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IMAGE COMPRESSION BASED ON HYBRID BIT-PLANE CODING

Abstract
for a Master's Degree
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INTRODUCTION

Image compression has always been highly valued in the field of image processing. From the 70s to the present day, image compression has undergone a revolution and innovation. From lossless encoding such as run length encoding in the early days, and lossy encoding such as Joint Photographic Experts Group, to hybrid encoding now, image data compression technology will continue to evolve in the future to meet the requirements of higher compression ratio, lower distortion, and faster processing speed.

Hybrid coding for image compression refers to a technique that combines multiple compression methods to compress an image. The purpose of hybrid coding is to reduce the file size while maintaining the quality and detail of the image as much as possible by taking full advantage of the advantages of different compression methods. There are many ways to combine hybrid compression encoding, and hybrid encoding can be combined with a variety of lossless compression encoding methods. At the same time, it can also be compressed through a combination of lossless and lossy compression encoding to achieve the target requirements.

The aim of this paper is to study the feasibility of a compression algorithm for lossless coding hybrid of bit plane-based images. The task of work is to design and conduct hybrid coding experiments. Firstly, this paper discusses the research status and development process of image compression, analyzes and studies bit plane compression and bit plane compression algorithms, discusses the advantages of using Python as a development language, and analyzes the methods and means of bit-plane hybrid coding. The bit plane based hybrid compression coding algorithm first converts the image into a grayscale map and decomposes it into the image bit plane, then designs an image hybrid compression coding algorithm based on bit plane by combining run length encoding and arithmetic coding, and uses the self-built database to test the dynamic environment to obtain the compressed data, and finally the experimental results are studied, the comprehensive compression ratio of the hybrid coding, as well as the temporal and spatial complexity, the compression ratio is studied and compared, and the advantages and disadvantages of the hybrid compression coding are analyzed. This gives a comprehensive understanding of the characteristics of hybrid coding.

GENERAL DESCRIPTION OF WORK

Relevance of the subject

The work corresponds to paragraph 1 «*Digital information and communication and interdisciplinary technologies, production based on them*» of

the State Program of innovative development of the Republic of Belarus for 2021–2025. The work was carried out in the educational institution Belarusian State University of Informatics and Radioelectronics.

The aim and tasks of the work

The aim of the work is to study the properties of hybrid coded compression based on bit-plane, which in turn improves the methods of image compression processing and improves the quality of image compression.

To achieve this aim, the following tasks were solved in the dissertation:

1 Collect and organize literature related to bit-plane compression;

2 Categorize and summarize planar compression methods;

3 Preparation of self-built database;

4 Design and conduct hybrid coding experiments;

5 Analyze and summarize the results of the experiment.

Personal contribution of the author

In this paper, the authors systematically categorize the bit-plane compression algorithms, as well as propose the idea that hybrid coding will improve the efficiency of image compression. From there, experiments are designed, a self-constructed database is built, hybrid coding experiments are conducted using python for scientific justification, the compression characteristics of the mixture of run length and arithmetic coding are studied, the efficiency of the developed algorithms is evaluated, the results obtained are processed and analyzed, and conclusions are drawn.

Structure and size of the work

The dissertation work consists of introduction, general description of the work, three chapters, conclusion, bibliography. The total amount of the thesis is 83 pages, of which 68 pages of text, 53 figures, 1 table, a list of used bibliographic sources, a list of the author's publications on the subject of the thesis.

Plagiarism

An examination of the dissertation « *Image compression based on hybrid bit-plane coding*» by Ying Wang was carried out for the correctness of the use of borrowed materials using the network resource «Antiplagiat» (access address: https://antiplagiat.ru) in the online mode 22.05.2024. As a result of the verification, the correctness of the use of borrowed materials was established (the originality of the thesis is 91.34%).

SUMMARY OF WORK

The introduction addresses the problems of feasibility of image compression using hybrid coding based on bit plane.

The general description of work shows the connection between the work and the priority areas of scientific research, the aim and tasks of the research, the personal contribution of the applicant for a scientific degree, the approbation of the dissertation results.

In the first chapter**,** background related to image compression is presented. This includes the background of research on image compression, its development, academic status, and the programs and application used for image compression.

Image compression is an important area of research whose background can be traced back to the increasing demand for digital media transmission and storage. Images are used in all areas of human existence. These image data will encounter various problems in the transmission, such as the limitation of channel bandwidth, which puts forward higher requirements for the transmission of images, requires the use of limited resources, solves the contradiction between the input data bit rate and the transmission channel bandwidth, and makes the image transmission have higher accuracy, reliability and real-time.

Therefore, researchers are committed to finding compression methods that can effectively reduce the size of image files to meet the needs of efficient transmission and storage. In recent years, image compression techniques have developed greatly in the fields of fractal coding, wavelet transform coding, vector quantization coding and other techniques. Image compression technology is constantly being improved by human beings, and is developing towards better compression quality and higher compression efficiency. With the support of new technologies, the future of image compression technology is worth looking forward to.

Python is a widely used interpreted, high-level, and general-purpose programming language. Python language and pycharm are used as software to develop compression based on bit plane hybrid coding. Write and implement code through pycharm. First, through the import of bitmaps, and then preprocessing, the bitmaps are converted, normalized, and converted into grayscale maps. After the image is preprocessed, the image is further segmented to make the image become an eight-layer bit plane map, and then the bit plane is mixed and encoded to complete the basic process of compression based on bit plane hybrid coding. Finally, the decoding of hybrid coding is carried out to restore the image to the original grayscale map.

In the second chapter, performance metrics of image compression, image gray scale transformation, bit plane compression algorithms and the concept of bit plane compression and scanning of the image are introduced.

Image compression refers to reducing the size of an image file by reducing the redundancy and imperceptible details of image data. The many data compression techniques can be divided into two main types according to the degree of distortion of compression: lossless compression and lossy compression.

Lossless compression refers to the use of compressed data for reconstruction (or restoring or decompressing) to obtain data that is the same as the original data. The common lossless coding algorithms are Huffman coding, arithmetic coding, run length encoding, etc. Lossy compression is suitable for situations where the reconstructed signal does not necessarily have to be the same as the original signal, because they often contain more information than our visual and auditory systems can receive.

Image compression parameters includes compression ratio, compression factor, compression gain and compression speed, etc. In the process of image compression, the spatial complexity and time complexity are commonly used to evaluate the algorithm.

In image preprocessing, the gray transformation of the image is an important means of image enhancement, the gray transformation can make the image contrast expand, the image is clear, the characteristics are obvious, the gray transformation mainly uses the point operation to correct the pixel grayscale, and the gray value of the corresponding output point is determined by the gray value of the input pixel, which is an operation based on image transformation. In the digital image, the pixel is the basic unit of representation, the brightness of each pixel is identified by the gray value, only contains brightness information, and the image without color information is called the gray image.

A bit plane map model of an image is a method used to represent and analyze images. In this model, each pixel value of an image is represented as a binary form, and each binary bit (bit) is processed and analyzed as an independent plane.

Bit plane scans can be performed in different scanning sequences, the most common of which is bit-by-bit scanning. Row scan is a common type of bit plane scanning that traverses the pixels of an image one by one in the order of rows (Figure 1). Hilbert Scan is one of the most common bit plane scanning methods that involves sequentially traversing the pixels of an image through a curved path (Figure 2). Morton Scan, also known as Z-scan, is an algorithm for bit plane scanning that traverses the pixels of an image sequentially through a curved path (Figure 3).

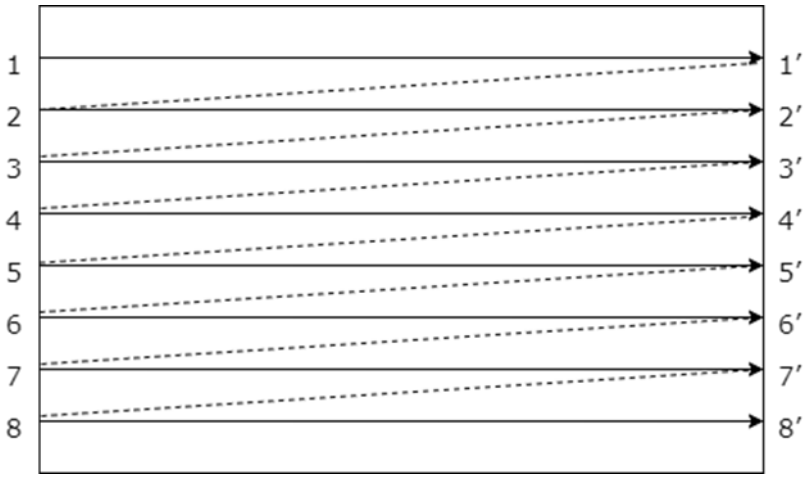

Figure 1 – Row scan sequence

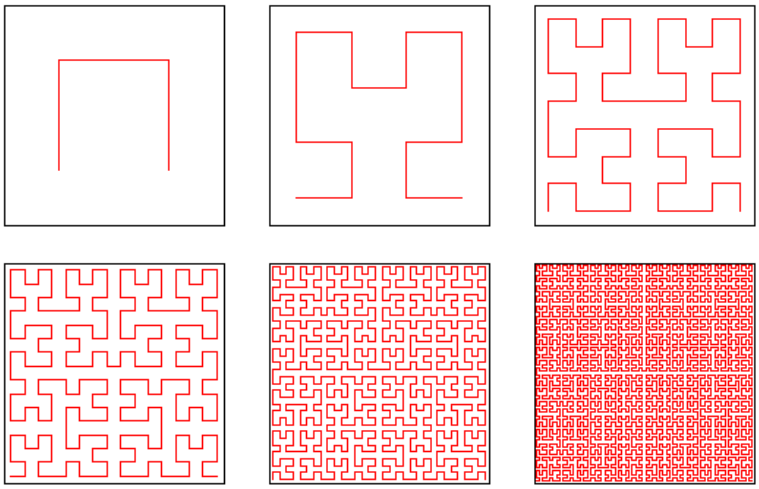

Figure 2 – Schematic diagram of the static scanning sequence of the Hilbert curve

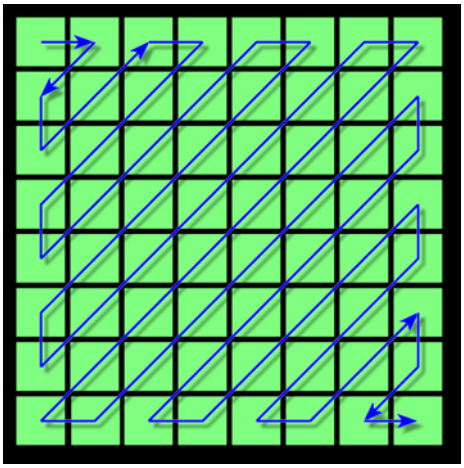

Figure 3 – Schematic diagram of the Z font scanning matrix

In the third chapter, the feasibility of hybrid coding to compress images is tested. Experiments are first designed to combine arithmetic coding and run length encoding. Then a self-built database of 200 images was prepared by camera and by taking or downloading public image data on the internet to ensure the completeness and comprehensiveness of this experiment. Finally, the properties of this hybrid coding were tested in python environment. The generated results are analyzed with arithmetic coding and run length encoding one by one comparison method.

After testing the bit plane-based hybrid compression coding using the images of the self-built database, it can be found that as shown in Figure 4, compared with the single run length encoding and arithmetic coding, the comprehensive compression ratio of the hybrid coding is much better than that of the single run coding or arithmetic coding, and the compression ratio of most images can be stably maintained between 61 % and 68 %. The comparison results are shown in Figure 5 below. It shows that the hybrid compression algorithm based on bit plane can maintain stable compression performance on different types of images. By importing 200 images from the self-built database, the comprehensive compression rate of the hybrid coding is 64.65 %, which indicates that the hybrid compression algorithm based on bit plane has a very good compression ratio and the compression effect is better than that of a single run length encoding and arithmetic coding.

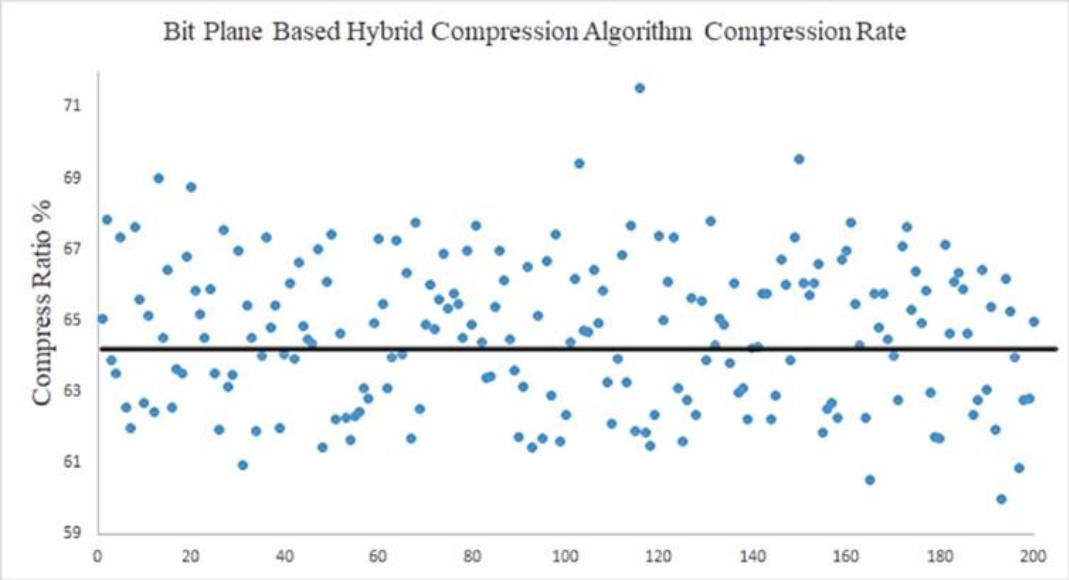

Figure 4 – Compression ratio of self-built database images based on bit plane-based hybrid compression algorithm

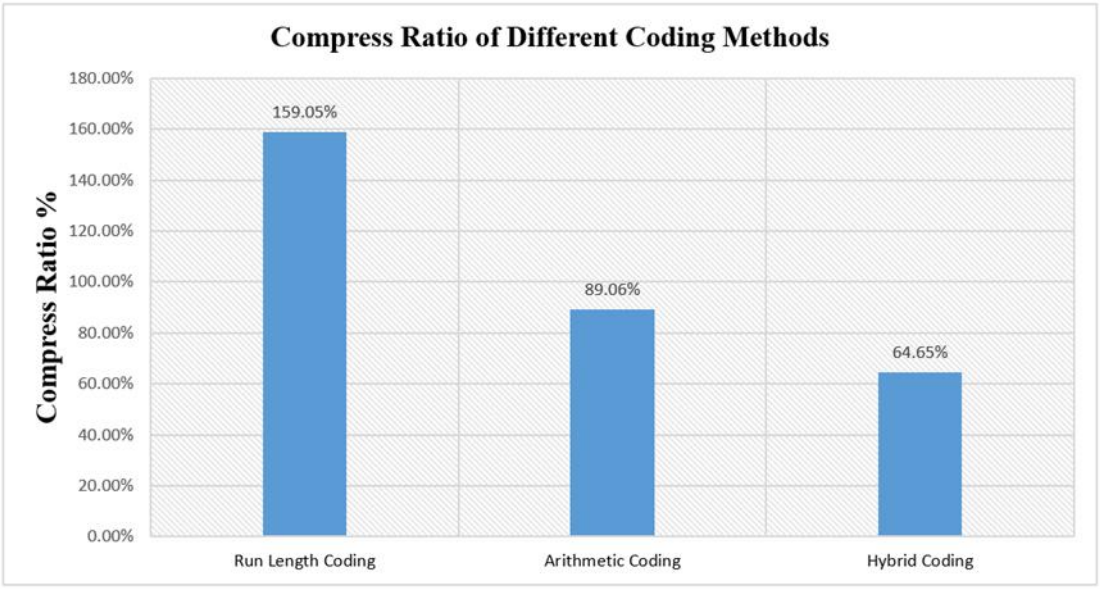

Figure 5 – Comparison of compression ratios of different compression algorithms

CONCLUSION

Image compression is one of the research hotspots in the field of image processing, and it is a field of extensive research and development. The research on image compression never stops. Image compression refers to reducing the size of an image file by reducing the redundancy and imperceptible details of image data. Image compression includes lossy compression and lossless compression. Lossless compression refers to the use of compressed data for reconstruction (or restoring or decompressing) to obtain data that is the same as the original data.

In the 70s of the 20th centuries, the earliest image compression coding began to appear. Among the common lossless coding algorithms are Huffman coding, arithmetic coding, and stroke coding. Lossy compression is suitable for situations where the reconstructed signal does not necessarily have to be the same as the original signal, because they often contain more information than our visual and auditory systems can receive. Common lossy image compression methods include discrete cosine transform, wavelet transform, vector quantization, etc. With the development of science and technology, more algorithms were subsequently proposed. In the future, image data compression technology will continue to evolve to meet the requirements of higher compression ratios, lower distortion, and faster processing speeds.

Hybrid coding for image compression refers to a technique that combines multiple compression methods to compress an image. The purpose of bit plane-based hybrid coding for image compression is to take full advantage of different compression methods while maintaining the quality and detail of the image as much

as possible while reducing the file size. There are many ways to combine hybrid compression coding, and different compression coding methods can be combined to compress hybrid coding. In this paper, two types of lossless compression coding are adopted, i.e., the bit plane-based image compression is processed by the hybrid coding of run compression coding and arithmetic compression coding. Then, through the self-built database, the performance of the hybrid coding compression based on bit plane was comprehensively evaluated in the Python 3.10 environment. The results show that the comprehensive compression ratio of the composite coding is much better than that of the run coding or arithmetic coding alone, with the time complexity of and the spatial complexity of.

Compared with the single coding algorithm, the main feature of bit plane-based image compression hybrid coding is that it can efficiently compress bit planes with large contiguous pixel value regions by using run coding at the same time, with the help of arithmetic coding, the irregular bit plane with high entropy can be accurately encoded, so that better compression effect can be obtained on different types of image data. By combining complementary coding techniques, various redundancies in the image data can be removed more comprehensively, and a higher compression ratio can be achieved under the given distortion constraints. At the same time, hybrid coding also provides more flexibility and freedom for encoder design, and the optimal combination of coding algorithms can be selected according to the statistical characteristics of different types of images.

However, there are some inherent drawbacks and challenges in this hybrid coding technology, such as the increase in overall system complexity, the difficulty of implementation, and the design of algorithm coordination strategies, which need to be considered in the encoder design. In addition, the design of the control strategy of the algorithm and the coordination between different coding algorithms are some of the challenges faced by this hybrid coding scheme. In addition, different coding algorithms may involve different patent and intellectual property issues, which is also an aspect that needs to be dealt with in hybrid coding applications.

In general, bit plane image compression-based hybrid coding provides new performance improvement space for image compression, but at the same time, it also adds some technical challenges. In practical applications, it is necessary to weigh the advantages and disadvantages of hybrid coding to make reasonable algorithm selection and system design.

LIST OF AUTHOR'S PUBLICATIONS

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