International Journal of Science and Research (IJSR)
ISSN (Online): 2319-7064
Index Copernicus Value (2016): 79.57 | Impact Factor (2017): 7.296

A Review of Recent Advancements in Implementation of FPGA in Magnetic Resonance Imaging (MRI) Technology

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Abstract: ***This paper speculates the recent advancements of FPGA technology in Biomedical Imaging. As per convenient customizable design feature and flawless embedded coding made FPGA an gateway of very wide range of applications. FPGA has specific application on digital signal processing, bioinformatics, ASIC prototyping, medical imaging, voice recognition, filtering and communication encoding, computer hardware emulation etc. Implantation of FPGA in the brain MRI classification is one of the important application which helps the medical industry to diagnose abnormality or tumor in much better way. It offers custom computation so that we can implement new algorithms on the existing hardware and it will be as fast as previous.***

Keywords: FPGA, MRI, Biomedical Imaging, Medical Imaging

1. Introduction

A Field Programmable Gate Array(FPGA) is an application specific integrated circuit(ASIC) which can be configured by the customer or the designer for a specific purpose, that's why it is called " field programmable". Hardware Description Language(HDL) is generally used for the configuration of FPGA. It's consist of array of logic blocks which can be programmed on your own necessity and these logic blocks are interconnected by wire in a hierarchical way which can also be reconfigured. In most of the FPGAs logic blocks contain memory unit like Flip-Flops or a complete memory block. By using the logic blocks we can construct a complex combinational circuit or simply AND or XOR gate.

2. FPGA in Recent Technology Trends:

The neuro-processor that appears in this article of FPGA Implementation of a synchronous and self-timed neuro-processor by Panduro J.J. et all,2005,IEEE ,is implemented in a FPGA virtex II .Here the circuit is divided into two main modules, one is Neuronal module SOM with self- timed execution, and another is b) Control module for executing operations. In the paper of 3D Brain MRI tissue Classification on FPGAs by koo et all,2009,IEEE, the SGI RASC RC100 FPGA accelerator is used. The RC100 system is connected to the Altix 350 multiprocessor system via a NUMA-link interconnect. The Altix 350 has eight 1.5-GHz Intel Itanium 2 CPUs with 16 GB of shared memory. A single RASC RC100 system is composed of two Xilinx Virtex-4 LX200 FPGAs, two TIO interface ASICs and a bitstream loader FPGA. From the previous two papers it is seen that in between five years a vast modification in technology have been take place and uses of FPGA is increased vastly in biomedical industry.

3. Biomedical Instruments using FPGA

One of the growing market of FPGA technology is the biomedical industry where we can a see a steady increase in development over the years specially in bioinformatics. In biomedical field one most important application is in brain MRI classification. Magnetic Resonance Imaging(MRI) gives us pictures from different planes of brain gives a three dimensional view and in this way giving a clear view of tumours. Detection of signals emitted from normal and abnormal tissue gives the difference between diseased and normal brain. Identification of the abnormal tissue is done by radiologist by visual interpretation of the films.

4. Problems Associated in MRI

Very large workforce is needed in the MRI industry due to large number of patient and also it is very much cost effective. Here it comes the necessity of automated system for the analysis of such medical images.

5. Implementation of FPGA

To overcome the bindings, Programmable Logic Device (PLD) is an option. Now PLD is an electronic component which can be used to build reconfigurable electronic circuits. It can handle many input variables at a time. FPGAs are one of the most important programmable logic devices(PLDs) as it can handle very high logic capacity. FPGA provides high performance and high bandwidth. It consists of reprogrammable logic blocks which are connected by switches. The gain will be obtained in the fetch-decode-execute manner and this process will execute in the general purpose processors and by the exploitation of the inherent parallelism of the digital hardware. FPGA can also map complex functions in a very efficient way, like convolution. When convolution of the images take place ,at the same time pixel windows will be multiplied by their coefficients respectively. Then the final result will come in pixel at the centre of the window location.

6. Methods of Capturing Perfect Brain Image:

A. Conventional MRI of Brain

In this process the normality and abnormality depends on the basis of symmetry of the axial and coronal images of brain. If there is any asymmetry noticed in the axial MRI brain image then the brain must not be normal, it is diseased fig 1.a and 1.b are showing the normal and diseased brain respectively.

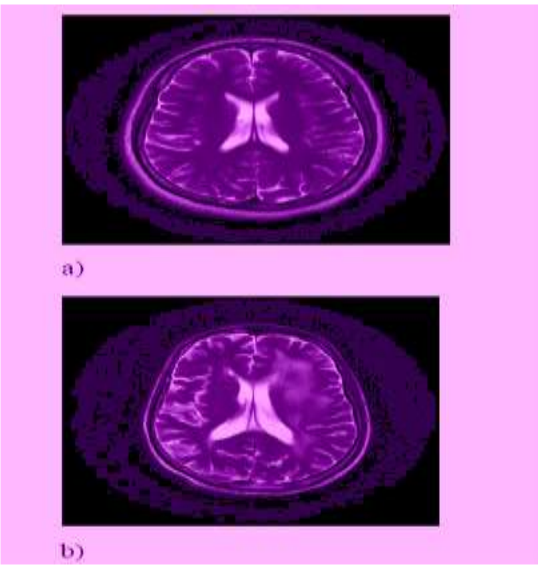

Figure 1: a) MRI Brain Image of Normal Brain b) MRI Brain Image of Diseased Brain

In this process input data (image) must be chosen in a very particular way, where lateral ventricles must be seen very clearly. The lateral ventricles are situated in the cerebral hemisphere of the brain. In fig 2. it is seen that the lateral ventricles are not clearly seen, so it is not a proper image for analysis.

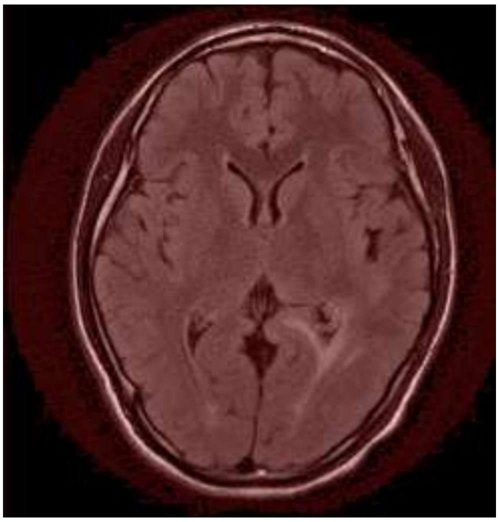

Figure 2: The Shape of lateral ventricle couldn't be seen obviously

B. Wavelet Transform:

When digitization of any image is being processed then there is a huge chance of getting noise, same thing is applicable for brain imaging. Wavelet transform is applied to the noisy point of the brain imaging and then inverse wavelet transform will be performed to recover the noise eliminated new image. The manipulation is done with the wavelet co-efficient when the wavelet transform is applied to the noisy image.Doubechies-4 is chosen for better resolution when the signal is changing smoothly and it is costly also.

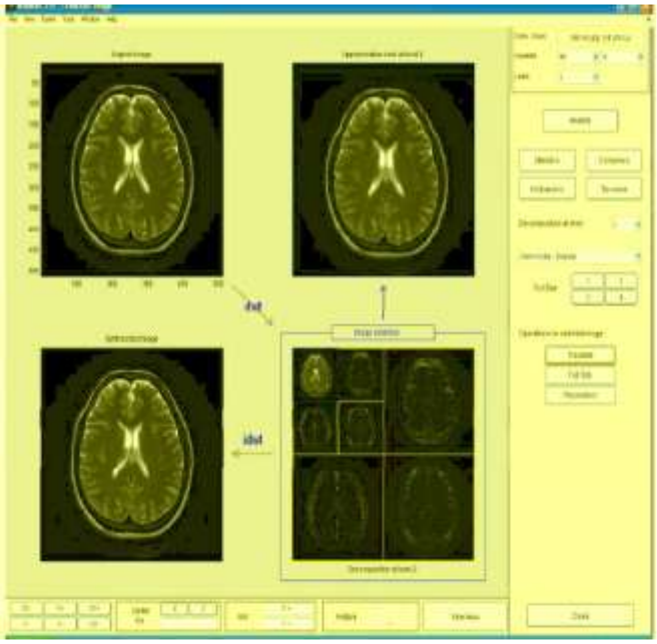

Figure 3: The normal brain image which was being decomposed and recovered properly to become noise free.

C. Feature Extraction Method:

In this method the input data will be reduced after checking the data on the basis of some properties or features. Now the reduced data will be fed to the classifier and then the classifier will classify the data on the basis of stored feature space in it. Now if a data set is given which indicates a tumour then if the classifier does not have any information about it then it could not classify the data. It is the main drawback of the system.

D. Classification Using Support Vector Machine

SVM is a machine which uses a process called kernel trick to transform the input data for classification or having regression problems by using Radiant Basis Function (RBF), then based on these transformations an optimal boundary is drawn between the possible outputs.

SVM is a supervised machine learning algorithm which can be used for classification or regression problems. It uses a technique called the kernel trick to transform your data and then based on these transformations it finds an optimal boundary between the possible outputs.

E. Drawbacks Of Various MRI classification

After a lot of testing of several brain MRI images it has been observed that the classification is done successfully for normal brain images but it fails maximum time for the abnormal one.In between 120 brain MRI images 78images are classified successfully but 42 images were misclassified by using Kernel RBF method. As the sample points are very large at some point for the abnormal MRI images, for that reason the algorithm which is pre-set can not work due to the following reasons:

1) Complexity in computation due to large number of data at some particular points.
2) Data precision is limited.

F. Implementation FPGA for MRI image processing

The FPGA is implemented as a system-ona-programmable-chip(SOPC) on a Altera Cyclone 2 chip and Nios 2 software processor is used. The Altera tools such as, DSP Builder, SOPC Builder, Nios® II CPU development kit, Nios II, C2H Compiler acceleration, and Quartus® development suite are used for the design implementation on FPGA.

Integration of processor, external and on chip memory is done by the SOPC system. Imaging oriented problems have better solution when implemented on software rather than hardware. As re-designing in hardware components is very difficult so C programming is being used after some setting is done. The algorithm implementation in the NIOS processor is shown in the Fig 4. below.

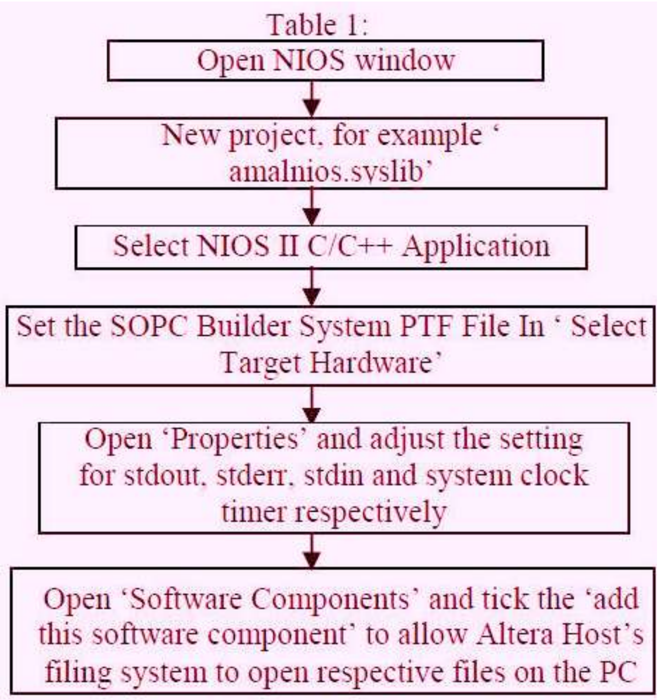

Figure 4: FPGA Implementation Algorithm in for MRI Image Processing using NIOS Processor

7. Conclusion

It is shown that the problems related to MRI imaging have been tried to get solved by various methods and in order to achieve maximum accuracy it is advisable to first use SVM classification by using Kernel RBF method. And then to overcome problems in re-configuration, FPGA is used so that any type of customizations can be done for different type of medical applications without any problem.

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Author Profile

Debolina Goswami have completed her M.Sc in Electronic Science from Calcutta University. She has been associated with a project on JLT(Junctionless Transistor).