Ministry of Education of the Republic of Belarus
Educational institution
Belarusian State University of
Informatics and Radioelectronics

UDC 621.391

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PROGRESSIVE IMAGE ENCODING BASED ON CLUSTERING

Abstract
for a Master's Degree
in the Specialty 1-45 80 01 Infocommunication Systems and Networks

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Minsk 2024

INTRODUCTION

In recent years, the rapid advancement of information communication systems and network technology has led to the widespread popularity of various media networks and mobile application terminals. Since the advent of digital images, researchers have been tirelessly studying image compression technology, and their efforts continue to this day. The prevailing image coding standards employ a hybrid coding framework based on prediction and transformation. There is a tool used in the image coding methods, it is wavelets transform. Wavelet transform is a global transform with good local optimization performance in both time domain and frequency domain. Wavelet transform can effectively extract information from signals to achieve data compression purposes.

The aim of this work is to use the clustering method to achieve progressive coding of images. Based on wavelet transform, understand the principle of wavelet transform, and implement three different progressive image coding methods: SPIHT, SPECK and JPEG 2000 algorithms, and compare their respective advantages and disadvantages, and finally draw conclusions and summaries.

To achieve this goal, the following tasks were solved in the paper:

1 Review the background of progressive image coding, understand the basic methods of digital image processing and the indicators for evaluating image quality.

2 Systematically study the theoretical basis of wavelet transform.

3 This paper explains the two-dimensional discrete wavelet transform in detail, and gives a specific example of clustering-based image coding.

4 Introduced the basic principles of three clustering-based progressive image coding algorithms. And completed the code writing. The JPEG 2000 algorithm is a distortion-based compression algorithm based on discrete cosine (DCT). The SPIHT algorithm inherits the zero-tree structure of the wavelet coefficients in the EZW algorithm, which is called the "spatial direction tree structure". The SPECK algorithm is another image encoding method based on wavelet transform.

5 Four different pictures were used, and four different wavelets and three different wavelet levels were selected for each picture to test the three algorithms respectively, and a large amount of experimental data was obtained.

Clustering-based image coding methods provide fresh perspectives for image coding and data analysis. However, several challenges still exist, including enhancing encoding and decoding efficiency, improving image quality, and adapting to various application domains. In future research, it is imperative to delve deeper into the theoretical foundations of progressive image coding, design optimization algorithms, and explore methods for expanding its applications.

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 this work is to use the clustering method to achieve progressive coding of images. Based on wavelet transform, understand the principle of wavelet transform, and implement three different progressive image coding methods: SPIHT, SPECK and JPEG 2000 algorithms, and compare their respective advantages and disadvantages, and finally draw conclusions and summaries.

To achieve this goal, the following tasks were solved in the paper:

1 Review the background of progressive image coding, understand the basic methods of digital image processing and the indicators for evaluating image quality.

2 Systematically study the theoretical basis of wavelet transform.

3 The image compression algorithm based on wavelet transform is essentially a two-dimensional discrete wavelet transform.

4 Introduced the basic principles of three clustering-based progressive image coding algorithms. And completed the code writing.

5 The tests of the above three algorithms were completed. Four different pictures were used, and four different wavelets and three different wavelet levels were selected for each picture to test the three algorithms respectively, and a large amount of experimental data was obtained.

Personal contribution of the author

The content of the dissertation reflects the personal contribution of the author. It consists in the scientific substantiation of SPECK algorithms, SPIHT algorithm and JPEG 2000 algorithm, organization and categorization of background information, writing code to perform experiments, processing and analyzing the obtained results, and drawing of conclusions.

Testing and implementation of results

The main provisions and results of the dissertation work were reported and discussed at: International scientific and technical seminar "Technologies of

information transmission and processing" (Minsk, April, 2024) and 60th scientific conference of graduate students, undergraduates and students (Minsk, March, 2024).

Author's publication

According to the results of the research presented in the dissertation, 2 author's works was published, including: 2 articles and abstracts in conference proceedings.

Structure and size of the work

The dissertation work consists of introduction, general description of the work, four chapters with conclusions for each chapter, conclusion, bibliography, eight appendixes.

The total amount of the thesis is 92 pages, of which 83 pages of text, 48 figures, 8 tables, a list of used bibliographic sources, a list of the author's publications on the subject of the thesis, 2 appendixes, graphic material on 9 pages.

Plagiarism

An examination of the dissertation «*Pogressive Image Encoding Based on Clustering*» by Zeng Peng was carried out for the correctness of the use of borrowed materials using the network resource «Antiplagiat» (access address: https://antiplagiat.ru) in the on-line mode 29.5.2024. As a result of the verification, the correctness of the use of borrowed materials was established (the originality of the thesis is 87.26 %)

SUMMARY OF WORK

The introduction addresses the problems of progressive image encoding based on clustering.

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 introduces some basic concepts in image processing, including digital image processing, general methods of digital image processing and indicators for evaluating compression quality.

Digital image processing, also known as computer image processing, refers to the process of converting image signals into digital signals and using computers to process them. Image coding, also known as image compression, refers to a technology that uses a smaller number of bits to represent an image or the

information contained in the image under the condition of meeting a certain quality. There are three quality standards, they are PSNR, SNR and MSE.

In the second chapter mainly introduces several progressive image compression algorithms based on clustering methods. The introduction of wavelet provides clustering ideas for image compression algorithms. Progressive image encoding is an image compression method that allows for the gradual display of different levels of detail in an image during the image transmission process. The wavelet transform of digital images is a two-dimensional discrete wavelet transform. Clustering-based progressive image encoding algorithms in this article are SPIHT, SPECK and JPEG 2000. The JPEG 2000 algorithm is a distortion-based compression algorithm based on discrete cosine (DCT). The biggest advantage of JPEG 2000 algorithm is that it provides great flexibility in the processing method and transmission sequence of image data. The SPIHT algorithm inherits the zero-tree structure of the wavelet coefficients in the EZW algorithm. The SPECK algorithm is another image encoding method based on wavelet transform. EZW, SPHIT and SPECK are all progressive image coding algorithms based on wavelet transform. These three algorithms all complete the embedding coding through four processes of initialization, sorting scan, refinement, and quantization step update.

In the third chapter tests the image compression algorithms of SPIHT, SPECK and JPEG 2000, compares these three clustering-based progressive image compression algorithms by comparing PSNR and time indicators, and draws a series of conclusions.

Results about Comparation of different wavelets effects in different images in SPIHT and SPECK algorithm shows in the Figure 1 and Figure 2.

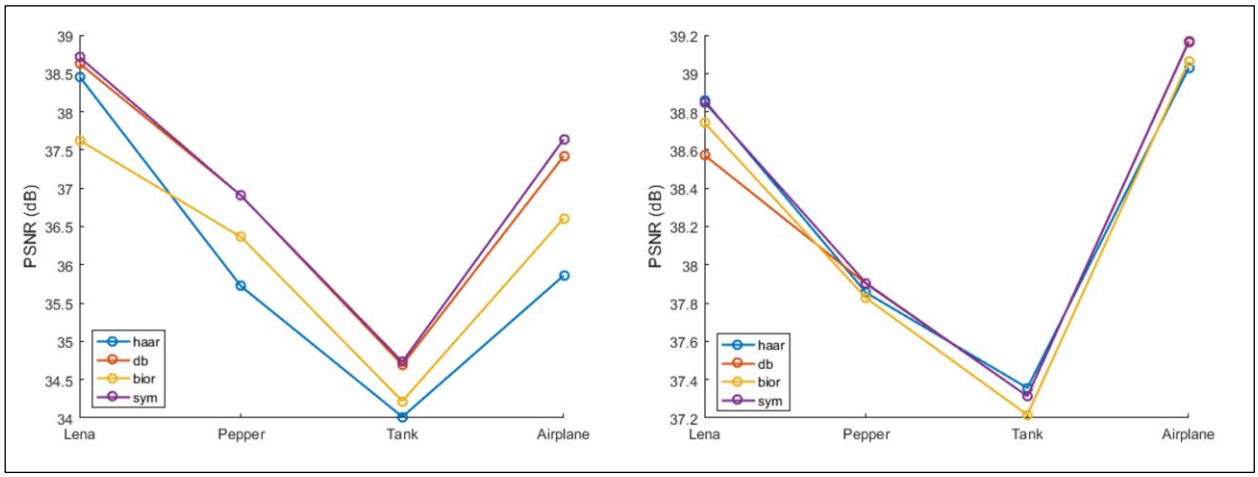

Figure 1 – Comparation of PSNR in SPIHT and SPECK algorithm

In SPIHT, the *sym* wavelet performs best and the *haar* wavelet performs the worst. In SPECK, the performance of each wavelet is relatively average. In JPEG 2000, the performance of each wavelet is similar to SPIHT algorithm.

Comparison of image processing quality and efficiency. Results show in Figure 2. From the images, we can conclude that the image compression quality of JPEG 2000 is the best, the image compression quality of SPIHT algorithm is the worst, and SPECK algorithm is second only to the JPEG 2000 algorithm.

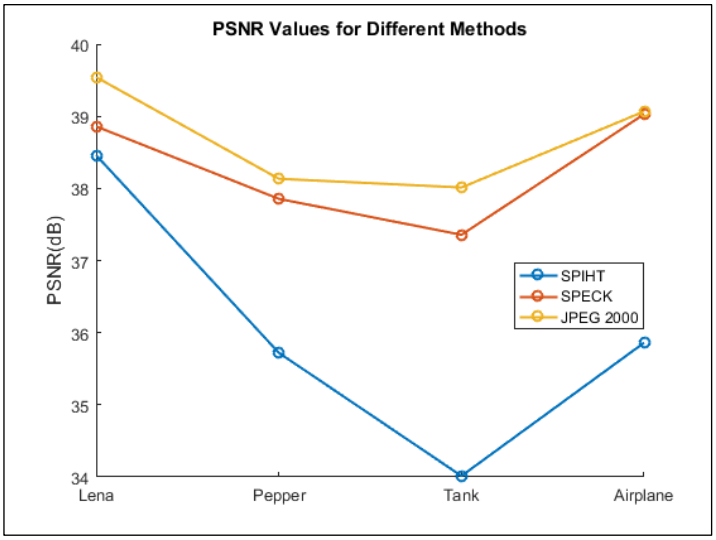

Figure 2 – Comparation of PSNR in different algorithm

Comparation of processing complex images. The results show in Figure 3.

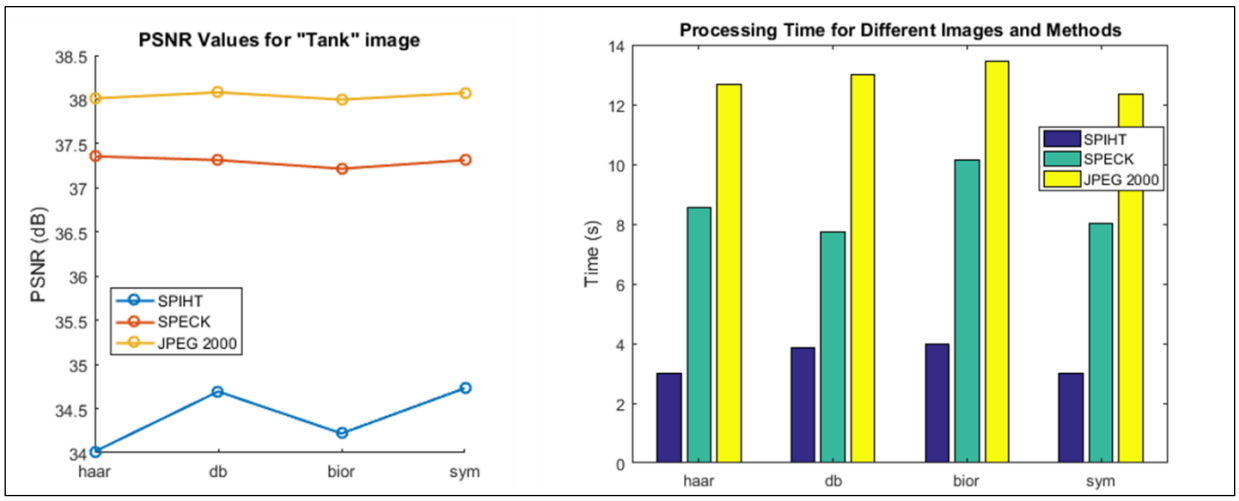

Figure 3 – Comparation PSNR and time of complex image

For processing complex images, SPECK is more efficient. When the JPEG 2000 algorithm processes complex images, its compression quality will decrease and

its processing time will also increase. The SPIHT algorithm takes less time to process details and textures but the quality of compressed image is not good. Although the compression time of the SPECK algorithm has also increased, its compression quality remains generally unchanged.

In conclusion, SPIHT has the largest number of iterations and the shortest compression time, but the quality of image compression is lacking. JPEG 2000 has the longest compression time, but has the best image compression quality. SPECK is in middle, with a suitable number of iterations and a suitable compression time.

In the last chapter of this article presents various experimental results and explains various algorithms and codes through the results. These algorithms include clustering methods for manipulating wavelet transforms and several examples of using algorithms for image compression.

CONCLUSION

This paper introduces three progressive image coding algorithms, SPIHT, SPECK and JPEG 2000, by introducing the clustering method wavelet transform. Their advantages and disadvantages are compared through experiments.

The innovation of this paper is that the clustering method is introduced as a key step in image coding. By clustering the image, it can compress the image data more effectively. The use of progressive coding is another innovation of this paper. Progressive coding allows image data to be transmitted and decoded gradually, so the image can be displayed gradually at the receiving end. In the image coding process, efficient and suitable clustering algorithms for image data are selected, such as SPIHT and SPECK algorithms, based on the JPEG 2000 algorithm that has been improved on JPEG. Unlike traditional methods, this study selects or adjusts adaptively according to image features to ensure the best effect.

The clustering-based progressive image coding method proposed in this paper can achieve a high quality. Through clustering analysis, it can discover and utilize redundant information in the image, thereby reducing the amount of data required for storage and transmission. The method proposed in this paper has a wide range of application potential. The combination of clustering and progressive coding can be applied to multiple fields such as image transmission, image storage, and network applications.

In addition. This paper has made the following contributions:

1 A new framework for clustering-based progressive image coding is proposed, which enriches the research content in the field of image compression and provides new directions and ideas for subsequent research.

2 Clustering algorithms suitable for image coding are tested and compared, and detailed algorithm descriptions are given, providing specific implementation methods for research and application.

3 Comparison of experimental results: Through a large number of experiments, it is proved that at the same compression rate, SPECK has a better cost-effectiveness than traditional progressive coding methods such as SPIHT and JPEG 2000.

In the future, more adaptive clustering algorithms can be studied, which can dynamically adjust clustering parameters according to image content to further improve coding efficiency and image quality. In addition, deep learning technology can be combined with clustering algorithms to automatically extract image features and cluster them through neural networks. Looking further ahead, clustering-based progressive image coding methods can be promoted to enter international image coding standards, such as JPEG, MPEG, etc., to enhance their wide application in the industry.

At the same time, although a large amount of data is analyzed in this paper, the scale is still limited. Large-scale experiments can be conducted to verify the performance of this method in different types of image data sets, and further optimize algorithm parameters and implementation details.

Through these future research directions, the performance and applicability of clustering-based progressive image coding methods can be further improved, and their application in more fields and scenarios can be promoted.

Overall, the innovation of this paper lies in the introduction of clustering methods and progressive coding strategies, and through these innovations, a progressive coding scheme with high compression ratio and high-quality images is achieved. Its contribution is to provide an effective image compression and transmission method with broad application prospects. Although there are still some shortcomings, they can be improved in future research.

LIST OF AUTHOR'S PUBLICATIONS

1–A Peng, Z. Image compression method based on wavelet transform / Z. Peng, W. Zijian, W. Ying, V. Yu. Tsvitkov // Технологии передачи и обработки информации: материалы Международного научно-технического семинара, Минск, март-апрель 2024 г. / Белорусский государственный университет информатики и радиоэлектроники; – Минск, 2024. – С. 58–62.

2–A Ying, W. Image compression method based on run length encoding / W. Ying, Z. Peng, W. Zijian // 60-я научная конференция аспирантов, магистрантов и студентов, Минск, 11-15 марта 2024 года / Белорусский государственный университет информатики и радиоэлектроники; – Минск, 2024. (in publish)