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Automated detection of arrhythmias using different intervals of tachycardia ECG segments with convolutional neural network

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ABSTRACT

Our cardiovascular system weakens and is more prone to arrhythmia as we age. An arrhythmia is an abnormal heartbeat rhythm which can be life-threatening. Atrial fibrillation (A_{fib}), atrial flutter (A_{fl}), and ventricular fibrillation (V_{fib}) are the recurring life-threatening arrhythmias that affect the elderly population. An electrocardiogram (ECG) is the principal diagnostic tool employed to record and interpret ECG signals. These signals contain information about the different types of arrhythmias. However, due to the complexity and non-linearity of ECG signals, it is difficult to manually analyze these signals. Moreover, the interpretation of ECG signals is subjective and might vary between the experts. Hence, a computer-aided diagnosis (CAD) system is proposed. The CAD system will ensure that the assessment of ECG signals is objective and accurate. In this work, we present a convolutional neural network (CNN) technique to automatically detect the different ECG segments. Our algorithm consists of an eleven-layer deep CNN with the output layer of four neurons, each representing the normal (N_{sr}), A_{fib}, A_{fl}, and V_{fib} ECG class. In this work, we have used ECG signals of two seconds and five seconds' durations without QRS detection. We achieved an accuracy, sensitivity, and specificity of 92.50%, 98.09%, and 93.13% respectively for two seconds of ECG segments. We obtained an accuracy of 94.90%, the sensitivity of 99.13%, and specificity of 81.44% for five seconds of ECG duration. This proposed algorithm can serve as an adjunct tool to assist clinicians in confirming their diagnosis.

1. Introduction

According to the report by the United Nations in 2015, the world is facing an aging population [33]. It is estimated that the number of people aged 60 years and above will grow by 56.00% from 901 million to 1.4 billion by 2030. Furthermore, the growing population (60 years and older) is expected to be double by 2050, rising to nearly 2.1 billion [33]. The increase in elderly population poses economic [3,33] and health care issues [28,33] to the world. Our cardiovascular system grows weaker and becomes more receptive to diseases as we grow older [29]. Moreover, the arteries stiffen and muscle wall of the

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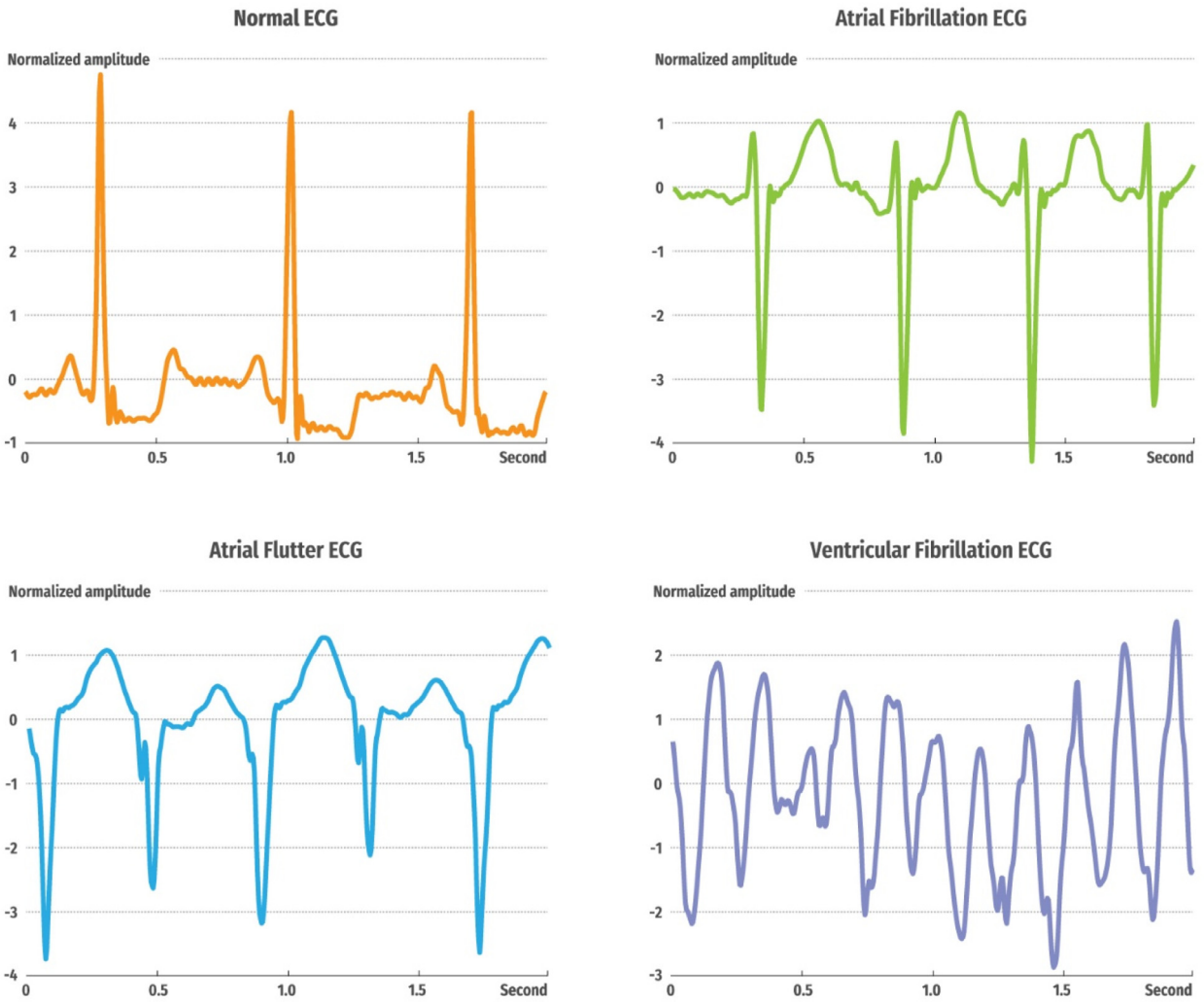

Fig. 1. An illustration of ECG segments for net A.

left ventricle thickens with aging, resulting in a decrease in the compliance of blood vessels of the arteries [6]. Consequently, it affects the overall function of the heart which leads to arrhythmia. Hence, arrhythmia is one of the health conditions that the elderly subjects encounter in the society [4,6]. Arrhythmia is defined as the abnormal rhythm of the heartbeat which can be harmless or critical. The atrial fibrillation (A_{fib}), atrial flutter (A_{fl}), and ventricular fibrillation (V_{fib}) are the recurrent types of arrhythmias reported in the elderly [6].

The A_{fib} is a commonly occurring arrhythmia caused due to various health complications. During A_{fib}, the contraction of the atria is asynchronous due to the fast firing of electrical impulses from several parts of cardiac re-entry [2]. Re-entry occurs when an impulse fails to die out after normal activation of the heart and continues to re-excite the heart. In fact, the electrocardiogram (ECG) rhythm of A_{fib} is fast and beating at a rate of 150 to 220 beats in a minute. It has an abnormal R-R interval, irregular and fast ventricular contraction, and P wave is absent in the ECG signal [29]. In A_{fl}, the atrial contracts rapidly between 240 and 360 beats per minute and have a replicating saw-tooth waveform, known as flutter wave. A_{fl} occurs when the atria undergo chaotic electrical signals [2]. V_{fib} is usually caused by rapid heartbeat known as ventricular tachycardia (VT). This abnormal heartbeat is due to abnormal electrical impulses in the ventricles. During this, ventricles contract chaotically and haphazardly. It can be seen in the ECG morphology, which records an unrefined and erratic fluctuation of ECG signal with the absence of QRS complex wave [29]. Typical plots of N_{sr}, A_{fib}, A_{fl}, and V_{fib} ECG signals are shown in Figs. 1 and 2.

Therefore, the morphology of ECG signals contains vital details about the conditions of the heart. Thus, the ECG signal is beneficial in the detection and diagnosis of cardiac health [2]. However, ECG signals are highly nonlinear and any changes in the ECG signals is difficult to observe as its amplitude is in millivolts [2,13]. Further, the indications of cardiac abnormalities are faithfully indicated in the ECG signals during 24-hour Holter recording. Thus, manual interpretation of the ECG signals