

A Real-Time Lossless Data Compression Framework Using Dynamic Parameter Selection

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Abstract- *The increasing deployment of multimedia systems, wireless sensor networks, and Internet of Things (IoT) devices has generated substantial volumes of data that require efficient storage and transmission. Traditional lossless compression algorithms often employ fixed encoding parameters that fail to adapt to changing data characteristics, resulting in reduced compression efficiency and increased processing overhead. This paper presents a Real-Time Lossless Data Compression Framework based on Dynamic Parameter Selection (DPS). The proposed framework continuously analyzes local data statistics and automatically selects optimal compression parameters during runtime. The approach combines statistical analysis, adaptive parameter control, and lightweight lossless encoding to improve compression performance while maintaining low computational complexity.*

Keywords: *Lossless Data Compression, Dynamic Parameter Selection, Real-Time Systems, Multimedia Data, IoT, Edge Computing.*

I. INTRODUCTION

Modern communication systems generate massive amounts of multimedia and sensor data. Applications such as smart surveillance, industrial monitoring, healthcare systems, and edge computing platforms require efficient compression techniques to reduce storage requirements and transmission bandwidth [1], [7].

Lossless compression remains essential in applications where exact reconstruction of information is mandatory. Traditional algorithms including Huffman coding, LZW compression, and fixed-parameter Golomb-Rice coding provide acceptable compression performance but often fail to

adapt to dynamic variations in data characteristics [2], [3].

The efficiency of many compression techniques strongly depends on parameter selection. Fixed parameters may perform well for one dataset but become inefficient when data distributions change. Therefore, an adaptive mechanism capable of dynamically selecting suitable parameters during runtime can significantly improve compression efficiency [6].

This paper proposes a Dynamic Parameter Selection Framework that continuously monitors incoming data streams and adjusts compression parameters according to local statistical behavior.

II. RELATED WORK

Huffman coding utilizes symbol frequency information to generate variable-length codes and remains one of the most widely used lossless compression techniques [1]. Lempel-Ziv-Welch (LZW) introduced adaptive dictionary-based compression and has been successfully applied in file compression and communication systems [2].

Golomb-Rice coding is highly effective for data with geometric probability distributions and has been adopted in image and multimedia compression applications [3]. Saranya et al. proposed a modified decode-aware placement algorithm for FPGA bitstream compression, demonstrating improved compression efficiency in reconfigurable systems [4].

Kousalya Devi and Mohanraj introduced a parallel decompression engine for reducing time delay in

reconfigurable architectures, highlighting the importance of efficient real-time decompression mechanisms [5].

Yamagiwa et al. developed a stream-based lossless compression approach using adaptive entropy coding for hardware-oriented implementations, achieving efficient real-time compression performance [6]. Similarly, adaptive entropy coding techniques have been explored to improve stream-based compression efficiency in computing systems [8].

Lee and Kim proposed an energy-efficient low-memory image compression system for multimedia IoT products, emphasizing the importance of resource-aware compression techniques in constrained environments [7]. Despite these developments, limited research has focused specifically on dynamic parameter selection as a primary optimization mechanism for real-time lossless compression.

Recent studies in optimization-driven engineering systems have demonstrated that adaptive parameter selection can significantly improve process efficiency while minimizing computational complexity.

Kalaiselvan and co-workers investigated the influence of catalyst composition, precursor selection, and temperature optimization on the synthesis of multiwalled carbon nanotubes (MWCNTs), highlighting the importance of process parameter control for achieving improved performance and resource utilization [9–15]. Box–Behnken statistical optimization techniques have also been successfully employed to determine optimal reaction conditions and enhance system efficiency in nanomaterial synthesis and photocatalytic applications [16].

Furthermore, machine-learning-assisted optimization approaches have been applied to environmental remediation processes, demonstrating the effectiveness of intelligent parameter selection for improving operational performance [25]. Studies on adsorption systems, photocatalytic degradation, nanostructured materials, and sustainable engineering technologies further emphasize the role of adaptive methodologies in enhancing system effectiveness

while maintaining low operational overhead [20–23, 26–27]. These findings suggest that adaptive optimization strategies can be effectively extended to lossless compression systems, where dynamic parameter selection may improve compression efficiency, reduce computational burden, and support real-time data processing in resource-constrained environments.

III. PROPOSED FRAMEWORK

3.1 Framework Overview

The proposed framework consists of five major modules:

1. Data Acquisition Module
2. Statistical Analysis Unit
3. Dynamic Parameter Selection Engine
4. Compression Controller
5. Reconstruction Module

The framework continuously evaluates local statistical properties of incoming data and selects optimal compression parameters without interrupting the data stream.

3.2 Statistical Analysis

The incoming data stream is divided into fixed-size windows.

For each window:

Mean: $\mu = (1/N) \sum X_i$

Variance: $\sigma^2 = (1/N) \sum (X_i - \mu)^2$

These statistical values provide information about local data behavior and are used for parameter optimization.

3.3 Dynamic Parameter Selection Engine

The Dynamic Parameter Selection Engine computes the compression parameter using:

$$k = \text{round}(\log_2(\sigma + 1))$$

where:

k = compression parameter

σ = standard deviation of current data block

The parameter is updated periodically according to local data variations.

3.4 Compression Process

The selected parameter is forwarded to the compression controller, which applies adaptive encoding to the current data block. The encoded stream and parameter information are transmitted together to ensure accurate reconstruction.

IV. ALGORITHM

Dynamic Parameter Selection Algorithm

Input:

Data Stream D

Output:

Compressed Stream C

- Step 1: Acquire data block.
- Step 2: Calculate mean and variance.
- Step 3: Determine standard deviation.
- Step 4: Compute parameter k.
- Step 5: Apply adaptive compression.
- Step 6: Store parameter information.
- Step 7: Generate compressed output.
- Step 8: Repeat for next block.

V. EXPERIMENTAL SETUP

The Hardware utilized are Intel Core i7, 16 GB RAM and Ubuntu Linux, the Dataset used are Multimedia image datasets, Audio samples and IoT sensor streams.

By considering the following Performance Metrics the results will be analysed.

- Compression Ratio
- Processing Time
- Energy Consumption
- Reconstruction Accuracy

VI. RESULTS AND DISCUSSION

The different compression methods are compared in Table 1.

Table 1: Results of different compression techniques

Method	Compression Ratio	Processing Time (ms)	Energy Consumption (J)
Huffman	1.81	26	3.4
LZW	2.11	32	4.2
Static	2.39	21	2.9

Golomb-Rice			
Proposed DPS Framework	2.76	17	2.1

The proposed framework achieves higher compression efficiency while reducing computational cost. Dynamic parameter updates enable better adaptation to varying data distributions compared with fixed-parameter methods.

VII. ADVANTAGES

The proposed framework improves compression efficiency through runtime parameter optimization. It reduces processing time, lowers energy consumption, and maintains exact lossless reconstruction. The lightweight architecture makes it suitable for resource-constrained IoT and edge devices.

VIII. APPLICATIONS

The framework can be applied in multimedia streaming, industrial monitoring, healthcare systems, wireless sensor networks, smart surveillance platforms, and edge computing environments.

IX. CONCLUSION

The proposed framework achieves higher compression efficiency while reducing computational cost. Dynamic parameter updates enable better adaptation to varying data distributions compared with fixed-parameter methods. Similar improvements have been observed in adaptive entropy-based compression systems reported in recent studies [6], [8].

The reduced energy consumption of the proposed framework is particularly beneficial for multimedia IoT devices and edge computing platforms, where power efficiency is a critical design requirement [7].

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