the weighting, developed from a large dataset, to the current model. This deep learning transfer strategy is generally employed for two-dimensional signals. Herein, the weighting of models pre-trained using two-dimensional large image data was applied to one-dimensional HR signals. The one-dimensional HR signals were then converted into frequency spectrum images, which were utilized for application to well-known pre-trained models, specifically: AlexNet, VggNet, ResNet, and DenseNet. The DenseNet pre-trained model yielded the highest classification average accuracy of 97.62%, and sensitivity of 100%, to detect DM subjects via HR signal recordings. In the future, we intend to further test this developed model by utilizing additional data along with cloud-based storage to diagnose DM via heart signal analysis.

Ahmed S.Eltrass, Mazhar B.Tayel, Abeer I.Ammar (2022)

Electrocardiogram (ECG) is an important noninvasive diagnostic method for interpretation and identification of various kinds of heart diseases. In this work, a new Deep Learning (DL) approach is proposed for automated identification of Congestive Heart Failure (CHF) and Arrhythmia (ARR) with high accuracy and low computational requirements. This study introduces, for the first time, a new ECG diagnosis algorithm that combines Convolutional Neural Network (CNN) with the Constant-Q Non-Stationary Gabor Transform (CQ-NSGT). The CQ-NSGT algorithm is investigated to transform the 1-D ECG signal into 2-D time-frequency representation that will be fed to a pre-trained CNN model, called AlexNet. Extracted features with the AlexNet architecture are used as relevant features to be discriminated by a Multi-Layer Perceptron (MLP) technique into three different cases, namely CHF, ARR, and Normal Sinus Rhythm (NSR). The performance of the proposed CNN with CQ-NSGT is compared versus CNN with Continuous Wavelet Transform (CWT), revealing the effectiveness of the CQ-NSGT algorithm. The proposed approach is examined with real ECG records, and the experimental results show the superior performance of the proposed approach over other existing techniques in terms of accuracy 98.82%, sensitivity 98.87%, specificity 99.21%, and precision 99.20%. This demonstrates the effectiveness of the proposed system in enhancing the ECG diagnosis accuracy.

Bazi, Haikel AlHichri, Naif Alajlan, Farid Melgani, Ronald R Yager (2022)

Atrial fibrillation (AF) is the most common heart rhythm disturbance in clinical practice. It often starts with asymptomatic and very short episodes, which are extremely difficult to detect without long-term monitoring of the patient’s electrocardiogram (ECG). Although recent portable and wearable devices may become very useful in this context, they often record ECG signals strongly corrupted with noise and artifacts. This impairs automatized ulterior analyses that could only be conducted reliably through a previous stage of automatic identification of high-quality ECG intervals. So far, a variety of techniques for ECG quality assessment have been proposed, but poor performances have been reported on recordings from patients with AF. This work introduces a novel deep learning-based algorithm to robustly identify high-quality ECG segments within the challenging environment of single-lead recordings alternating sinus rhythm, AF episodes and other rhythms. The method is based on the high learning capability of a convolutional neural network, which has been trained with 2-D images obtained when turning ECG signals into wavelet scalograms. For its validation, almost 100,000 ECG segments from three different databases have been analyzed during 500 learning-testing iterations, thus involving more than 320,000 ECGs analyzed in total. The obtained results have revealed a discriminant ability to detect high-quality and discard low-quality ECG excerpts of about 93%, only misclassifying around 5% of clean AF segments as noisy ones. In addition, the method has also been able to deal with raw ECG recordings, without requiring signal preprocessing or feature extraction as previous stages. Consequently, it is particularly suitable for portable and wearable devices embedding, facilitating early detection of AF as well as other automatized diagnostic facilities by reliably providing high-quality ECG excerpts to further processing stages.

Han Lia, Xinpei Wanga, Changchun Liua, Peng Lib Yu Jiaoa (2021)

Electrocardiogram (ECG) and phonocardiogram (PCG) are both noninvasive and convenient tools that can capture abnormal heart states caused by coronary artery disease (CAD). However, it is very challenging to detect CAD relying on ECG or PCG alone due to low diagnostic sensitivity. Recently, several studies have attempted to combine ECG and PCG signals for diagnosing heart abnormalities, but only conventional manual features have been used. Considering the strong feature extraction capabilities of deep learning, this paper develops a multi-input convolutional neural network (CNN) framework that integrates time, frequency, and time-frequency domain deep features of ECG and PCG for CAD detection. Simultaneously recorded ECG and PCG signals from 195 subjects are used. The proposed framework consists of 1-D and 2-D CNN models and uses signals, spectrum images, and time-frequency images of ECG and PCG as inputs. The framework combining multi-domain deep features of two-modal signals is very effective in classifying non-CAD and CAD subjects, achieving an accuracy, sensitivity, and specificity of 96.51%, 99.37%, and 90.08%, respectively. The comparison with existing studies demonstrates that our method is very competitive in CAD detection. The proposed approach is very promising in assisting the real-world CAD diagnosis, especially under general medical conditions.

Mehmet Akif Ozdemir, Gizem Dilara Ozdemir & Onan Guren (2021)

Two different classification scenarios are conducted on a publicly available paper-based ECG image dataset to reveal the diagnostic capability and performance of the proposed approach. In the first scenario, ECG data labeled as COVID-19 and No-Findings (normal) are classified to evaluate COVID-19 classification ability. According to results, the proposed approach provides encouraging COVID-19 detection performance with an accuracy of 96.20% and F1-Score of 96.30%. In the second scenario, ECG data labeled as Negative (normal, abnormal, and myocardial infarction) and Positive (COVID-19) are classified to evaluate COVID-19 diagnostic ability. The experimental results demonstrated that the proposed approach provides satisfactory COVID-19 prediction performance with an accuracy of 93.00% and F1-Score of 93.20%. Furthermore, different experimental studies are conducted to evaluate the robustness of the proposed approach.

Yong Xiaa, Naren Wulana, Kuanquan Wanga, Henggui Zhangab (2020)

Atrial fibrillation (AF) is the most common cardiac arrhythmia. The incidence of AF increases with age, causing high risks of stroke and increased morbidity and mortality. Efficient and accurate diagnosis of AF based on the ECG is valuable in clinical settings and remains challenging. In this paper, we proposed a novel method with high reliability and accuracy for AF detection via deep learning.The proposed method using deep convolutional neural networks shows high sensitivity, specificity and accuracy, and, therefore, is a valuable tool for AF detection.

Jagdeep Rahula, Marpe Sorab, Lakhan Dev, Sharmac Vijay, KumarBohatd (2021)

Accurate and early detection of cardiac arrhythmia present in an electrocardiogram (ECG) can prevent many premature deaths. Cardiac arrhythmia arises due to the improper conduction of electrical impulses throughout the heart. In this paper, we propose an improved RR interval-based cardiac arrhythmia classification approach. The Discrete Wavelet Transform (DWT) and median filters were used to remove high-frequency noise and baseline wander from the raw ECG. Next, the processed ECG was segmented after the determination of the QRS region. We extracted the primary feature RR interval and other statistical features from the beats to classify the Normal, Premature Ventricular Contraction (PVC), and Premature Atrial Contraction (PAC). The K-Nearest Neighbour (k-NN), Support Vector Machine (SVM), Decision Tree (DT), Naïve Bayes (NB), and Random Forest (RF) classifier were utilised for classification. Overall performance of SVM with Gaussian kernel achieved Se % = 99.28, Sp % = 99.63, +P % = 99.28, and Acc % = 99.51, which is better than the other classifiers used in this method. The obtained results of the proposed method are significantly better and more accurate.

Xiuzhu Yanga, Xinyue Zhanga, Mengyao Yanga Lin Zhangab (2021)

Owing to widely available digital ECG data and recent advances in deep learning techniques, automatic ECG arrhythmia classification based on deep neural network has gained growing attention. However, existing neural networks are mainly validated on single-lead ECG, not involving the correlation and difference between multiple leads, while multiple leads ECG provides more complete description of the cardiac activity in different directions. This paper proposes a 12-lead ECG arrhythmia classification method using a cascaded convolutional neural network (CCNN) and expert features. The one-dimensional (1-D) CNN is firstly designed to extract features from each single-lead signal. Subsequently, considering the temporal correlation and spatial variability between multiple leads, features are cascaded as input to two-dimensional (2-D) densely connected ResNet blocks to classify the arrhythmia. Furthermore, features based on expert knowledge are extracted and a random forest is applied to get a classification probability. Results from both CCNN and expert features are combined using the stacking technique as the final classification result. The method has been validated against the first China ECG Intelligence Challenge, obtaining a final score of 86.5% for classifying 12-lead ECG data with multiple labels into 9 categories.

Kuldeep Singh Chouhan, Jyoti Gajrani, Bhavna Sharma, and Satya Narayan Tazi (2021)

As cardiovascular diseases (CVDs) are a serious concern to modern medical science to diagnose at an early stage, it is vital to build a classification model that can effectively reduce mortality rates by treating millions of people in a timely manner. An electrocardiogram (ECG) is a specialized instrument that measures the heart's physiological responses. To accurately diagnose a patient's acute and chronic heart problems, an in-depth examination of these ECG signals is essential. The proposed model consists of a convolutional neural network having three convolutional, two pooling, and two dense layers. The proposed model is trained and evaluated on the MIT-BIH arrhythmia and PTB diagnostic datasets. The classification accuracy is 99.16%, which is higher than state-of-the-art studies on similar arrhythmias. Recall, precision, and F1 score of the proposed model are 96.53%, 95.15%, and 99.17%, respectively. The proposed model can aid doctors explicitly for the detection and classification of arrhythmias.

Ahmed S. Eltrass, Mazhar B. Tayel & Abeer I. Ammar (2020)

Electrocardiogram (ECG) serves as the gold standard for noninvasive diagnosis of several types of heart disorders. In this study, a novel hybrid approach of deep neural network combined with linear and nonlinear features extracted from ECG and heart rate variability (HRV) is proposed for ECG multi-class classification. The proposed system enhances the ECG diagnosis performance by combining optimized deep learning features with an effective aggregation of ECG features and HRV measures using chaos theory and fragmentation analysis. The constant-Q non-stationary Gabor transform technique is employed to convert the 1-D ECG signal into 2-D image which is sent to a pre-trained convolutional neural network structure, called AlexNet. The pair-wise feature proximity algorithm is employed to select the optimal features from the AlexNet output feature vector to be concatenated with the ECG and HRV measures. The concatenated features are sent to different types of classifiers to distinguish three distinct subjects, namely congestive heart failure, arrhythmia, and normal sinus rhythm (NSR). The results reveal that the linear discriminant analysis classifier has the highest accuracy compared to the other classifiers. The proposed system is investigated with real ECG data taken from well-known databases, and the experimental results show that the proposed diagnosis system outperforms other recent state-of-the-art systems in terms of accuracy 98.75%, specificity 99.00%, sensitivity of 98.18%, and computational time 0.15 s. This demonstrates that the proposed system can be used to assist cardiologists in enhancing the accuracy of ECG diagnosis in real-time clinical setting.

HassanSerhal, NassibAbdallah, Jean-Marie MarionaPierre, Chauveta Mohamad Oueidatb Anne Humeau-Heurtiera (2021)

Atrial fibrillation (AF) is the most common supraventricular cardiac arrhythmia, resulting in high mortality rates among affected patients. AF occurs as episodes coming from irregular excitations of the ventricles that affect the functionality of the heart and can increase the risk of stroke and heart attack. Early and automatic prediction, detection, and classification of AF are important steps for effective treatment. For this reason, it is the subject of intensive research in both medicine and engineering fields. The latter research focuses on three axes: prediction, classification, and detection. Knowing that AF is often asymptomatic and that its episodes are often very short, its automatic early detection is a very complicated but clinically important task to improve AF treatment and reduce the risks for the patients. This article is a review of publications from the past decade, focusing on AF episode prediction, detection, and classification using wavelets and artificial intelligence (AI). Forty-five articles were selected of which five are about AF in general, four articles compare accuracy, recall and precision between Fourier transform (FT) and wavelets transform (WT), and thirty-six are about detection, classification, and prediction of AF with WT: 15 are based on deep learning (DL) and 21 on conventional machine learning (ML). Of the thirty-six studies, thirty were published after 2015, confirming that this particular research area is very important and has great potential for future research.

Parul Madan,Vijay Singh, Devesh Pratap Singh, Manoj Diwakar, Bhaskar Pant (2022)

Arrhythmias are defined as irregularities in the heartbeat rhythm, which may infrequently occur in a human's life. These arrhythmias may cause potentially fatal complications, which may lead to an immediate risk of life. Thus, the detection and classification of arrhythmias is a pertinent issue for cardiac diagnosis. (1) Background: To capture these sporadic events, an electrocardiogram (ECG), a register containing the heart's electrical function, is considered the gold standard. However, since ECG carries a vast amount of information, it becomes very complex and challenging to extract the relevant information from visual analysis. As a result, designing an efficient (automated) system to analyse the enormous quantity of data possessed by ECG is critical. (2) Method: This paper proposes a hybrid deep learning-based approach to automate the detection and classification process. This paper makes two-fold contributions. First, 1D ECG signals are translated into 2D Scalogram images to automate the noise filtering and feature extraction. Then, based on experimental evidence, by combining two learning models, namely 2D convolutional neural network (CNN) and the Long Short-Term Memory (LSTM) network, a hybrid model called 2D-CNN-LSTM is proposed. (3) Result: To evaluate the efficacy of the proposed 2D-CNN-LSTM approach, we conducted a rigorous experimental study using the widely adopted MIT–BIH arrhythmia database. The obtained results show that the proposed approach provides ≈98.7%, 99%, and 99% accuracy for Cardiac Arrhythmias (ARR), Congestive Heart Failure (CHF), and Normal Sinus Rhythm (NSR), respectively. Moreover, it provides an average sensitivity of the proposed model of 98.33% and a specificity value of 98.35%, for all three arrhythmias. (4) Conclusions: For the classification of arrhythmias, a robust approach has been introduced where 2D scalogram images of ECG signals are trained over the CNN-LSTM model. The results obtained are better as compared to the other existing techniques and will greatly reduce the amount of intervention required by doctors. For future work, the proposed method can be applied over some live ECG signals and Bi-LSTM can be applied instead of LSTM.

Mahwish Naz, Jamal Hussain Shah, Muhammad Attique Khan, Muhammad Sharif, Mudassar Raza1, Robertas Damaševičius (2021)

Provocative heart disease is related to ventricular arrhythmias (VA). Ventricular tachyarrhythmia is an irregular and fast heart rhythm that emerges from inappropriate electrical impulses in the ventricles of the heart. Different types of arrhythmias are associated with different patterns, which can be identified. An electrocardiogram (ECG) is the major analytical tool used to interpret and record ECG signals. ECG signals are nonlinear and difficult to interpret and analyze. We propose a new deep learning approach for the detection of VA. Initially, the ECG signals are transformed into images that have not been done before. Later, these images are normalized and utilized to train the AlexNet, VGG-16 and Inception-v3 deep learning models. Transfer learning is performed to train a model and extract the deep features from different output layers. After that, the features are fused by a concatenation approach, and the best features are selected using a heuristic entropy calculation approach. Finally, supervised learning classifiers are utilized for final feature classification. The results are evaluated on the MIT-BIH dataset and achieved an accuracy of 97.6% (using Cubic Support Vector Machine as a final stage classifier).