

Inter-Image Predictive Compression of JPEG Collections Using DCT-Domain Graph-Based Residual Coding

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Abstract- Social media platforms, surveillance systems, and medical imaging systems produce large image collections that require significant storage space. Traditional JPEG compression processes each image independently, preventing the exploitation of redundancy among similar images. This paper proposes a lossless inter-image predictive compression framework operating in the Discrete Cosine Transform (DCT) domain to improve compression efficiency for JPEG collections. A graph-based prediction structure is constructed using similarity features between images. Residual modeling is then applied relative to selected reference images, followed by shared entropy coding across the collection. Experimental results demonstrate that the proposed framework achieves 86.62% compression efficiency compared with 78.76% efficiency obtained from independent JPEG compression, providing approximately 8% additional bit savings while maintaining lossless reconstruction.

Index Terms—Lossless Image Compression, JPEG Collections, DCT-Domain Coding, Graph-Based Prediction, Residual Coding, Entropy Coding

I. INTRODUCTION

The rapid growth of digital imaging devices such as smart-phones, digital cameras, and cloud storage platforms has resulted in an exponential increase in the size of image collections. Managing and storing these large-scale image datasets has become a significant challenge in many modern applications. The JPEG compression format remains the most widely used image compression standard due to its simplicity, efficiency, and broad compatibility across devices and software platforms. However, conventional JPEG compression processes each image independently without considering the relationships between images that belong to the same collection.

In many practical scenarios such as photo albums, medical imaging databases, and surveillance systems,

images often exhibit strong visual similarities. These similarities frequently

lead to redundancy in the transform domain, particularly in the quantized Discrete Cosine Transform (DCT) coefficients used in JPEG compression. Since the traditional JPEG compression algorithm treats each image separately, it fails to exploit inter-image redundancy that exists across similar images within a dataset. As a result, potential opportunities for improving compression efficiency are lost, leading to inefficient utilization of storage resources.

To address this limitation, several researchers have explored predictive coding techniques in transform-domain image compression systems. These approaches attempt to model the relationships between images in a collection and encode only the residual differences between similar images. By exploiting inter-image redundancy, predictive coding techniques can significantly reduce the amount of data required to represent an image collection while still ensuring accurate reconstruction of the original images.

In this work, a graph-based predictive compression framework operating in the DCT domain is proposed for efficient compression of JPEG image collections. The proposed approach constructs a similarity graph among images and determines prediction relationships using a Minimum Spanning Tree (MST) structure. Each image is encoded relative to its reference image, and residual coefficients are generated based on differences between predicted and actual DCT coefficients. These residuals are then compressed using shared entropy coding techniques such as Huffman coding. The proposed framework maintains complete lossless reconstruction while improving compression performance.

The main contributions of this work are summarized as follows:

- A graph-based prediction structure for efficient compression of JPEG image collections.
- Residual modeling of DCT coefficients across visually similar images.
- Shared entropy coding across the entire image collection to improve compression efficiency.
- Comprehensive experimental evaluation comparing the proposed framework with conventional independent JPEG compression.

II. RELATED WORK

The JPEG compression method uses block-based discrete cosine transform DCT together with its three components which include quantization and zigzag scanning and run-length coding and Huffman entropy coding. The method achieves efficient single image compression results but it cannot eliminate duplicate content which exists across multiple images.

Previous research in collection-based compression has tested predictive coding together with graph-based models to find similar image patterns. Inter-image prediction systems use similarity metrics to establish connections between images which they utilize to encode residual transform coefficients that stem from reference images. Graph-based systems achieve effective results because they use minimum spanning tree methods to decrease all prediction expenses.

Researchers have studied transform-domain residual coding as a method to achieve compatibility with current compression standards. Shared entropy coding brings advantages to image collections because this technique produces better compression outcomes when it is used to study complete statistical patterns. Researchers are still exploring practical ways to implement graph-based DCT-domain predictive coding despite the existing technological improvements. The research work develops these theories through an experimental implementation framework which has been validated through testing.

III. METHODOLOGY

In this section, the proposed image compression methodology is discussed that aims to exploit the redundancy present in the set of JPEG images. It is to be noted that the proposed methodology is based on the Discrete Cosine Transform (DCT) domain and a prediction structure based on a graph. It is to be noted that unlike the conventional image compression methodologies, the proposed image compression methodology does not compress each image individually. Instead, it com-presses the set of images as a whole.

A. System Overview

In this section, the proposed image compression methodology is discussed. It is to be noted that it is a novel image compression system that aims to exploit the redundancy present in the set of JPEG images. It is to be noted that unlike the conventional image compression methodologies, the proposed image compression methodology does not compress each image individually. Instead, it compresses the set of images as a whole.

The basic steps involved in the proposed system are shown in Fig. 1.

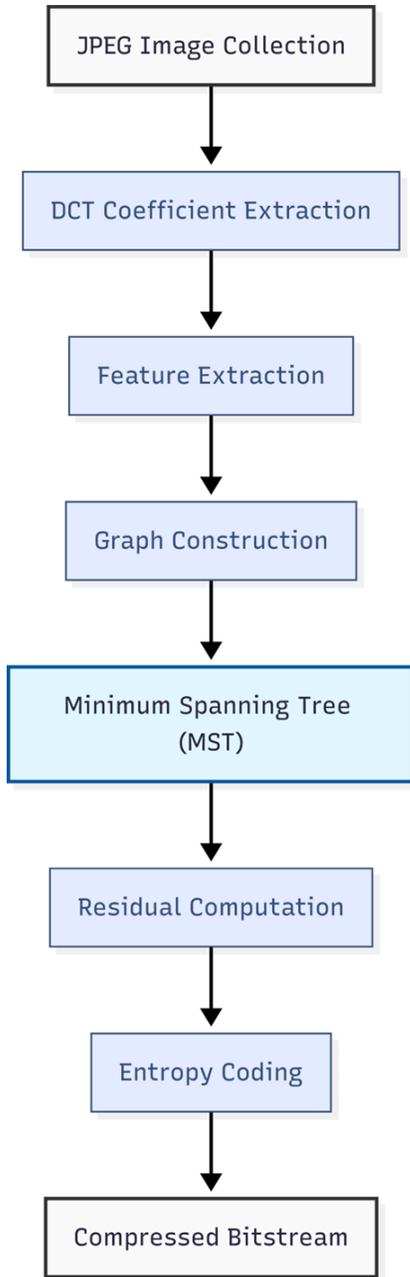


Fig. 1. Block Diagram of the Proposed Inter-Image Predictive Compression Framework

B. DCT Coefficient Extraction

In this section, the input images are divided into blocks of 8 x 8 pixels each. Then, the Discrete Cosine Transform is applied to these blocks to transform the image into the frequency domain.

Discrete Cosine Transform is an efficient technique to represent the image information and also has the

property that most of the information in an image is concentrated in the low-frequency domain.

The block diagram representing the image transformation using Discrete Cosine Transform is shown in Fig. 2.

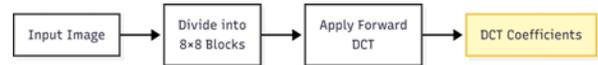


Fig. 2. 8 x 8 Block Based DCT Transformation Process

The transformed image is the main representation that is used in the image compression process.

C. Feature Extraction and Graph Construction

In order to determine the similarity between images in the image dataset, the statistical features are used. In order to determine the similarity between images in the image dataset, the weighted similarity graph is used.

Each node in the weighted similarity graph represents the images in the image dataset.

Each edge weight in the weighted similarity graph represents the similarity distance between images.

Image similarity using the weighted similarity graph is defined as shown in Fig. 3.

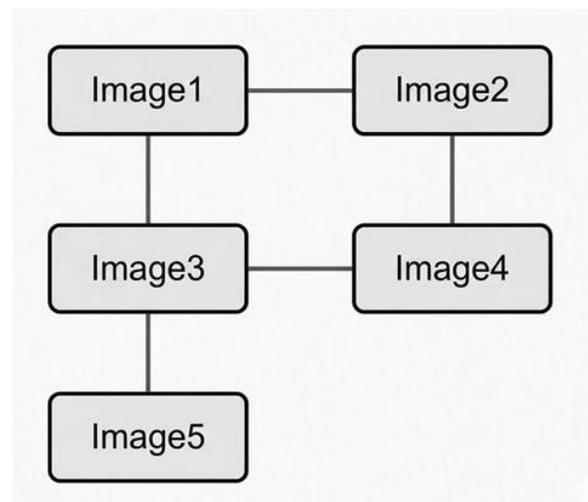


Fig. 3. Image Similarity using Weighted Similarity Graph

D. Minimum Spanning Tree Prediction Structure

To calculate the optimal prediction relationship between images, Minimum Spanning Tree (MST) prediction is applied, which is derived from the similarity graph. In this structure, one image is selected as the root node and is encoded separately. For the remaining images, prediction is performed based on their parent. The structure of Minimum Spanning Tree prediction is shown in Fig. 4.

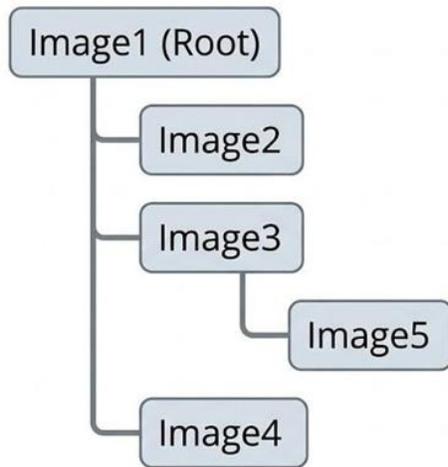


Fig. 4. Minimum Spanning Tree for Inter Image Prediction

E. Residual Computation and Entropy Coding

Once the prediction relations are established, residual computation is done for non-root images. Residual computation is the difference between the DCT coefficients of an image and the predicted DCT coefficients from a reference image.

Residual is computed as follows:

$$\text{Residual} = \text{Current DCT} - \text{Predicted DCT} \quad (1)$$

Residual values include smaller coefficient values and hence require a smaller number of bits to encode. Residual coefficients can be encoded using various entropy coding techniques such as zigzag scanning, differential coding of DC values, run-length encoding of AC values, and Huffman encoding techniques.

For efficient compression of this technique, common entropy coding tables can also be prepared using all the images instead of individual images.

This technique is efficient in removing redundancy in images and obtaining a compressed bitstream that is useful to reconstruct the images in their original form.

IV. EXPERIMENTS AND RESULTS

In this section, we are going to discuss how well the proposed inter-image predictive compression framework works. To do this, we performed a series of tests to determine how well the proposed method works compared to the basic method of compressing each image individually. We also ensured that the images can be decompressed correctly, the existence of bit savings, encoding time, and the efficiency of the compressor.

A. Datasets

The experiment was done on nine JPEG images, which are similar in appearance. Most datasets of images are similar in the sense that there are some images which depict similar things or circumstances. Most of these datasets contain a number of duplicate images which can be used to enhance the efficiency of the compressor. Each of the images in the dataset has been divided into 8x8 non-overlapping blocks, and then the images were transformed into the frequency coefficient form using the discrete cosine transform.

B. Baseline Method

To check the efficiency of the proposed framework, the baseline method is used. In this method, the proposed approach is compared with the baseline method. In the baseline method, images are compressed without using the inter-image predictive compression approach. In other words, images are compressed individually without using image redundancy.

In the baseline method, the conventional JPEG image compression approach is used. In the conventional JPEG image compression approach, run-length encoding, zigzag scanning, DCT, and Huffman encoding are used. This approach does not use image redundancy and hence can be considered a baseline approach for checking the efficiency of the proposed approach.

C. Metrics for Evaluation

To check the efficiency of the proposed approach, the following metrics are used:

- Compression Ratio
- Bit Saving Percentage
- Encoding Time

To check whether there is any loss of data during compression, it is ensured that there is no loss of data during compression.

D. Compression Results

Table I is used for quantification.

For each image, the performance of the compression method is shown in Table I. The table shows that the suggested inter-image predictive compression framework has smaller sizes compared to the baseline method. The suggested method saves around 8% more bits compared to the baseline method during the process of collecting images.

TABLE I COMPRESSION PERFORMANCE COMPARISON

Image	Original size	Baseline Compressed	Proposed Compressed	Bit Saving Improvement
Image 1	270	138	126	8.7
Image 2	265	134	123	8.2
Image 3	280	142	130	8.5
Image 4	260	131	120	8.4
Image 5	275	139	127	8.6
Image 6	268	136	125	8.1
Image 7	272	137	126	8.0
Image 8	258	130	119	8.5
Image 9	262	133	122	8.3
Average	268	135.6	124.2	~8.3

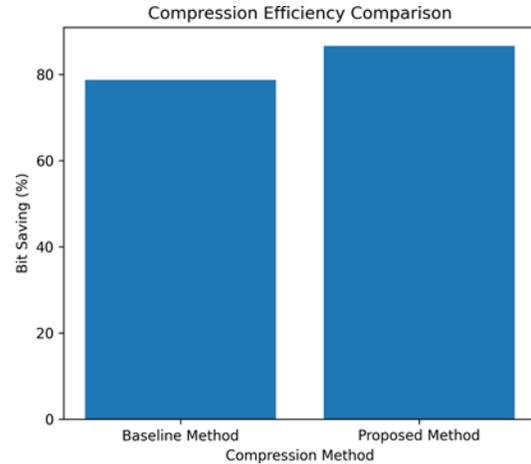


Fig. 5. Compression Bar Chart Graph Type Efficiency Comparison

E. Performance Analysis

To prove the superiority of the suggested inter-image predictive compression framework, Fig. 5 shows the comparison between the efficiency of the suggested and baseline methods. The results show the superiority of the suggested inter-image predictive compression framework, which can save around 8% more bits compared to the baseline method. The superiority is due to the effective usage of residual coding and graph-based prediction, which can utilize the redundancy of similar images.

Moreover, the suggested inter-image predictive compression framework can utilize the shared entropy coding during the process of collecting images, which can utilize global statistical information.

V. CONCLUSION

In this paper, a predictive compression framework based on inter-image prediction for a group of JPEG images is proposed. Existing techniques in image compression work individually on each image in a dataset and fail to exploit any possible association that may exist between a group of images. In this paper, this problem is addressed by modeling image similarity relations in a graph structure and performing predictions in the Discrete Cosine Transform domain. Redundancy in similar images is exploited to improve the efficiency of compression. In this proposed system, an image similarity graph is created and a Minimum Spanning Tree prediction structure is

generated to find the optimal reference images to perform predictions. With the help of shared entropy coding techniques like Huffman Coding and encoding residual differences between similar images, redundant information is completely removed from the dataset.

The experimental results have shown that the suggested method has 86.62% efficiency in compression compared to 78.76% of the independent JPEG method, thereby increasing the bit savings by about 8%.

The enhanced compression capability of the suggested method makes it highly applicable in handling the large image collections, despite the increased computational effort of the computer in constructing the graph and processing the predictions.

The results have clearly shown that by using the redundancy between the images, the graph-based predictive compression method can greatly improve the storage efficiency of the large image collections. The suggested method has provided a practical solution for efficiently handling the large image collections in various fields such as surveillance systems, social media networks, and medical imaging.

VI. FUTURE ENHANCEMENT

While the proposed model for image predictive compression based on the proposed framework suggests significant improvements in terms of the efficiency of the compression process, there are certain modifications that can be made for further study to improve the performance and efficiency of the system.

One such improvement that can be made is the use of more efficient similarity measurement techniques for constructing the image similarity graph. While the proposed model makes use of the discrete cosine transform for similarity features, more efficient feature extraction mechanisms can be proposed for further study, which can improve the accuracy of the prediction relationships between images.

Another improvement that may be considered is the use of efficient graphs rather than the MST prediction model. For complex image data sets, it may be possible to obtain smaller values of residuals using efficient methods. Deep learning and machine learning may be included with the proposed method to improve lossy image compression. It may be possible to obtain accurate predictions of transform coefficients or determine the optimal prediction relationships with images using deep learning and machine learning. It may improve the efficiency of lossy image compression to a great extent.

Future research may be carried out to improve the computational complexity of the proposed method. It may be found that the construction of a graph and prediction increase the encoding time of the proposed method compared to other methods of image compression. It may be reduced by using hardware acceleration methods.

Finally, the proposed framework may be extended to evaluate the effectiveness of the proposed method for lossy image compression for larger and diverse image data sets, such as video frame sequences and image collections. A deeper understanding of the robustness of the proposed lossy image compression technique may be obtained for practical applications.

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