ISSN (Online): 2583-7052

International Journal of Advanced Trends in Engineering and Management (IJATEM)
Vol. 03 (04), April 2024, pp. 54-61

Article Title: Circuit-Level Realization of an Adaptive Trending Prediction Algorithm for Lossless ECG Compression

Circuit-Level Realization of an Adaptive Trending Prediction Algorithm for Lossless ECG Compression

P. Manimala

Full Time Research Scholar, Department of Electrical and Electronics Engineering, Government College of Engineering, Bodinayakkanur, Theni, Tamil Nadu, India, pmanimala967@gmail.com

ABSTRACT

This paper introduces an advanced approach to the hardware implementation of lossless compression for electrocardiogram (ECG) signals, combining Content-Adaptive Golomb-Rice (CAGR) coding with Adaptive Trending Prediction (ATP). The CAGR technique dynamically adjusts its parameters based on local signal characteristics, effectively optimizing compression efficiency. Simultaneously, Adaptive Trending Prediction analyzes and predicts signal trends to further minimize redundancy before encoding, enhancing overall compression ratios. The hardware architecture presented in this study is meticulously designed to leverage these techniques, ensuring efficient utilization of resources while maintaining real-time performance suitable for medical applications. Design considerations include algorithmic complexity, throughput, and resource utilization metrics tailored to meet the stringent requirements of medical monitoring systems. Experimental evaluations validate the efficacy of the proposed method, demonstrating substantial reductions in data size while preserving clinical fidelity crucial for accurate diagnosis and monitoring. The findings underscore the feasibility and practicality of integrating advanced compression algorithms into dedicated hardware platforms, thereby facilitating more efficient data transmission and storage in medical environments.

Keywords: ECG compression, lossless compression, Content-Adaptive Golomb-Rice coding, Adaptive Trending Prediction, medical monitoring, real-time systems.

1 Introduction

The heartbeats are captured during an ECG test, which generates electrical impulses. Data is produced in vast quantities by the widespread usage of digital ECGs. Effective methods for compression are employed because it's essential for keeping and transferring ECG recordings [1, 2]. Transmission time and necessary storage space are decreased by employing effective compression techniques. An average Compression Ratio (CR) of roughly 2:1 to 50:1 has been reported for various ECG compression algorithms that have been used in recent years [3]. Cardiovascular disease (CVD) is estimated to be responsible for about 31% of all fatalities globally and has emerged as the leading cause of death in the past few decades

International Journal of Advanced Trends in Engineering and Management (IJATEM)
Vol. 03 (04), April 2024, pp. 54-61

[4].Cardiovascular disease and many other disorders are diagnosed with the use of ECG signals. The ECG signal is a biological signal that provides information about the health of the heart. It is the most widely used screening method for cardiac disorders [5]. An ECG signal monitoring system produces enormous amounts of data for the detection system.

The two subsequent distinct frequencies can be used as examples to better understand the volume of data produced throughout the ECG monitoring procedure. Typically, each sensor generates data for one minute at the sampling frequency of the ECG [6, 7]. Thus, a method to compress the ECG signal data is needed in order to save this enormous amount of data. In this situation, ECG compression is carried out as a remedy to conserve storage space [8]. Waves, segments, and intervals are some of the components that make up an ECG signal. A long-term ECG recording is frequently performed on individuals who are hospitalized for heart issues. With monitors designed for mobile patients, ECG data can also be continuously recorded for longer than 48 hours [9]. As a result, during this period of time, continuous ECG monitoring systems collect a significant amount of data. A real-time data compression algorithm that can sustain storage space is required to reduce the volume of data [10].

Numerous studies have been conducted in the past on the VLSI implementation of lossless ECG compression. In [11] combined signal VLSI design for the ECG compression that uses entropy coding and predictive modelling to provide a clever analog-to-digital converter (ADC) and lossless ECG compression. This architecture is not appropriate for the low power devices of today, despite being meant for low power applications because to its relatively high power consumption. In [12] have presented another VLSI implementation of ECG compression that makes use of wavelet transform and Run-Length Encoding (RLE). However, the design's disadvantage is that it requires a rather high working frequency, making it inappropriate for use in real-time ECG data compression. ECG equipment samples at a frequency between a few hundred and a thousand hertz [13, 14]. Therefore, the architecture suggested by [15] is helpful when compression is applied after ECG data is currently captured in a storage medium.

Thus, this paper presents an efficient hardware implementation of a combined approach using CAGR coding and ATP for achieving lossless compression of ECG signals. The CAGR coding method dynamically adjusts its parameters based on the local statistics of the ECG signal, enhancing compression efficiency. Concurrently, ATP predicts signal trends to further reduce redundancy before encoding.

2 Proposed Methodology

This work proposes employing the VLSI technology shown in Figure 1 to develop the lossless ECG compression approach for devices with low power consumption.

International Journal of Advanced Trends in Engineering and Management (IJATEM)
Vol. 03 (04), April 2024, pp. 54-61

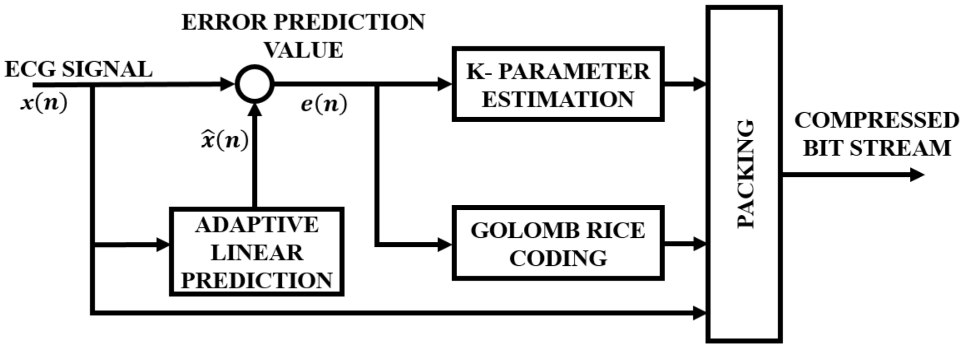

Figure 1: *Proposed System Block Diagram*

The predicted value, $X\ (n)$, is determined in the first phase by processing the ECG data input. The loss-predicted data, $x\ (n)$, is subjected to adaptive trend prediction in the second step. This technique may predict the waveform's location and subsequently lower the prediction error. An entropy-based dimensionality-reducing approach called Golomb coding is applied in the management information training module. The projected error distribution of every window is used to determine the k variable.

3 Modelling of Proposed System

3.1 Technique for Compressing Data without Loss

Entropy coding is characterized by typically recurring patterns or values being provided with few binary bits and occasionally happening ones being shown using numerous binary bits, constitute a crucial coding approach in data compression. The program's implementation is based on the work of the reference programme, makes use of the Golomb-Rice code, a low-complexity entropy encoder.

3.2 Adaptive Trending prediction

Predictive coding is a lossless compression method that encodes the error among the data and information “predicted" derived from previous observations, enabling an easy comprehension of the data. The prediction algorithms use previous samples $x(n-1), x(n-2), x(n-3)$, to generate estimation $x'(n)$ for a particular sample $x(n)$ of the signal. $PD = x(n) - x'(n)$ Is the projection difference that takes position of the sample $x(n)$. The biological signals are distributed predictably in nature and are somewhat sluggish. Therefore, the prediction methodology is applied to enhance the encoding technique's effectiveness. For the purpose of to enhance forecasting performance, the present value of the biological signals is estimated by transferring two values through a first order forecasting strategy centered around linear prediction and a second order forecasting technique that relies on slope prediction [1]. By

International Journal of Advanced Trends in Engineering and Management (IJATEM)
Vol. 03 (04), April 2024, pp. 54-61

combining two values of $x(n-1)$ and $x(n-2)$ using the formula $diff-1 == diff-2$, the present value $x\ (n)$ is derived.

$$[a]diff-1 = diff-2[b]diff-1 = 2*(diff-2)-(diff-3)$$

This is made up of 4 substractors, single shifter, single multiplexer, single adder, and registers. For the purpose of storing and calculating the outcome of the prediction difference, four out of the five registers are used: $x\ (n), x\ (n-1), x\ (n-2)\ and\ x\ (n-3)$. Another pipeline register for enhancing the efficiency of the suggested encoder design is register $PD(n)$. By using two substractors, the values of $diff\_2$ and $diff\_3$ can be obtained. Using the acquired values of $diff\_2$ and $diff\_3$, a shifter and a substractor may derive the value of $diff\_2\ and\ 2*diff\_2-diff\_3$.

3.3 Content-Adaptive Golomb-Rice code

The most intricate and computationally demanding component of the entire compression technique is the colomb rice coding. Furthermore, because data processing is ongoing, the hardware design maintains the lowest possible latency for Golomb Rice coding data processing. Furthermore, area-saving measures were taken to prevent the chip area from growing. To cut down on processing latency, processes in the computation section have been split up into separate clock cycles. The division, mod, and multiplication operations have all been carried out via bit shifting as opposed to the built-in division and power operators. The design can benefit from a reduction in the number of gates and power usage by utilising this small adjustment. For instance, moving the value one bit to the right or left, respectively, has been used to divide and multiply an integer by two. Additionally, division is carried out following the summing of one window's values; the possible values fall within the range of 1 and 127. Therefore, a log table containing the log values of these parameters is retrieved each time a log operation is needed for the design. To cut down on resource use, data reading and storing are managed by a single counter. Additionally, having a single counter for both controllers saves switching power because it requires less activity than utilizing two counters.

4 Results and Discussion

This article proposes an effective hardware implementation of a combination strategy that uses ATP and CAGR coding to achieve lossless ECG signal compression. The CAGR coding technique improves compression efficiency by constantly modifying its settings in response to the local statistics of the ECG signal.

ISSN (Online): 2583-7052

International Journal of Advanced Trends in Engineering and Management (IJATEM)
Vol. 03 (04), April 2024, pp. 54-61

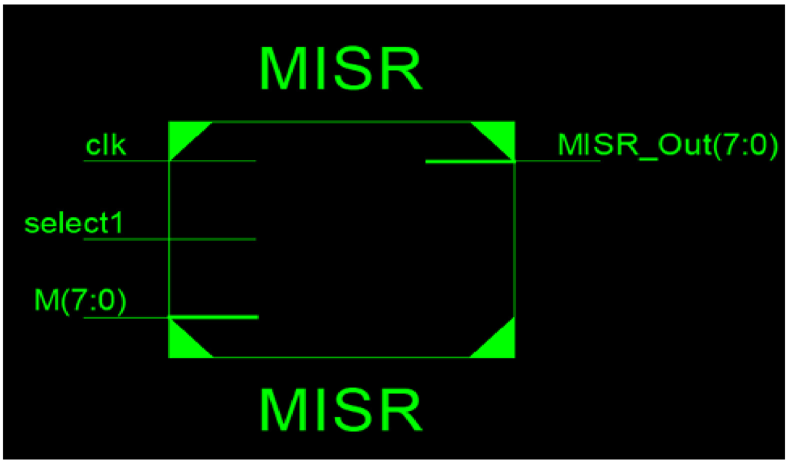

Figure 2: *Testing Block*

Figure 2 shows a block diagram of a Multiple Input Signature Register (MISR). A MISR is a type of linear feedback shift register (LFSR) used in built-in self-test (BIST) mechanisms for digital circuits to compress multiple bit streams into a single signature.

Figure 3: *Schematic Diagram of Testing Block*

Figure 3 shows a detailed schematic diagram of a MISR. The schematic includes various components like XOR gates, multiplexers (labeled Mxor), and feedback loops, illustrating the internal logic and connections within the MISR.

ISSN (Online): 2583-7052

International Journal of Advanced Trends in Engineering and Management (IJATEM)
Vol. 03 (04), April 2024, pp. 54-61

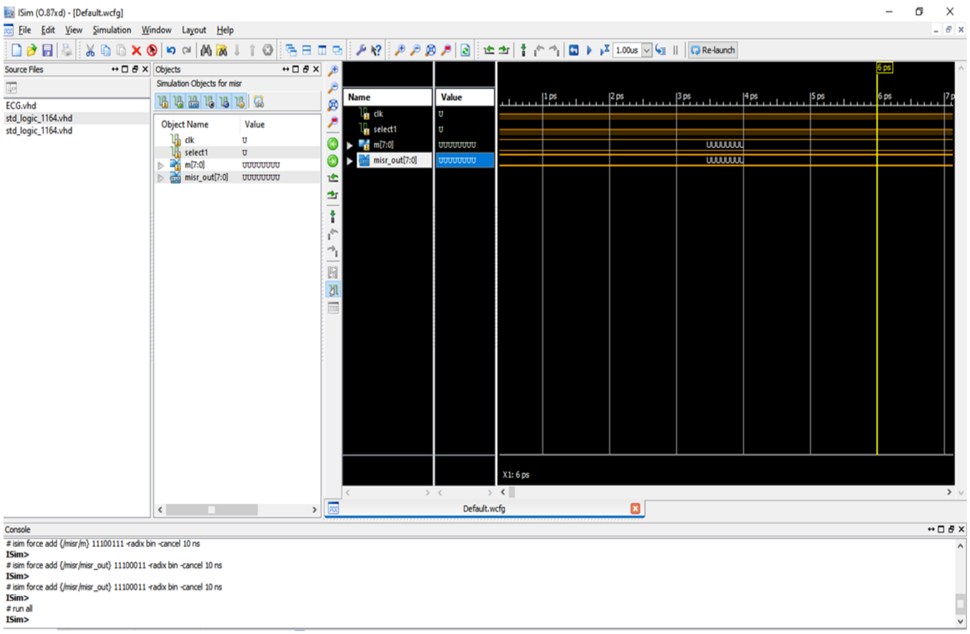

Figure 4: *Simulated Outcome 1*

Figure 4 illustrates the results of the simulation to completion. The bit-stuffing block's input data signal ($data\_in$) and output data signal ($data\_out$) are identical. The count value is increased if the input data ($data\_in$) are high. The status is altered to "10" since the count number is 6. The bit is regarded as invalid and the count value is set to 0 when the valid bit is indicated as 0.

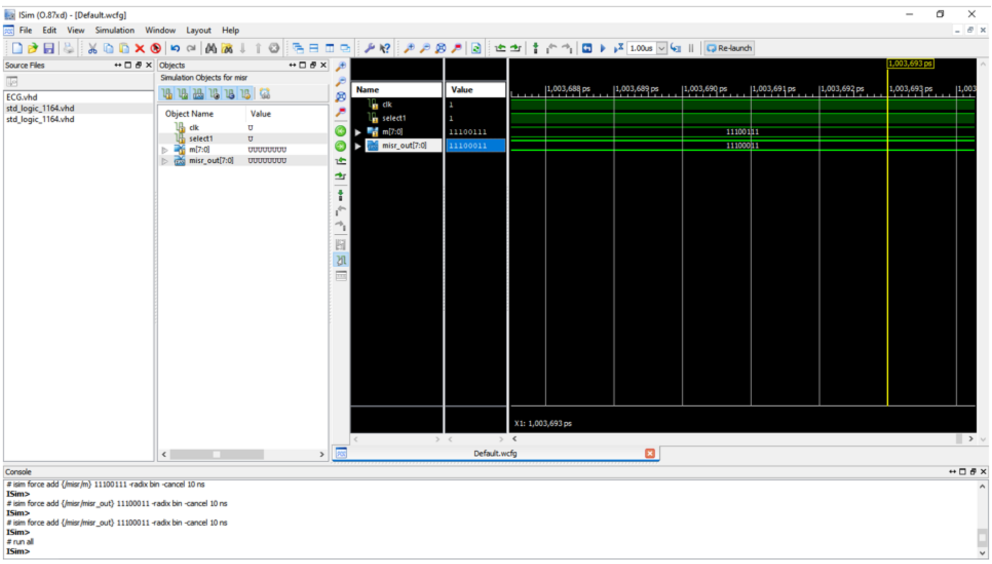

Figure 5: *Simulated Outcome 2*

International Journal of Advanced Trends in Engineering and Management (IJATEM)
Vol. 03 (04), April 2024, pp. 54-61

Figure 5 displays the simulation's results and by analyzing compression codecs, the proposed approach approximates human comprehension of restoration efficiency. Although a greater PSNR typically indicates a higher-quality repair, this is not always the case. One needs to exercise extreme caution when dealing with the validity range of this metric, as it is only considered decisively accurate when applied to results that share the same codec and content.

5 Conclusion

In conclusion, the efficient hardware implementation of CAGR coding and ATP represents a significant advancement in the field of ECG signal compression. Through this study, feasibility and effectiveness of integrating these sophisticated compression techniques into dedicated hardware architectures have demonstrated. The combination of CAGR coding's adaptability to local signal characteristics and ATP's predictive capabilities enables substantial reductions in data size while maintaining clinical fidelity, essential for accurate diagnosis and monitoring in medical applications. The optimized hardware design ensures that the proposed solution meets the demanding requirements of real-time medical monitoring systems, offering enhanced data management capabilities and facilitating faster transmission of ECG data. This research contributes not only to the technical advancement of compression algorithms but also highlights practical pathways towards improving healthcare delivery through efficient data handling in medical devices.

References

1. Tsai Tsung-Han; Muhammad Awais Hussain, Year: 2020, "VLSI implementation of lossless ECG compression algorithm for low power devices", IEEE Transactions on Circuits and Systems II: Express Briefs, Vol: 67, no: 12, pp. 3317-3321.2.

2. Zhu Huaiyu; Yun Pan; Ke Li; Ruohong Huan, Year: 2019, "Method and VLSI implementation of lossy-to-lossless LTM ECG compression framework", Electronics Letters, Vol: 55, no: 2, pp. 70-72.

3. Tsai Tsung-Han, and Fong-Lin Tsai, "Efficient lossless compression scheme for multi-channel ECG signal processing." Biomedical Signal Processing and Control 59 (2020): 101879.

4. Janveja Meenali; Ashwani Kumar Sharma; Abhyuday Bhardwaj; Jan Pidanic; Gaurav Trivedi, Year: 2023, "An Optimized Low-Power VLSI Architecture for ECG/VCG Data Compression for IOHT Wearable Device Application", IEEE Transactions on Very Large Scale Integration (VLSI) Systems.

5. Sarma Jitumani; Rakesh Biswas, Year: 2022, "A VLSI-based hybrid ECG compression scheme for wearable sensor node", IEEE Sensors Letters, Vol: 6, no: 4, pp. 1-4.

International Journal of Advanced Trends in Engineering and Management (IJATEM)
Vol. 03 (04), April 2024, pp. 54-61

6. Baskar Vijaya; Sivakumar; Vimal; Vadivel; Selvi, Year: 2023, "FPGA Implementation of Novel Lossless ECG Compression Algorithm for Low Power Device", In 2023 4th International Conference on Electronics and Sustainable Communication Systems (ICESC), pp. 38-41. IEEE.

7. Chen Yuan-Ho; Yun-Hua Tseng; Pao-Hsien Chu; Yen Juan; Shun-Ping Wang, Year: 2020, "VLSI implementation of a cost-efficient 3-Lead lossless ECG compressor and decompressor", Circuits, Systems, and Signal Processing, Vol: 39, no: 3, pp. 1665-1671.

8. Wang Liang-Hung; Zong-Heng Zhang; Wen-Ping Tsai; Pao-Cheng Huang; Patricia Angela Abu, Year: 2022, "Low-power multi-lead wearable ECG system with sensor data compression", IEEE Sensors Journal, Vol: 22, no: 18, pp. 18045-18055.

9. Balasubramani; Swathi Krishna, Year: 2022, "A vlsi-based multi-level ECG compression scheme for wearable sensor node".

10. Reddy Palagiri Veera; Satyanarayana Tallapragada, Year: 2024, “FPGA-enabled lossless ECG signal compression system using an integer adaptive compressor”, Analog Integrated Circuits and Signal Processing, Vol: 119, no: 2, pp.331-361.

11. Banerjee Soumyendu; Girish Kumar Singh, Year: 2023, "A new real-time lossless data compression algorithm for ECG and PPG signals", Biomedical Signal Processing and Control, Vol: 79, pp. 104127.

12. Kumar Manoj, "VLSI Implementation of ECG data Compression and Decompression using Differential Encoding Method".

13. Rzepka Dominik, Year: 2020, "Low-complexity lossless multichannel ECG compression based on selective linear prediction", Biomedical Signal Processing and Control, Vol: 57, pp. 101705.

14. Jia Menghan; Feiteng Li; Yu Pu; Zhijian Chen, Year: 2020, "A lossless electrocardiogram compression system based on dual-mode prediction and error modeling", IEEE Access, Vol: 8, pp. 101153-101162.

15. Premalatha Mohana; Suvitha; Manikandan, Year: 2021, "Implementation of VLSI based efficient lossless EEG compression architecture using verilog HDL", In Journal of Physics: Conference Series, Vol: 1964, no: 6, pp. 062048, IOP Publishing.