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A Survey On Recent Research Trends Towards Compression Of Image Using DPCM

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Abstract: Efficient image compression is essential for minimizing storage requirements and reducing transmission bandwidth while preserving the visual quality of reconstructed images. Among the various compression techniques there is a Differential Pulse Code Modulation (DPCM) represents an effective predictive compression approach has gained considerable attention so because of its predictive coding mechanism, which utilizes the spatial dependency among the adjacent pixels by encoding prediction errors rather than absolute pixel values. This approach effectively reduces data redundancy by maintaining low computational complexity, making it well suited for real-time image computing applications.

This paper presents a detailed review of DPCM-based image compression methods, including their operating principles, prediction techniques, hardware architectures, and performance evaluation. It also discusses recent improvements in adaptive and hybrid DPCM approaches that enhance compression efficiency and reconstructed image quality. Furthermore, the study compares existing research based on compression performance, hardware resource utilization, implementation complexity, and processing speed. Finally, current research challenges, emerging trends, and future opportunities involving intelligent prediction methods, machine learning, and next-generation image coding techniques are highlighted. The review concludes that DPCM continues to be a practical, efficient, and hardware-friendly approach for real-time image compression applications.

Keywords: Differential Pulse Code Modulation (DPCM), comparative analysis, Image compression, Wavelet Transform, Biomedical Signal Processing, Real-Time Signal Processing, Sustainable Healthcare, Wearable Healthcare.

1. INTRODUCTION

The rapid advancement of digital imaging technologies has significantly increased the demand for efficient image storage and high-speed data transmission. Since high-resolution images require substantial memory and communication bandwidth, image compression has become a fundamental component of modern multimedia systems. The primary objective of image compression is to reduce the amount of data required to represent an image while preserving its visual quality. Compression methods are generally classified into lossless and lossy techniques.

Differential Pulse Code Modulation (DPCM) is one of the earliest predictive image compression methods and remains widely used because of its simplicity and efficiency. Instead of transmitting complete pixel values, DPCM encodes the difference between the predicted and actual pixel values by exploiting the strong correlation among neighboring pixels. This strategy effectively reduces spatial redundancy, resulting in lower bit rates and improved compression efficiency. Owing to its low computational requirements and straightforward hardware implementation, DPCM has been applied in image transmission, medical imaging, satellite communication, and video coding. Although modern standards such as JPEG, JPEG2000, and learning-based compression methods provide higher performance in many applications, DPCM continues to serve as an important foundation for predictive image compression and hardware-accelerated imaging systems.

2. LITERATURE REVIEW

Image compression has been an active research area due to the increasing demandtransmission in multimedia, medical imaging, remote sensing, a for high-capacity storage and rapid image data transfer alond with emerging Internet

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of Things (IoT) technologies. Differential Pulse Code Modulation (DPCM) is well-known as an effective predictive coding technique. It uses the high spatial dependency among adjacent pixels by encoding prediction errors instead of absolute pixel values. Early studies showed that DPCM significantly reduces data redundancy while maintaining low computational needs, making it suitable for real-time image compression systems. However, traditional DPCM algorithms use fixed linear predictors, which often result in poor reconstruction quality, particularly when processing image containing intricate texture and sharp edges.

To address these challenges, several advanced approaches were introduced Adaptive Differential Pulse Code Modulation (ADPCM), an enchanced predictive coding method where predictor coefficients adjust dynamically based on local image statistics. Adaptive prediction significantly enchances image compression performance compression efficiency and the quality of reconstructed images by reducing prediction errors across different image regions. Several studies report that ADPCM higher PSNR values together with reduced MES values to compared the traditional DPCM while maintaining low computational demands.

Later studies have focused on combining DPCM with transform-domain compression techniques to boost coding efficiency. Hybrid methods that pair DPCM with the transforms-based methods such as Discrete Cosine Transform (DCT) and the Discrete Wavelet Transform (DWT), and entropy coding techniques such as Huffman coding, Arithmetic coding, and Run-Length Encoding (RLE) have shown improved compression ratios without significantly degrading the quality of reconstructed images. These techniques effectively utilize both spatial and frequency-domain redundancies, making them suitable for high-resolution image compression applications.

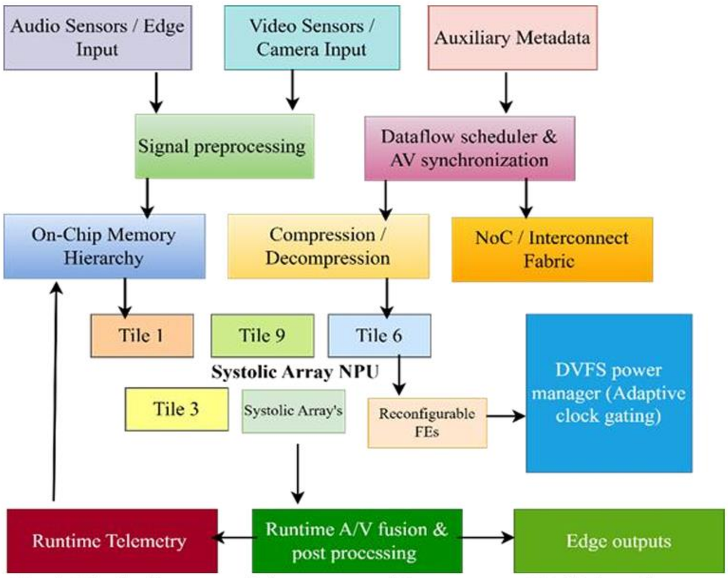
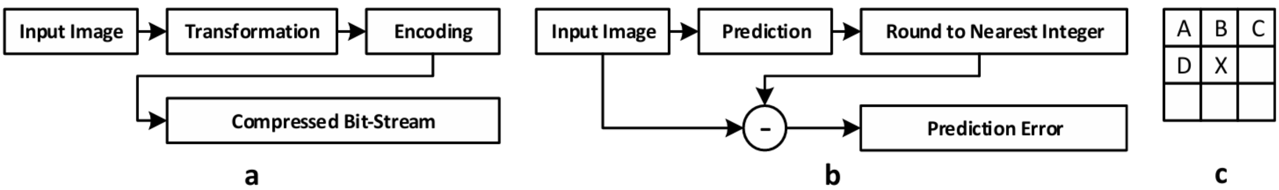


Fig.1 Block diagram of Low power VLSI Accelerator

With the rising demand for real-time image processing, hardware acceleration has emerged as a major ares of research. FPGA-based implementations of DPCM have attracted widespread attention because of their parallelism, low processing latency, predictable execution, and energy efficiency. Recent IEEE research has reported optimized FPGA architectures that use pipelining, parallel processing, and resource-sharing techniques to improve throughput while reducing resource utilization use and power consumption. These implementations are especially suited for embedded vision systems, medical imaging devices, autonomous platforms, and edge-computing applications that require real-time performance. Recent advances also explore combining DPCM with artificial intelligence and deep learning methods. AI-driven image compression models use CNN-based neural networks architectures, autoencoders, and transformer-based architectures to achieve significantly greater compression performance and reconstructed image quality than traditional predictive coding



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methods. However, these approaches often demand high substantial computing resource, extensive trainig data, and dedicated hardware accelerators, limiting their use in low-power embedded systems. As a result, DPCM-based architectures remain appealing for applications where hardware simplicity, consistent performance, and energy efficiency are crucial design factors.

Recent IEEE publications (2022–2025) have further examined adaptive prediction models, hardware-aware compression algorithms, and AI-assisted predictive coding frameworks for edge devices. Current research emphasizes lowering implementation complexity, enhancing compression performance, minimizing power use, and increasing compatibility with diverse computing platforms. Although learning-based image compression has become a highly effective alternative approach, DPCM continues to achieve an effective trade-off between computational needs, compression efficiency, and hardware implementation costs, particularly for FPGA-based and VLSI-based real-time image processing systems. These findings underscore the necessity for continued investigation of adaptive and intelligent DPCM architectures that combine the ease of predictive coding with the performance benefits of modern machine learning techniques.

3. RESEARCH GAP

Although considerable research has been conducted on Differential Pulse Code Modulation (DPCM), several challenges remain. Most traditional DPCM algorithms use fixed prediction models, which struggle with images that have complex textures, sharp edges, or rapidly changing intensity values. While adaptive prediction techniques have enhanced image compression performance, they often increase computational demands, making them unsuitable for resource-limited systems. Moreover, many existing studies primarily emphasize improving compression efficiency while paying less attention to perceptual image quality and visual fidelity. However, limited research has compared DPCM thoroughly with contemporary compression standards like JPEG2000, HEVC-based coding, and deep learning-based methods using standardized datasets and evaluation metrics. There is also relatively little work on creating lightweight DPCM algorithms optimized for IoT devices, edge computing platforms, and real-time embedded systems. These gaps point to the importance of developing adaptive, resource-aware, and intelligent DPCM-based image compression methods that can meet the requirements of modern image processing applications.

Although Differential Pulse Code Modulation (DPCM), a predictive image coding approach has been widely studied as an efficient predictive image compression method, several research challenges remain. Most conventional DPCM algorithms rely on fixed prediction prediction models that show limited performace when processing an image that have complex textures, sharp edges, and high-frequency details. While adaptive and hybrid DPCM techniques have improved image compression efficiency and reconstruction quality, they often increase computational demandsthere by reducing their effectiveness in real-time and resource-constrained applications. Additionallya large proportion of existing research primarily concentrates on grayscale images with limited exploration into color, high-resolution, multispectral, and hyperspectral image compression. The strength of DPCM under noisy image conditions and varying image characteristics has also received too little attention.

4. FUTURE SCOPE

Future research on DPCM-based predictive image compression techniques can aim enhance prediction precision without significantly increasing computational demands low. Integrating DPCM with artificial intelligence, including machine learning and deep learining methods techniques can develop intelligent predictors that adapt to various image characteristics and improve compression efficiency. Hybrid compression frameworks combining DPCM with advanced transform techniques, such as the Discrete Wavelet Transform, Discrete Cosine Transform, and advanced entropy encoding methods, can further enhance image compression performance while maintaining high reconstructed image quality.

Additionally, optimized hardware implementations using FPGA, ASIC, and System-on-Chip (SoC) technologies can enable real-time, energy-efficient image compression for embedded systems and portable devices. Future studies may also explore DPCM applications in high-resolution imaging, medical image compression, satellite imaging, hyperspectral imaging, and IoT environments, where effective bandwidth use and low power consumption are critical. Moreover, incorporating perceptual quality metrics and AI-based optimization techniques could help create next-generation predictive image coding frameworks that achieve a better trade-off among compression ratio, computational efficiency, and image quality.

5.CONCLUSION

DPCM-based predictive image compression remains among the most established basic predictive coding techniques in image compression because of its simplicity, low computational needs, and effective reduction of spatial redundancy.

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Over the years, numerous studies have introduced adaptive prediction methods, hybrid compression schemes, and hardware implementations to improve compression performance and the quality of reconstructed images. While modern transform-based and deep learning-based compression techniques generally achieve higher compression ratios and better visual quality, DPCM continues to be relevant for applications needing low-cost implementation, real-time processing, and limited computational resources. Addressing existing research gaps through adaptive prediction algorithms, hybrid coding strategies, and intelligent optimization methods can further enhance the efficiency and applicability of DPCM. Thus, DPCM remains a crucial foundation for predictive image compression and continues to inspire the development of advanced image coding techniques for future multimedia and communication systems.

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