# SEVERITY BASED HIERARCHIAL ECG CLASSIFICATION USING NEURAL NETWORKS

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## Abstract

Timely detection of cardiac arrhythmia characterized by abnormal heartbeats can help in the early diagnosis and treatment of cardiovascular diseases. Wearable healthcare devices typically use neural networks to provide the most convenient way of continuously monitoring heart activity for arrhythmia detection. However, it is challenging to achieve high accuracy and energy efficiency in these smart wearable healthcare devices. In this work, we provide architecture-level solutions to deploy neural networks for cardiac arrhythmia classification. We have created a hierarchical structure after analyzing various neural network topologies where only required network components are activated to improve energy efficiency while maintaining high accuracy. In our proposed architecture, we introduce a severity-based classification approach to directly help the users of the wearable healthcare device as well as the medical professionals. The principle motivation for this project is to develop a method of monitoring heart activity for patients with heart disease, pacemakers, and other special heart conditions so the patient can lead a relatively active life without being confined to a specific region. By being able to monitor sickly patients remotely, peace of mind can be offered to extended family knowing that emergency services can be dispatched in the event of cardiac arrest, or severe irregular heart patterns.

## 1. INTRODUCTION

The heart plays an important role in human survival and any heart-related disorders, commonly known as cardiovascular diseases (CVDs), can present a significant danger to human life. CVDs are reported to be one of the leading causes of death worldwide [1] and are estimated to cause up to 23 million deaths by 2030 [2]. Diagnosis of CVDs at an early stage can facilitate timely medical treatment and greatly reduce CVD-related health risks. Such early diagnosis can be achieved by detecting the abnormal activity of the heart known as arrhythmia. There exist several types of arrhythmias based on the manner in which the heart activity deviates from its normal behavior. Timely detection of various types of arrhythmias requires monitoring of the activity of the heart. Wearable healthcare devices provide the most convenient way of achieving such monitoring. These devices are equipped with sensors that can record the heart activity in the form of electrocardiogram (ECG) signal. The task of identifying various types of arrhythmias is then expressed as the classification of heartbeats in the recorded ECG signal into different arrhythmia types (classes). As neural networks are inherently best suited for such classification tasks, these devices use neural networks as ECG classifiers to automatically identify various types of arrhythmias. The neural network-based ECG classifier in a wearable healthcare device should have high classification accuracy

to detect various arrhythmia types correctly. Moreover, it has to be energy-efficient as wearable healthcare devices are battery-powered and thereby have limited energy resources. Its classification outputs should also indicate the severity impact of detected arrhythmia classes which can help the users in knowing how urgently they need to seek medical attention, which can potentially prove to be life-saving. However, state-of-the-art neural network-based ECG classifiers fail to meet these requirements. Many works have adopted neural networks with a large number of layers to obtain high accuracy [3], [4], [5]. This results in high energy consumption as such big neural networks require a lot of hardware resources. Most of the existing works just focus on developing ECG classification models without taking into account the implications on hardware performance metrics such as energy [6], [7], [8], [9], [10], [11], [12], [13], [14]. Moreover, none of them take the severity impact into account. Hence, there is a strong need for ECG classification hardware that can deliver high accuracy and energy efficiency while also considering severity impact. In this paper, we address the challenge of designing a severity-based, accurate, and energy-efficient ECG classifier. We first create a classification architecture that consists of multiple small sub-classifiers connected in a hierarchical manner instead of a single large and complex classifier. Each sub-classifier deals with only a subset of arrhythmia classes which leads to good accuracy. This hierarchical design also allows us to activate various sub-classifiers only when needed, thereby saving energy. The proposed architecture uses a novel severity-based activation structure for sub-classifiers. The top levels of the hierarchy indicate how quickly the user should seek medical attention. The bottom hierarchical levels help the doctors in diagnosis (the process of finding the physiological root cause of arrhythmia) and then prescribing treatment (medicines, medical procedures, etc.) for arrhythmia based on the diagnosis.

## 1.2 Scope of the Project:

The scope of the project involves the development of a method for continuous monitoring of heart activity in patients with cardiovascular diseases (CVDs) and special heart conditions, using wearable healthcare devices equipped with sensors to record electrocardiogram (ECG) signals. The primary focus is on achieving timely detection and classification of various types of arrhythmias, facilitating early diagnosis and treatment of CVDs. The project aims to design and implement a severity-inclusive, accurate, and energy-efficient ECG classification system, utilizing hierarchical hardware architecture. Key tasks include algorithm development, hardware design,

integration with wearable devices, and performance evaluation in terms of accuracy, energy efficiency, and severity detection capabilities.

## 2. LITERATURE SURVEY

There are many works that achieve high accuracy (around 98-99%) by leveraging various complex neural network topologies such as LSTMs [8], BLSTMs [7], [10], CNNs [4], [9], [12] and hybrid networks which combine LSTMs with CNNs [11], [19]. However, they just focus on software model development without any consideration of hardware resource requirements. Hence, they end up with networks that provide high accuracy at the expense of large energy consumption. This is not desirable for personalized healthcare devices which are battery-powered as frequent charging due to fast draining of the battery makes continuous health monitoring impractical and cumbersome. Hence, there is a need for energy-efficient ECG classification where such energy efficiency is achieved while still maintaining high accuracy. Works like [6], [13] leverage spiking neural networks to provide energy efficiency but suffer from low accuracy. Alternatively, RRAM-based hardware for ECG classification using non-spiking neural network in [14] can be leveraged for energy efficiency. However, it does not even consider the full AAMI classes (just considers a subset and ignores many types of possible input heartbeats) and still suffers from low accuracy. This is because it performs ECG classification in a naive manner without any innovation at the architecture or neural network level. The network architecture in [5] allows some parts of the network to be deactivated when not needed. However, as it uses AAMI classes which have intermixing of arrhythmia types with different severity impacts, it cannot take advantage of the fact that more severe arrhythmia types occur rarely and its network parts cannot be deactivated for a significant amount of time, which makes the energy savings very small. Moreover, as the architecture in [5] internally uses large neural network components, its energy efficiency is reduced. The most energy-efficient ECG classification among state-of-the-art works is provided by [3] which exploits the characteristics of ECG data to achieve a high degree of computation reuse. However, as it also uses AAMI classes having intermixing of arrhythmia types with different severity impacts, it misses out on a potentially huge improvement in energy efficiency that can be achieved via severity-based classification. In this paper, we develop a highly energy-efficient ECG classification architecture by leveraging the difference in severity impact of arrhythmia classes, while still

maintaining high accuracy.

## 3. OVERVIEW OF THE SYSTEM

### 3.1 Existing System

Earlier, a 1-D CNN was used to read ECG signals for end-to-end diagnosis of arrhythmia. Therefore, Deep Neural Networks (DNN) can classify different arrhythmias into a single class. The neural networks are computationally intensive and consume remarkable memory, making it challenging to deploy deep neural networks on resource-constrained devices. But in earlier systems, the accuracy wasn't up to the mark. There was a classification architecture that consists of a single large and complex classifier. The energy efficiency wasn't also very good as the problem of deploying the architecture in a resource-constrained device (for instance, a wristband). Use of a single classifier isn't very appreciable these days because of the increasing variations of arrhythmia and many other factors to consider. So, to be on a safe side, attempts to include an architecture which consists of multiple classifiers to increase the quality of the results and accuracy have been made, but none of them was successful in doing so.

### 3.1.1 Disadvantages of Existing System
*Suboptimal Accuracy*: The existing 1-D CNN-based classification model may not achieve high accuracy in detecting arrhythmias, potentially leading to misdiagnosis or missed detections.

*Limited Energy Efficiency:* The existing system may consume significant energy due to the use of large neural networks with high computational requirements, which can drain battery power quickly in wearable devices.

*Lack of Severity Impact Consideration*: The existing systems often overlook the importance of indicating the severity impact of detected arrhythmias, potentially delaying or missing critical medical interventions.

*Single Classifier Architecture:* Existing systems typically employ a single large and complex classifier, which may not be efficient in handling the diverse range of arrhythmias and variations in heart conditions.

### 3.2 Proposed System

The neural network-based ECG classifier in a wearable healthcare device should have high classification accuracy to detect various arrhythmia types correctly. Moreover, it has to be energy-efficient as wearable healthcare devices are battery-powered and thereby have limited energy resources. Its classification outputs should also indicate the severity impact of detected arrhythmia classes which can help the users in knowing how urgently they need to seek medical attention, which can potentially prove to be life-saving. However, state-of-the-art neural network-based ECG classifiers fail to meet these requirements. Many works have adopted neural networks with a large number of layers to obtain high accuracy. This results in high energy consumption as such big neural networks require a lot of hardware resources. Most of the existing works just focus on developing ECG classification models without taking into account the implications on hardware performance metrics such as energy. Moreover, none of them take the severity impact into account. Hence, there is a strong need for ECG classification hardware that can deliver high accuracy and energy efficiency while also considering severity impact. We proposed a 2-D CNN-based classification model for automatic classification of cardiac arrhythmias using ECG signals. We plan to use two classifiers- Convolutional Neural Network (CNN) and Support vector machines (SVMs) and give out the best possible outputs which deliver high accuracy results and also indicate the severity of the situation, and most importantly creating an energy-efficient architecture with two best classifiers – CNN and SVM.

### 3.2.1 Advantages of Proposed System
*Improved Classification Accuracy:* The proposed 2-D CNN-based classification model offers higher accuracy in detecting various types of arrhythmias compared to the existing 1-D CNN approach.

*Energy Efficiency:* The proposed system aims to be more energy-efficient, crucial for wearable healthcare devices with limited battery power, by optimizing hardware resources and reducing computational complexity.

*Severity Impact Consideration:* Unlike existing systems, the proposed system takes into account the severity impact of detected arrhythmia classes, providing users with valuable information on the urgency of seeking medical attention.

*Hierarchical Architecture:* The proposed system utilizes a hierarchical architecture consisting of multiple classifiers, which can enhance the quality of results and accuracy, especially in dealing with increasing variations of arrhythmias.

### 3.3 Proposed System Design
In this project work, there are three modules and each module has specific functions, they are:

1. System

2. Classifier

3. User

### 3.3.1 System

This module acts as a bridge between user and classifier modules. It performs loading of dataset and then does the preprocessing of the data. It requires training and testing data in order to train the classifier. This module also provides higher security by authenticating the user credentials. It then generates results according to the classification and suggests the necessary medication or action to be taken.

### 3.3.2 Classifier

This model is solely dedicated to the classifiers. The classifiers are pre-equipped with arrhythmia data and severity levels. It takes the ECG data provided by the user and classifies the arrhythmia into severity levels. Classifiers then generate results providing accuracy and visual representation in the form of graphs.

### 3.3.3 User

Users register themselves with valid credentials and can add their present or past health condition. The users upload their ECG data and then after classification can view the reports and take necessary actions. Users can also view information about the website, contact for support.
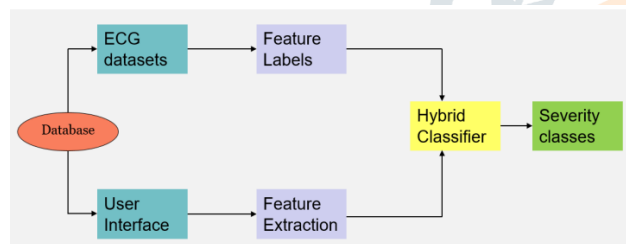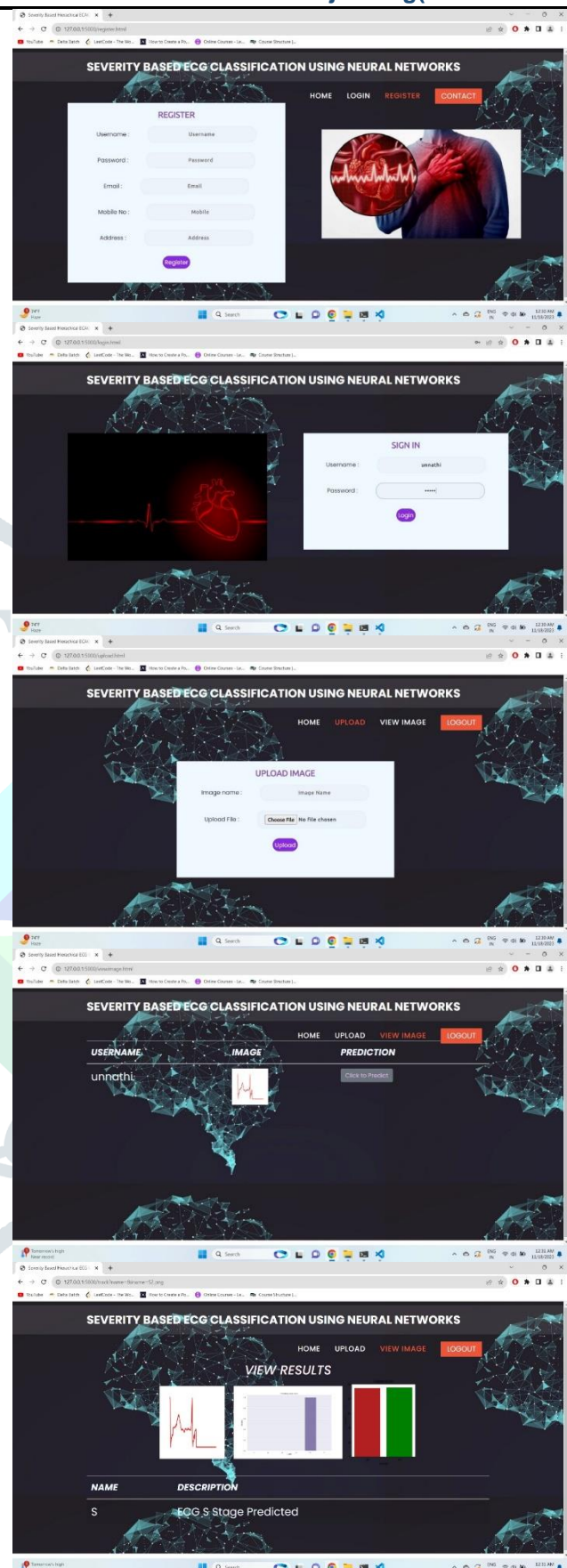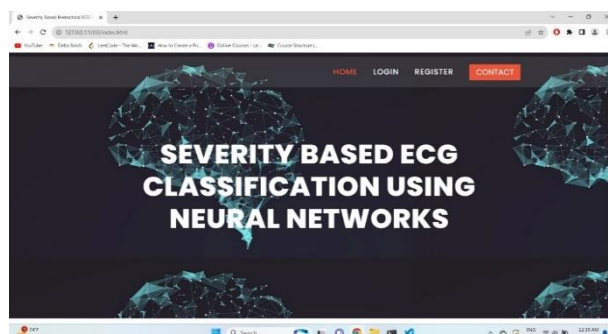
### 3.4 Architecture



Fig 1: System Architecture

## 4. RESULT SCREEN SHOTS



## 5. CONCLUSION

"Severity-based Hierarchical ECG Classification Using Neural Networks" represents a significant advancement in the field of medical diagnostics and cardiovascular health. Through the utilization of cutting-edge neural network

technologies, this research has successfully demonstrated the potential to revolutionize the way we categorize and assess the severity of cardiac arrhythmias and abnormalities in electrocardiogram (ECG) data. The hierarchical approach employed in this project not only enhances the accuracy of ECG classification but also provides a deeper understanding of cardiac conditions. The integration of severity-based classification further contributes to the clinical relevance of the system, allowing for more timely and effective patient care. The implications of this research are far-reaching, as it holds the promise of improving patient outcomes, reducing healthcare costs, and enhancing the overall quality of cardiovascular care. As the field of machine learning and healthcare continue to evolve, this project serves as a remarkable example of the potential for artificial intelligence to make a meaningful impact on medical practice.

In the future, we will further develop and validate the severity-based hierarchical ECG classification to improve user easiness. Additionally, we will be collaborating with medical professionals and institutions which will be crucial to ensure its successful deployment. With continued dedication to refining and expanding this innovative approach, the project's outcomes have the potential to positively impact countless lives, making it a significant milestone in the ongoing quest to enhance healthcare through technology.

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