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Design and Implementation of Low Power Stochastic Computing for Atrial Fibrillation Data Analysis

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Abstract-The use of artificial neural networks featuring biological guidance, like the Restricted Boltzmann Machine (RBM), has generated a lot of attention because of its superior estimation capabilities for challenging tasks. They are useful for many applications, especially machine learning techniques. A powerful DNN design based on integral stochastic computation is provided in the current system. Quasi-synchronous execution of the suggested architecture results in a 33% decrease in the use of energy. The suggested method provides a block processing unit that utilizes energy-efficient stochastic computing. The data frame is handled block by block. These results are further examined using the correlation and decorrelation functions. The proposal is to classify atrial fibrillation data as normal or pathological. A formula for the Matthew's correlation constant (MCC) is developed.
Keywords: Artificial Intelligence, Wireless Communication, Underground Sensor Network, Disaster Management, Internet of Things.

1. Introduction

A wearable device for the diagnosis and tracking of atrial fibrillation (AFib) has emerged as an exciting advancement in the field of medicine. The use of wearable devices, such as fitness bands and smartwatches, that can measure heart rate allows for constant, instantaneous monitoring of a user's heart rate over time. AFib, which is distinguished by abnormal and sometimes accelerated heart rate, may appear difficult to identify, thus these tools tend to be critical for prompt identification and management. Wearable devices can detect anomalies in heart rate variations and offer users with immediate notifications by utilising advanced algorithms and sensors. This allows for prepared healthcare administration. With the ease of constant tracking, people may monitor their cardiovascular condition every day, which lowers the risk of consequences from undiagnosed AFib and facilitates prompt treatment. Wearable technology that detects AFib has the potential to improve the tracking of one's own health as well as improve our knowledge of cardiac health. Additionally, it improves cardiovascular treatment in general by providing essential information for larger-scale clinical studies. To fully realise their abilities in the efficient identification and treatment of atrial fibrillation, wearable devices have to tackle issues including precision, inaccurate results, and acceptance by users.

The prevalent heart rate condition known as atrial fibrillation (AFib) has been defined by unpredictable and frequently fast heart rates. Health trackers and smartwatches are examples of wearable technology that is becoming more and more popular tool for tracking various health metrics, including heart rate. The following are some ways that wearable technology can help identify and treat atrial fibrillation:

Heart Rate Monitoring

The user's heart rate is constantly tracked by means of wearable technology that contains pulse rate sensors.

An irregular heart rate is frequently linked to AFib, and wearable technology can notify users when their heart rate varies significantly from usual.

ECG/EKG Monitoring

Advanced wearables can have sensors for an electrocardiogram (ECG or EKG) integrated into them. For a more thorough examination of the electrical function of the heart, users can record their ECG immediately. Healthcare providers can access the information that is produced to follow up and treatment.

Pulse Wave Analysis

Pulse wave monitoring is a technique used by some wearables to identify blood circulation deviations that might be signs of AFib.

This method detects abnormal cardiac rhythms by examining the minute changes in the pulse wave.

Real-time Notifications

When an abnormal heartbeat, such as AFib, is recognised, wearables may alert users in real time.

Users may be advised by these messages to see a doctor or seek other medical attention.

Long-Term Monitoring

The benefit of wearables is constant, long-term tracking, which gives a more complete picture of the condition of the heart.

Finding variations and trends throughout time can be helpful in determining when an irregular episode of AFib occurs.

Integration with Health Apps

Users can track and examine their cardiovascular data as time goes on through connecting wearable devices with smartphone health apps.

Sharing information with medical experts during consultations is made easier by this link.

Research and Population Health

Research investigations and community health programmes can benefit from the utilisation of consolidated and categorised information from wearable devices. This helps to obtain a better understanding of the frequency and trends of AFib.

User Education and Engagement: Wearables have the potential to help inform users regarding AFib, its signs, and the purpose of consulting a physician.

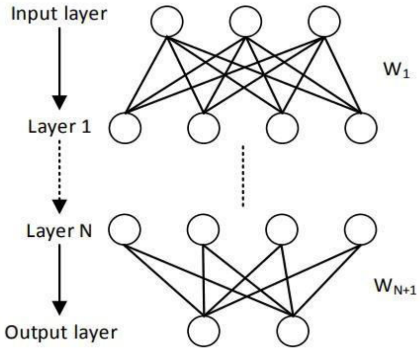

Figure 1. DNN Architecture

The remaining sections of the publications are organised as follows: the second section analyses concepts and current papers; the third section addresses system design vital issues; and the fourth section examines the procedure, execution method, and assessment of different indicators. The last part discusses the outcomes of the suggested layout as well as its difficulties, DNN Architecture shown in fig. 1.

2. Background Study

C. Chen et al., (2020) The architecture optimises the duties associated with the local execution of AF recognition. This is done by utilising the varied characteristics of the Zynq system-on-chip (SoC). In order to produce meaningful features for AF identification, the embedded micro controller is used in the multi-domain feature acquisition procedure. This consists of entropy and RR interval elements. The SoC's programmable logic then performs an AF classifier that uses an artificial neural network (ANN) method for acceleration. The practical electrocardiogram (ECG) information from the CPSC 2018 dataset and the MIT-BIH dataset are used to confirm the suggested system. Testing on these two databases yielded experimental findings with reliability levels of 93.60% and 97.78%, correspondingly. The embedded approach's AF detection efficiency is nearly comparable to the performance of the PC-based approach. This suggests a strong hardware execution of AF identification.

S. Ross-Howe et al. (2019) By using the short-time Fourier transform, important temporal and frequency domain features of the ECG signal are recovered in this study. Further, the data is then graphically displayed in a spectrogram. Deep characteristics found in the spectrograms created from ECG segments were used to examine two distinct categorization strategies. In the first method, features were taken out by a previously trained DenseNet model and subsequently identified using Support Vector Machines. In the second method, spectrograms were directly fed into a convolutional network. When compared to established automated atrial fibrillation detection methods, the convolutional network approach achieved a 93.16% rate of classification on the MITBIH AFIB dataset. These results appear encouraging and call for more research because they weren't dependent on any kind of noise pre-filtering, distinctive features, or dependability on beat monitoring.

R. Sanghavi et al. (2021) One form of cardiac anomaly that is frequently referred to as an arrhythmia is atrial fibrillation. When the heart beats irregularly, or at erroneous intervals, it is identified. Scientists and technology professionals have been working on the issue of automatic atrial fibrillation (AFib) diagnosis for several decades now. Among the arrhythmias, it is particularly prevalent. A lot of individuals are prone to developing AFib. The Centres for Disease Control and Prevention (CDC) estimate that 2% of adults under 65 and 9% of adults with 65 and over suffer with atrial fibrillation (AFIb). For those suffering from this condition, a gadget that can distinguish between sinus rhythm and AFib will provide an immense relief.

L. Zhu et al.,(2022) For each 5-minute PPG section examined, this approach demonstrated an accuracy of 87.8% and a resolution of 97.4%. In order to extend the period of coverage and check for AF even during times that contain noise along with additional distortions that would be experienced in everyday circumstances, we also incorporate unique algorithm blocks as well as system architectures. A proper decision was made by 67.8% of the patients who wore the smartwatch for the full duration. At last, we demonstrate our algorithm's capacity to work over the day and calculate the AF load, an innovative measure employing a wearable sensor, presenting a 98% correlation to the real-world data and having a typical error of 6.2%.

3. System Design

Based on integral stochastic computing, a novel and effective Deep Neural Network (DNN) architecture has been introduced in the present system. The technique combines integral processing to improve the accuracy of neural network functions while employing the built-in benefits of stochastic computing. This uses random bit streams to execute computations. The effective execution of the suggested design attests to its efficacy in generating notable decreases in energy use.

The structure includes a quasi-synchronous execution, which is an important part of the concept. A synchronisation strategy that balances synchronous and asynchronous systems is used in quasi-synchronous operation to maximise the relationship between energy effectiveness and performance. With this quasi-synchronous deployment, the DNN shows an impressive 33% energy savings over conventional techniques. Hence, it suggests significant progress towards powerefficient computation.

This strategy has potential for use in edge computing, Internet of Things devices, and various other energyconstrained settings where energy usage management is essential. Incorporating integral stochastic computing improves the neural network's durability and tolerance for error. This in turn increases its ability to endure in actual-life circumstances while also conserving energy. This suggested design, with potential for an extensive variety of technical uses, thus offers an impressive step towards better and longerlasting deep learning system deployments.

4. Methodology

A.System Design

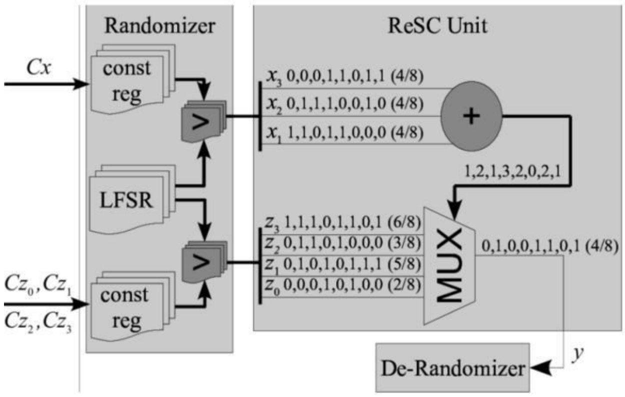

Figure 2. Proposed Stochaatic Computing Unit

Fig 2.Shows the proposed stochastic computing unit Afib analysis.

The novel method involves analysing information frames block-wise using a minimal power consumption block processing device based on stochastic computing. This approach provides a major improvement in the speed of processing, especially when considering applications like the identification of atrial fibrillation (AFib). Stochastic computing is used to improve the block unit's multitasking abilities while simultaneously promoting minimal power consumption function.

The correlation and decorrelation functions are applied to the frame-wise data that the block unit is analysing. When examining the connections and patterns in the data, these tasks are essential. In particular, the correlation and decorrelation functions are used to discriminate among healthy and sick heart rates in the setting of atrial fibrillation data. This makes it possible to classify the data in a way that is more reliable and intricate. Thus, it makes them easier to find possible cases of AFib.

The suggested classification system's effectiveness is measured by the calculation of the Mathew's correlation constant (MCC). A popular metric for evaluating the accuracy of a model in binary classification issues is the MCC, which takes into consideration for true positive, true negative, false positive, and false negative estimates. Accurately measuring sensitivity as well as specificity, the MCC formulation offers a thorough assessment of the classification efficiency. A strong and dependable categorization algorithm is indicated by a high MCC score. This is especially significant for healthcare purposes where reliability is crucial, such as the identification of AFib.

5. Results and Discussions

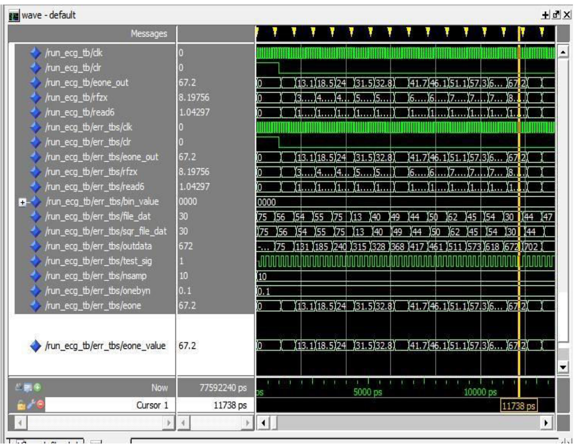

Figure 3.Detection of Abnormality in Wearable Devices

Fig 3. Shows the detection of abnormality in wearable devices through Stochastic computing technique

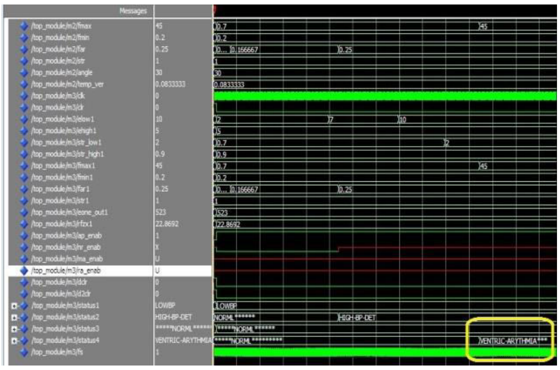

Figure 4. Cardiac Abnormality Detection

Fig 4. Shows the cardiac abnormality named ventricular arrhythmia is detected through proposed stochastic computing technique.

6. Conclusion

The use of artificial neural networks featuring biological guidance, like the Restricted Boltzmann Machine (RBM), has generated a lot of attention because of its superior estimation capabilities for challenging tasks. They are useful for many applications, especially machine learning techniques. A powerful DNN design based on integral stochastic computation is provided in the current system. Quasi-synchronous execution of the suggested architecture results in a 33% decrease in the use of energy. The suggested method provides a block processing unit that utilises energy-efficient stochastic computing. The data frame is handled block by block. These results are further examined using the correlation and decorrelation functions. The proposal is to classify atrial fibrillation data as normal or pathological. A formula for the Matthew's correlation constant (MCC) is developed.

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