J-Component - Final Report Format

EEE-4019

Real-Time Seizure Prediction using FPGA

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Introduction

Epilepsy is the tendency to have seizures that start in the brain. The brain uses electrical signals to pass messages between brain cells. If these signals are disrupted, this can lead to a seizure.

Epilepsy is usually diagnosed when someone has had more than one seizure. Seizures can affect your feelings, awareness or movement. Different types of seizures involve different things. These may include confusion, strange feelings, repetitive movements, 'blank' moments (where you are briefly unresponsive), muscle jerks, sudden falls, or jerking movements (while unconscious). For some people living with epilepsy, the risk of Sudden Unexpected Death in Epilepsy (SUDEP) is an important concern.

Sometimes other conditions can look like an epileptic seizure, for example fainting. Doctors will check for other conditions as well as epilepsy before you are diagnosed.

Problem Identification

Background details/Motivation/Suitability for Real-World problem

From a brief introduction to epilepsy, it is rather clear and certain how concerning epileptic seizures are, and their impact on the day-to-day activities. The human brain and the entire neural system work on electrical impulses minutely and delicately systemized. Hence the unpredictability of seizure is a major hindrance.

This gives to the development of an effective predictive model for early detection of seizure in real-time, thus allowing the avail of proper medical care and treatment at the right time. The seizure pattern varies from person to person, hence the need to patient-specific models arises.

Objectives

- Development and Training of seizure prediction model for early detection of epileptic seizures.
- Development of blocks for the FPGA development board. Deployment of the classification block for the system using XILINX VIVADO.

Literature Review

[1] The proposed work has been divided into two subheadings, the initial being description and validation of detection of epileptic seizure using AntMiner+ Classification algorithm, then followed by the implementation using Xilinx ZC702 Embedded board.

Saidi, Afef; Ben Othman, Slim; Kacem, Wafa; Ben Saoud, Slim (2018)

[2] The study overviews the impact of epileptic seizures on the patient life and put forwards a real-time monitor system specific to the patient based on Soc implementing processor and PLBs. the given work preprocesses the EEG signal and engages the rusboosted tree classifier to train the prediction model. the work supports a wearable seizure prediction system to be achievable.

Ercan Cosgun, Anil Çelebi (2021)

[3] The given study proposes a patient-specific algorithm for seizure prediction using the spectral powers from the intracranial EEG (ieeg) signal. It goes forward with the support vector machine for classification After preprocessing of EEG.

Park Y, Luo L, Parhi KK, Netoff T.(2011)

[4] The proposed work put forwards a novel patient-specific algorithm for the prediction of seizures in epileptic patients from either one or two single-channel or bipolar channel intra-cranial or scalp EEG. The study has used Freiburg database and MIT database. the study radial basis function kernel SVM (RBF-SVM) classifier.

Zhang Z, Parhi KK.(2015)

[5] This study provides updated national estimates and the first modeled estimates of active epilepsy cases for all States. Public health practitioners, health care providers, policy makers, epilepsy researchers, and other epilepsy stakeholders including family members and people with epilepsy, can use these findings to ensure that evidence-based programs meet the complex needs of adults and children with epilepsy and reduce the disparities resulting from it.

Zack MM, Kobau R. united States, (2015).

Methodology

Dataset electrodes according to the international system "10-20" will be processed.

The signal is decomposed into 5 different group of wavelet corresponding to deta, theta, alpha,beta and gamma.

This decomposition process is based on the successive application of high pass filter (HPF) and low pass filter (LPF).

- We will implement our epileptic seizure detection system in the XLINX board which will provides an AP-SoC development environment

The development of this project will be done in the following stages.

- All the results obtained from our program execution(Filter signals, energy ratios, etc) will be compared with Python implementation
- The first is hardware development using Xilinx Vivado in order to define hardware architecture using the logical elements offered by the board and the FPGA.

DATA Collection

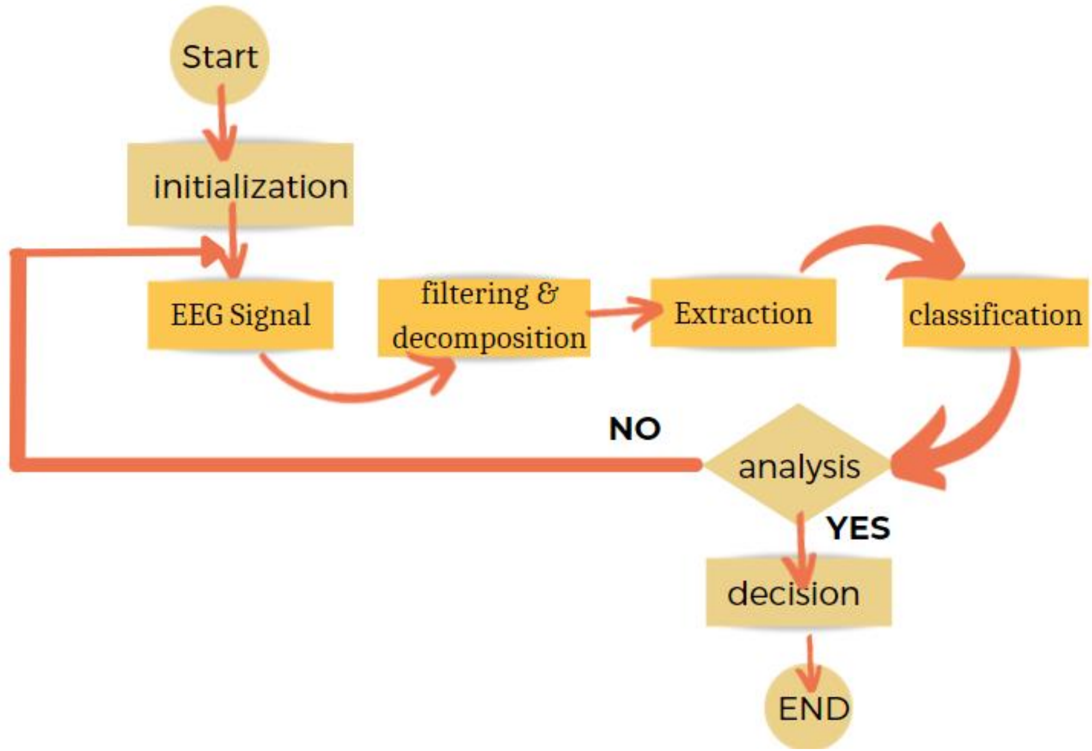
The database is collected at the Children's Hospital Boston. It consists of EEG recordings from paediatric subjects with intractable seizures. Subjects were monitored for up to several days following withdrawal of anti-seizure medication in order to characterize their seizures and assess their candidacy for surgical intervention.

DATA Analysis

The sampling rate of the data was 173.61 Hz. The time series have the spectral bandwidth of the acquisition system, which is 0.5 Hz to 85 Hz. The dataset consists of five sets: Set B, Set C, and Set E.

1. Set B refers to healthy data
2. Set C refers to Inter-ictal (transition between healthy to seizure) data
3. Set E is of ictal or seizures.

Algorithm Development



Algorithm Implementation

- Python Code – Platform used – Google Colaboratory

```
import numpy as np
import pandas as pd
import matplotlib.pyplot as plt
from time import sleep
import pyeeg
import os
from google.colab import drive
drive.mount('/content/drive')
dirB="/content/drive/MyDrive/Colab Notebooks/FPGA/Datasets/setB/"
tempB = []
for file in os.listdir(dirB):
    fl = dirB + file
    tempB.append(fl)
tempB = sorted(tempB)

dirC="/content/drive/MyDrive/Colab Notebooks/FPGA/Datasets/setC/"
tempC = []
for file in os.listdir(dirC):
    fl = dirC + file
    tempC.append(fl)
tempC = sorted(tempC)

dirE="/content/drive/MyDrive/Colab Notebooks/FPGA/Datasets/setE/"
tempE = []
for file in os.listdir(dirE):
    fl = dirE + file
    tempE.append(fl)
tempE = sorted(tempE)

tb=[]
st = 'A'
for i in range(len(tempB)):
    x = pd.read_table(tempB[i],header=None)
    x.columns=[st+str(i)]
    tb.append(x)

tc=[]
st = 'A'
for i in range(len(tempC)):
    x = pd.read_table(tempC[i],header=None)
    x.columns=[st+str(i)]
    tc.append(x)

te=[]
```

```python
st = 'A'
for i in range(len(tempE)):
    x = pd.read_table(tempE[i],header=None)
    x.columns=[st+str(i)]
    te.append(x)
def table(table):
    big_table = None
    for ta in table:
        big_table = pd.concat([big_table, ta],axis=1)
    return big_table
bigB = table(tb)
bigC = table(tc)
bigE = table(te)
head = list(bigB.columns.values)
def creat_mat(mat):
    matx = np.zeros((len(mat),(len(head))))
    for i in range(len(head)):
        matx[:,i] = mat[head[i]]
        sleep(0.01)
    return matx
matB = creat_mat(bigB)
matC = creat_mat(bigC)
matE = creat_mat(bigE)

matB = np.nan_to_num(matB)
matC = np.nan_to_num(matC)
matE = np.nan_to_num(matE)

health, = plt.plot(matB[0],label='noramal person')
plt.legend(handles=[health])

before_seizure, = plt.plot(matC[0],label='State just before seizure')
plt.legend(handles=[before_seizure])

seizure,  = plt.plot(matE[0],label='seizures')
plt.legend(handles=[seizure])

healthy,      = plt.plot(matB[0],label='normal person')
before_seizure,    = plt.plot(matC[0],label='State just before seizure')
seizure, = plt.plot(matE[0],label='seizures')
plt.legend(handles=[healthy,before_seizure,seizure])
```

- Verilog code on VIVADO

```verilog
module magComp ( A,
   Th1,
   Th2,
   Th3,
```

```
    Sez,
    Bod,
    Hel
    );

input [7:0]  A,  Th1, Th2 , Th3;
output   Sez , Bod, Hel; //The Outputs of comparison
reg Sez, Bod, Hel;
always @ (*) //Check the state of the input lines
begin
 Hel <= ( A < Th1 )? 1'b1 : 1'b0 ;
 Bod <= ( A < Th2 && A>Th1)? 1'b1 : 1'b0 ;
 Sez <= ( A > Th2 && A<Th3 )? 1'b1 : 1'b0 ;
end
endmodule
```

- Test Bench

```
`timescale 1ns / 1ps
module magComp_tb;

// Inputs
 reg [7:0] A;
 reg [7:0] Th1;
 reg [7:0] Th2;
 reg [7:0] Th3;

 // Outputs
 wire Sez;
 wire Bod;
 wire Hel;

 // Instantiate the Unit Under Test (UUT)
 magComp uut (
  .A(A),
  .Th1(Th1),
  .Th2(Th2),
  .Th3(Th3),
  .Sez(Sez),
  .Bod(Bod),
  .Hel(Hel)
 );
initial begin

  // Initialize Inputs
  A = 8'b0;
  Th1 = 8'd40;
  Th2 = 8'd60;
  Th3= 8'd80;
  // Wait 100 ns for global reset to finish
  #100;
  // Add stimulus here
  A = 8'd8;
  #20;

  A = 8'd56;
  #20;
```

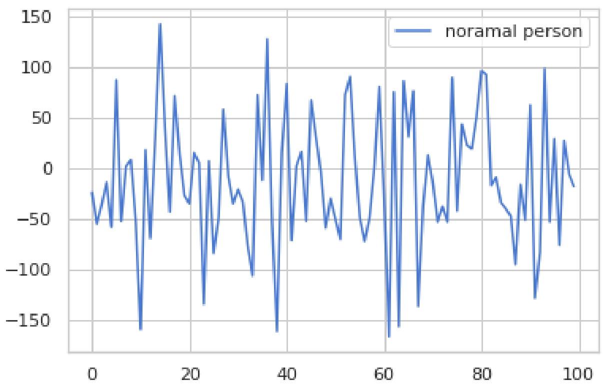
```
  A = 8'd32;
  #20;

  A = 8'd22;
  #20;

  A = 8'd19;
  #20;

  A = 8'd73;
  #20;

  A = 8'd66;
  #20;

  A = 8'd66;
  #20;

  A = 8'd59;
  #20;

  A = 8'd42;
  #20;

  A = 8'd49;
  #20;

  A = 8'd19;
  #20;

  A = 8'd19;
  #20;

  A = 8'd19;
  #20;

  A = 8'd19;
  #20;

  A = 8'd51;
  #20;

  A = 8'd58;
  #20;
A = 8'd88;
#20;

A = 8'd98;
#20;

A = 8'd54;
#20;

A = 8'd55;
#20;

A = 8'd65;
```

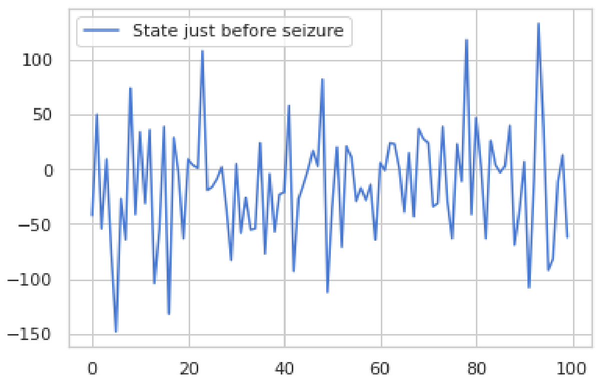
```
#20;

A = 8'd77;
#20;

A = 8'd77;
#20;

end
endmodule
```

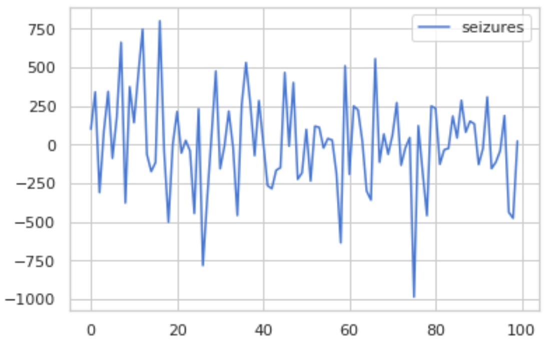
Demonstration of Outcome/ Results and Discussion

Upon the pre-processing of the database of the EEG signal, we took the recording for just one patient and upon classification and plot, we observed a negative slope for the healthy patient, whereas the observations revealed a positive slope for the patients under borderline condition and patients suffering with epileptic seizures, implicating the spike in the energy signals. On closer graph analysis, its is viewed the epileptic readings have a greater slope magnitude.

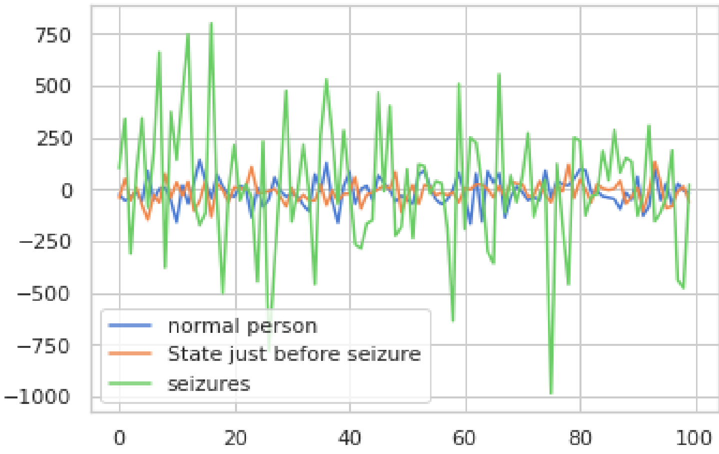
After the completion of analysis for one person, we took it forward for the entire dataset.



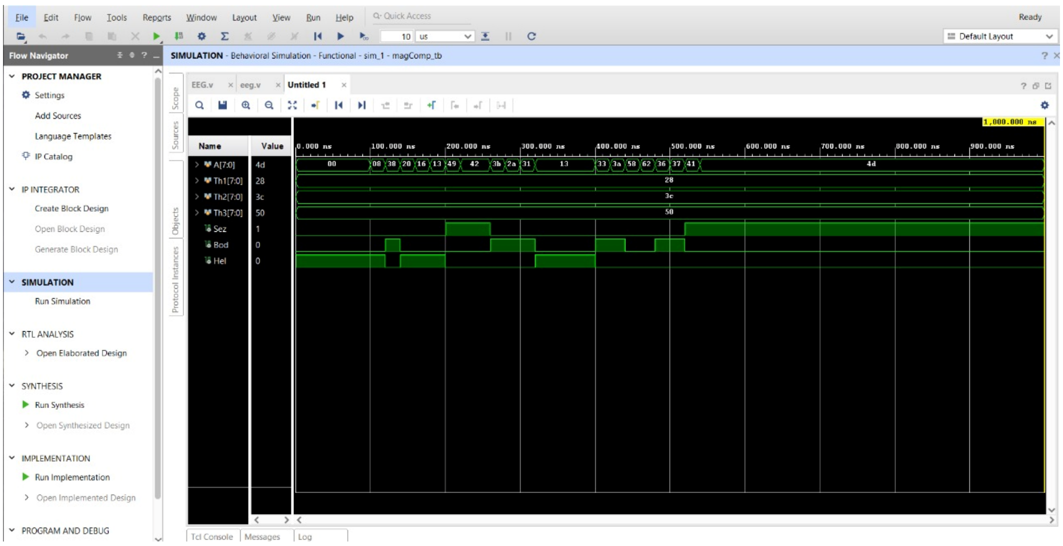




We see the different energy spikes occurring on the graph for all the three categories. This can be better visualised and studied by using a single graph.



After the completion of pre-processing and graphical analysis and visualisation, we developed the Verilog code for the classification of the EEG signal into Seizure, Borderline and Healthy conditions. For the testbench we set the data input to A from the pre-processed dataset. We were able to successfully clean and classify the EEG signals.



References

1]Saidi, Afef; Ben Othman, Slim; Kacem, Wafa; Ben Saoud, Slim (2018). FPGA implementation of EEG signal analysis system for the detection of epileptic seizures. , (), 415–420. doi:10.1109/ASET.2018.8379892

[2] Ercan Cosgun, Anil Çelebi (2021) FPGA based real-time epileptic seizure prediction system

https://doi.org/10.1016/j.bbe.2021.01.006

[3] Park Y, Luo L, Parhi KK, Netoff T.(2011)Seizure prediction with spectral power of EEG using cost-sensitive support vector machines. Epilepsia 2011;52:1761–70.

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