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FPGA Implementation of a CNN Application for ECG Class Detection

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ABSTRACT

Convolutional Neural Networks (CNN) show huge necessity in medical area diagnosis, CNN can be used for ECG features extraction, heartbeats classification and abnormal beats detection, helping clinicians to get the true diagnosis of cardiovascular diseases at early stage. In this context, an optimized CNN is proposed to be implemented on Pynq-Z2 board for Electrocardiography (ECG) signal class detection. As first step, a CNN has been implemented on the processor ARM Cortex A9 of Pynq Z2. Implementation results show the efficiency of our purpose, achieving accuracies results of 98.86%, 98.61% and 98.39% for the training, validation and test process respectively. Then to improve the inference results a Hardware/Software Codesign has been proposed due to the parallel architecture of FPGA, time process acceleration has reached 10 times compared to the implementation on the Processor. Moreover, a gain of the surface has been achieved by using low number of resources. Thus, a real time application has been reached with a very excellent class accuracy detection going to 99.45% for the training, 99.12% for the validation and 99.03% for the testing processes, when tested on MIT-BIH ECG signals in a short time process with 0.0018s/signal through the test process and 0.005s/ signal during the training.

1. INTRODUCTION

Nowadays, medical image and signal processing applications are preferred due to the importance of human health alongside technological developments in deep learning or (DL), which currently represents the key solution for related medical applications to an automatic diagnosis. In this context, a major interest is given to convolutional neural networks (CNN) for the automatic detection of different heart diseases from real-time ECG signals. Where, the electrocardiogram (ECG) has become a useful tool for the diagnosis of cardiovascular diseases as it is fast and noninvasive. The most important criteria for the applications used in these fields is to guarantee that the system operates at high speed and in real time. Thus, FPGAs are commonly used in such applications. In this work, a CNN algorithm for class detection of ECG signals is implemented in real time on the Pynq Z2 based FPGA board. The detected signals are implemented on Pynq FPGA It has been widely used for research and machine learning prototyping for medical applications. In this context, a medical application is developed based CNN architecture for the detection of ECG signals in real time on Pynq Z2 FPGA.

The implementation of CNN application on Pynq Z2 is done to more accelerate time processing, due to the parallel FPGA architecture, which speed up the mathematical operations and enhance precision results, thanks to the creation of a new additionner multiplier IP.

1.1 Contributions

The contribution in this paper is illustrated as follows: First, a design of a new IP has been made, which plays a huge role to accelerate time execution of the proposed CNN algorithm. Then a deep CNN architecture has been proposed consisting of convolutional layers, where more we are going deeper through layers, more we get excellent precision and detection results. Finally, our proposed codesign architecture present a medical real time application that can be needed in hospitals; helping clinicians to get the true diagnostic in a short time process. Thus, the importance of an embedded medical system.

2. STATE OF THE ART

Deep Learning neural networks models such as Convolutional neural networks CNN and Reccurent Neural Network RNN have shown a huge development [1, 2]. The CNN has shown an interesting role [3] in various area such medical and internet of Things axes [4, 5]. Moreover, it has shown excellent classification precision, in cardiovascular diseases detection such atrial fibrillation [6] and myocardial infarction [7]. Moreover, it shows excellent role in heartbeats