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Lossless EEG Compression based on Highly Efficient Multilevel Compression Method for VLSI Implementation

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***Abstract*-This paper proposes a lossless EEG compression based on highly efficient multilevel compression method.It includes a two-stage prediction,voting prediction and quad-encoding.In proposed algorithm,at two stages prediction,27 conditions and 6 functions are used to decide how to predict the current data from previous data.Voting prediction finds optimal function according to 27 conditions for finding the difference of predicted data and current data.Moreover, a quad-entropy coding technique is developed with two huffman coding,one golomb rice coding & one dictionary method.The results have been simulated by Modelsim using Verilog HDL.The CHB-MIT Scalp EEG Database was used to test the performance of the proposed technique.The proposed multilevel compression part shows that it can achieve more compression efficiency in less transmission time.**

Keywords—Electroencephalography(EEG), Wireless Body Sensor Network(WBSN), Prediction(PD)

I. INTRODUCTION

Electroencephalography(EEG) can be defined as the process of recording of brain's electrical activity at the scalp.This is useful for several applications,such as medical diagnosis,psychological research,and it is being used in the field of Brain Computer Interfaces[1].Electroencephalography is a method of recording electrical brain activity and it doesn't require any surgical implants in order to collect the datas. EEG datas are collected by placing electrodes on a human's scalp.The electrodes can be spread out over the head and its count can be one electrode to hundred,depending on our application it may change[2].

Since EEG is widely used,it is inevitable that problems begins to occur as the amount of datas recorded,stored,and transmitted accumulates[3].Some of the medical procedures require EEG data to be recorded for a very long period of time,may be upto 24 hours.Hence we can choose data compression as a best solution for this problem[4-6].

The main advantages of compression are reductions in data transmission time,communication bandwidth and storage hardware.Compressed files requires less storage capacity than uncompressed files,means a significant decrease in expenses for storage.A compressed file also requires less transfer time while using less network bandwidth[8].A lossless EEG compression based on highly efficient multilevel compression method needs to be developed for reducing data transmission time and for keeping data qualities[9].

Thus,a lossless EEG compression algorithm based on semi-supervised learning technique is proposed in this project.The compression algorithm can achieve high compression efficiency in CHB-MIT Scalp EEG Database.And this can be easily implemented by VLSI architecture.

II. LOSSLESS EEG COMPRESSION ALGORITHM

This EEG Compression algorithm consists of two major parts, a predictor and an encoder. In the predictor part, there are three steps.First the raw data will go through first-stage prediction given this data preliminary processing. Second, the two stage fuzzy decision is used to classify them into different cases. Finally,the voting prediction decides an optimal outcome of the predictor part.After receiving the outcome of the predictor,quad-entropy coding will give us the compressed output.

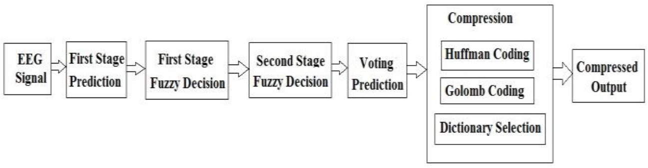

Fig.1. Lossless EEG compression algorithm flow

A. *First Stage Prediction*

There are two outcome of First-stage prediction, value diff1 and diff2, where diff1 is defined by the difference between X(n) and X(n-1),diff2 is defined by the difference between
X(n-2) and X(n-3).These two values diff1 and diff2 are also indicating the slope of the passed signals.Both of them will play an important role in the fuzzy decision section.

B. *Prediction Functions*

The main idea of the prediction is to create a function which uses several previous incomes X(n-1) to X(n-4).The six prediction functions we have used are shown in equations:

Function1 PD = X(n-1) (1)
Function2 PD = 2*X(n-1)-X(n-2) (2)
Function3 PD = (3*X(n-1)-X(n-2))/2 (3)
Function4 PD = -X(n-2) + X(n-3) (4)
Function5 PD = 3*X(n-1)-3*X(n-2) + 3*X(n-3) (5)
Function6 PD = -3*X(n-1)-3*X(n-2) (6)

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C. Fuzzy Decision

Fuzzy Decision is based on the characteristics of passing three signals and then classifying them in to several modules. According to the value of X(n-1),it can be defined in three classes, Low, Medium and High.This is first stage fuzzy decision.The outcome of the first-stage prediction diff1 and diff2 can be classified to another three different classes, Low, Medium and High(Fig 2.1).The result of first-stage prediction will be sent to twenty-seven modules M1 to M27(Fig 2.2).

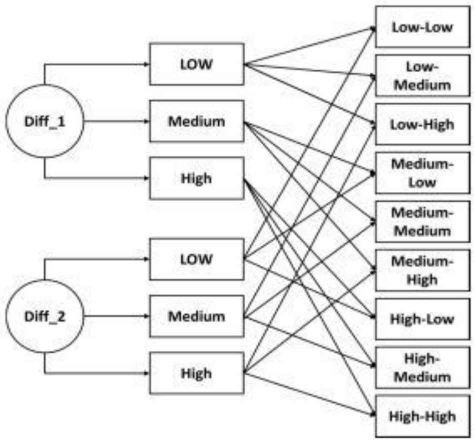

Fig.2.1 Block diagram of the first-stage fuzzy decision

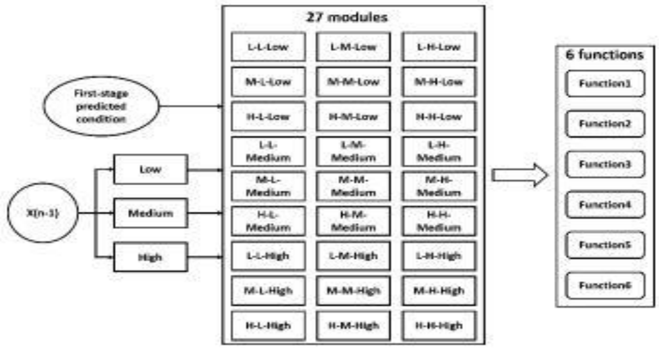

Fig.2.2 Block diagram of the second-stage fuzzy decision

D. Voting Prediction

In order to adaptively select best function to fit current situation, the first-stage prediction classifies data by the passed two values of slope diff1 and diff2. Next, to consider the most current data X(n-1) and then put them into three different section.After the data denoting into twenty-seven modules from L-L-Low to H-H-High,one of these six functions will be selected by the second stage fuzzy decision module.This is to provide an easy way for decoding side to recognize which prediction function was selected.Once data is sent to one of the twenty-seven modules, the system will check which function has most votes and selected this function as the optimal function to produce outcome PD.After executing all of six prediction functions, the function which has smaller absolute value will get an extra vote. If they have same amount of votes, the smaller label of function has higher priority(Fig 2.3).

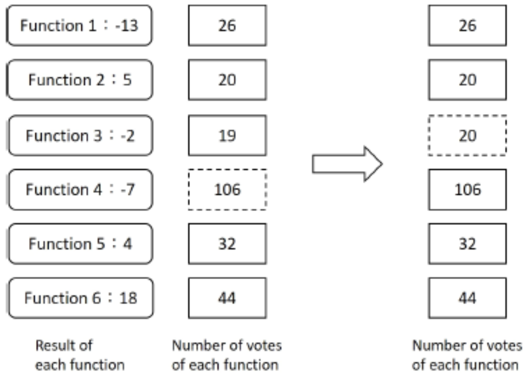

Fig.2.3 Example of voting prediction process

E. Quad Encoding

A quad-entropy coding technique is developed with two huffman coding,one golomb rice coding and one dictionary method.

- Huffman Coding:Huffman coding is a lossless data compression algorithm.The process is to assign variable length codes to input characters,lengths of the assigned codes depends on frequencies of the corresponding characters.The most frequently occuring character gets the smallest code and the least frequently occuring character gets the largest code.After making huffman tree,huffman codes are calculated and hence we can also find out the number of bits.Here we are applying two layers of huffman coding.
- Golomb Coding:It is a type of lossless data compression algorithm.It is a practical and powerful implementation of run-length encoding of binary streams.Rather than being based on the data, like Huffman, it's based on a simple model of the probability of the values.We are applying one layer of golomb coding to huffman output.
- Dictionary Method: It is known as dictionary coder or substitution coder method,which means a dynamic dictionary is created depending upon the presence of substring chosen from the original file.Then the sub-string is matched with the dictionary, if the string is found then a reference of the dictionary is mentioned in the encoded file.If the string is not found then a new dictionary entry is made with a new reference.While compression process,if bitstream is matching with predefined dictionary index,it is considered as compressed else uncompressed.Fig 2.4 shows an example.If compressed,code is represented by 1 concatinated with binary of index value,ie;total 2 bits.If uncompressed,code is represented by 0 concatinated with uncompressed bitstream-ie;total 9 bits.

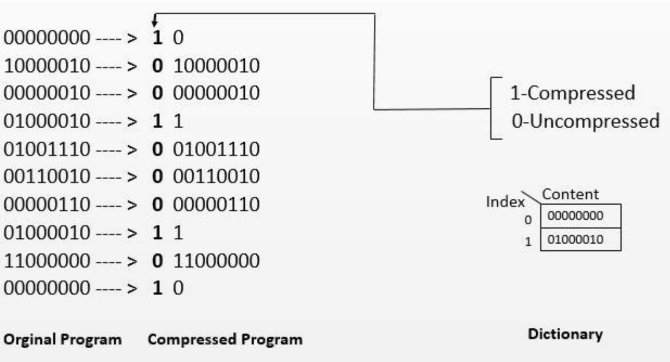

Fig 2.4 Example of dictionary method

III. SIMULATION RESULTS

Existing system was having only tri-encoding in the compression part.ie;two level Huffman coding and one Golomb coding.In proposed system,to improve compression efficiency we have added dictionary method to Golomb output.

To evaluate the performance of the proposed lossless compression algorithm,CHB-MIT Scalp EEG Database were selected as the test dataset.The results of proposed system have been simulated by ModelSim SE 6.3f using Verilog HDL.

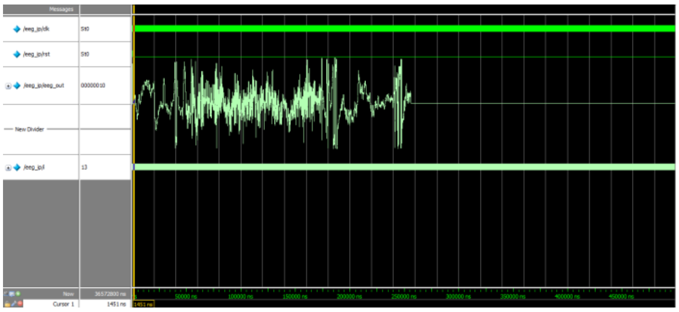

Fig 3.1 Simulation result of EEG Signal

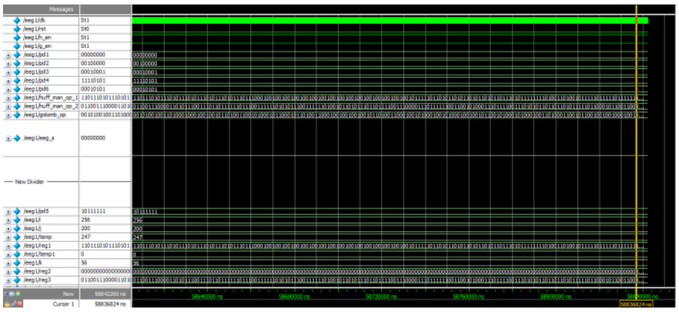

Fig 3.2 Simulation result of existing tri-encoding

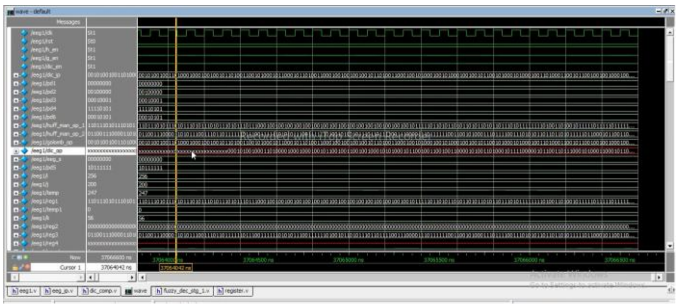

Fig 3.2 Simulation result of proposed quad-encoding

Also,from simulation results,

Compression ratio = Uncompressed size/Compressed size
=352/291=1.209

Space saving(%) = {1-(Compressed size/ Uncompressed size)}*100
={1-(291/352)}*100
= 17.329%

CONCLUSION

A lossless EEG compression hardware oriented algorithm based on first stage prediction,fuzzy decision,voting prediction and quad-entropy coding technique is proposed.The proposed algorithm increases compression efficiency.In CHB-MIT Scalp EEG Database, this study achieved a compression ratio of 1.209 and a space saving of 17.329%.The proposed algorithm was developed for hardware implementation,which is suitable for realizing on chip and for using in WBSN system.

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