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**PARALLEL ALGORITHMS FOR SKELETONIZATION OF BINARY  
IMAGES**

Abstract  
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## INTRODUCTION

Thinning is also called skeletonization, which is the process of quickly and accurately converting graphic lines with a width greater than one pixel into one-pixel-wide lines with the least number of iterations as possible without affecting the topological connection of the image. That is, the skeleton of the extracted image. Thinning can not only show the topological shape of the original image well, but also greatly reduce the memory space required to store the image. Because it only needs to store the necessary structural information in the image, it simplifies the data structure in image processing, and is a commonly used technology in image analysis, information compression, feature extraction and pattern recognition, so it plays an important role in image processing. . For example, in text recognition and fingerprint recognition, text strokes or fingerprint ridges with a single pixel width can be obtained through thinning, which will facilitate the extraction of text and fingerprint features. In addition, in the recognition of engineering drawings, the skeleton image obtained through thinning is also beneficial to the extraction of various graphics and lines and the recognition of various symbols. After thinning processing, a compact and effective representation form can be provided for subsequent image analysis processing, and it also plays a role in reducing the calculation time and space required in subsequent processing steps.

A variety of thinning algorithms have been proposed by predecessors. According to the different iteration methods of these algorithms, there are usually serial algorithms and parallel algorithms. In the serial refinement algorithm, the result of each iteration not only depends on the result of the previous iteration, but also related to the current processing situation. In the parallel method, the current iteration is only determined by the last iteration. Since the processing results of the serial thinning algorithm depend on the sequence of pixel processing, whether a certain pixel is eliminated or retained is related to the processing order, which is unpredictable in advance, while the parallel thinning algorithm can use the same The condition of detecting all pixels at the same time, not only can refine all the pixels at the same time, but also the result is isotropic, so the parallel method is better than the serial method in terms of algorithm principle. The parallel algorithms that have been proposed include OPTA thinning algorithm, Hilditch algorithm, Pavlidis algorithm, Rosenfeld algorithm and ZS algorithm.

In this paper, we discuss the advantages and disadvantages of some commonly used parallel skeletonization algorithms and propose an FPGA-based parallel image thinning algorithm. Finally, the image thinning is realized by using VHDL language programming, and it has passed the simulation verification.

The innovation of this paper lies in the use of FPGA devices and the hardware description language VHDL for binary image skeletonization. The system is real-time, and an image thinning algorithm suitable for hardware implementation has been found. Voting is used in the algorithm. method, which improves the speed of the algorithm. At the same time, this research uses simulation to realize the gray-scale thinning algorithm. Through a large amount of experimental data, good thinning results have been achieved, and the accuracy and speed have been greatly improved.

## **GENERALDESCRIPTION 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 within the framework of research work 21 – 2033 "Processing, coding and transmission of information in network-centric systems".

### **The aim and tasks of the work**

The aim of this work is to improve image skeletonization algorithms based on FPGA.

To achieve this goal, the paper completes the following tasks:

1 Use VHDL language programming to realize image skeletonization and pass the simulation verification.

2 Adopt the voting method to realize image collection and skeletonization at the same time, and improve the parallelism and processing speed of the system.

### **Personal contribution of the author**

The content of the dissertation reflects the personal contribution of the author. It consists in the scientific substantiation of image skeletonization algorithms, setting and conducting experiments to study characteristics, assessing the efficiency of the developed algorithms, processing and analyzing the obtained results, formulation of conclusions.

Task setting and discussion of the results were carried out together with the supervisor doctor of Sciences , full professor head of the department of infocommunication technologies.

### **Testing and implementation of results**

The main provisions and results of the dissertation work were reported and discussed at: 58th scientific conference of postgraduates, undergraduates and students, (Minsk, April 18–22, 2022) and International scientific and technical seminar "Technologies of information transmission and processing" (Minsk, March – April 2023)

### **Author's publications**

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 72 pages, of which 48 pages of text, 14 figures on 9 pages, 2 tables on 1 pages, a list of used bibliographic sources (39 titles on 3 pages), a list of the author's publications on the subject of the thesis (2 titles on 1 page ), graphic material on 11 pages.

### **Plagiarism**

An examination of the dissertation «Parallel Algorithms for Skeletonization of Binary Images» by Qiu Yuepeiyan 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 18.06.2023. As a result of the verification, the correctness of the use of borrowed materials was established (the originality of the thesis is 91.7%)

## **SUMMARY OF WORK**

This study improves the image skeletonization algorithm based on FPGA, and the improved algorithm is verified by simulation, and it is found that the gray-scale thinning algorithm has improved both in speed and accuracy. And the thinning results are more in line with the thinning requirements, and the connectivity and anti-noise processing are better. At the same time, some special points, such as endpoints and intersections, are better processed. Moreover, the algorithm is improved by adopting the voting method, which can be carried out simultaneously with image collection, which improves the parallelism and processing speed of the system.

The **introduction** addresses the problems of describing the background and purpose of the study.

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** Introducing the background and significance of the subject research, and then introduces the classification and standards of thinning algorithms, as well as the current domestic and foreign research status of thinning algorithms.

**In the second chapter** introducing the properties of the skeleton and common image thinning algorithms. This chapter mainly introduces several types of image thinning algorithms commonly used at present, and compares their experimental results, and analyzes the advantages and disadvantages of different algorithms.

**In the third chapter** Introducing the image gray-scale thinning algorithm based on and its application in the real-time gauge measurement system, and introduced the basic principle of the gray-scale algorithm in detail, and analyzed the simulation results.

## CONCLUSION

After half a year of research on this topic, with the help of tutors and classmates, some results have been achieved, but there is still room for improvement. This chapter briefly summarizes this research, and makes an outlook on the future development and application of the system.

This paper mainly conducts related research on how to use FPGA to realize the skeletonization of binary images, and mainly completes the following work:

1 On the basis of the research on image skeletonization, the structure and characteristics of FPGA are deeply understood, and compared with other schemes, the feasibility of FPGA to realize image skeletonization processing is verified.

2 Based on the characteristics of FPGA, compare with existing thinning algorithms, find out the advantages and disadvantages of various algorithms, and finally determine a gray thinning algorithm suitable for FPGA. In order to make better use of the advantages of FPGA devices, some improvements have been made to the gray-scale thinning algorithm. The voting method is used in the algorithm, that is, some basic operations of thinning are performed while image acquisition is performed, and the processing speed of the algorithm is improved. , while also reducing the running time of the entire system.

3 Design and debug the software of the gray-scale thinning algorithm based on FPGA, write the algorithm program for the system, and finally verify the function of the system through simulation.

The innovation of this paper lies in the use of FPGA devices and the hardware description language VHDL for binary image skeletonization. The system is real-

time, and an image thinning algorithm suitable for hardware implementation has been found. Voting is used in the algorithm. method, which improves the speed of the algorithm. At the same time, this research uses simulation to realize the gray-scale thinning algorithm. Through a large amount of experimental data, good thinning results have been achieved, and the accuracy and speed have been greatly improved.

## LIST OF AUTHOR'S PUBLICATIONS

### *Conference abstracts*

1–A. Qiu, Y. P. Y. Object recognition based on skeleton / Y. P. Y. Qiu, J. Ma, Z. M. Liao // Инфокоммуникации : сборник тезисов докладов 58 - ой научной конференции аспирантов, магистрантов и студентов, Минск, 18–22 апреля 2022 г. – Minsk : BSUIR, 2022. – С. 74–76.

2–A. Qiu Yuepeiyan. Research on Chinese sign language recognition based on skeleton features / Qiu Yuepeiyan // Технологии передачи и обработки информации (Technologies of information transmission and processing): материалы Международного научно - технического семинара, Минск, март – апрель 2023 г. – Minsk : BSUIR, 2023. – С. 186–188.