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ADAPTIVE AND ROBUST IMAGE SKELETONIZATION UNDER NOISE CONDITIONS

Abstract
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INTRODUCTION

Bones are popular descriptors because they preserve the original topology and connectivity of objects. They are currently widely used in many fields, such as target recognition, shape retrieval, vessel analysis and vessel segmentation, image matching, liver sketch-based modelling, character animation and quantitative structural imaging, gesture recognition. Skeleton images can be extracted directly from depth images captured by depth cameras, such as Kinec, or from images captured by ordinary cameras using traditional skeletonization methods. For depth camera-based methods, the generated skeleton may not be affected by lighting, shadows, and colors; thus, recognition based on it tends to have better results. However, the cost, size, and availability of depth cameras limit their widespread use. Therefore, the scope of application of the traditional method is wider than the method based on the depth camera, because it only needs an ordinary camera to realize. In order to use the traditional method, it is also necessary to convert the RG image to make it a grayscale image, and then perform binarization to extract the region of interest (ROI) as the foreground object. Then, the skeleton can be extracted on the binary image by applying a skeletonization method.

One of the challenges of traditional skeletonization methods is that the generated skeletons have a lot of noise, which leads to some skeletons not being able to preserve the original topology and connectivity of objects well. Extracting stable skeletons from noisy images is a challenging problem because skeletonization methods are easily affected by noise. This noise can be observed in binary images and can significantly affect the final generated skeleton. From the perspective of binary images, noise can be divided into two types: boundary noise and internal noise. Boundary noise can cause small changes in foreground edges, resulting in many unwanted branch images in skeleton extraction. Intrinsic noise occurs in the interior of the foreground image, and this type of noise can produce many unwanted skeletal rings.

Based on this problem, many different algorithms have recently been proposed to reduce the impact of these noises on skeletons, and have been used for decades while obtaining many more stable skeletons than traditional methods. In general, there are tow different approaches to address the problem caused by noise: pruning-based methods, and scale-space-based methods.

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 Radio electronics 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

This paper presents an improved refinement framework Automatic extraction based on scale space technology Image skeletons without manual adjustments.

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

1 Introduce the concept of skeletonization and the basic content of development.

2 Analyse the shortcomings of the skeletonization algorithm and the deficiencies of the existing noise reduction methods.

3 Improve the existing noise reduction method to achieve better results.

Personal contribution of the author

The content of the paper reflects the individual contributions of the authors. It includes algorithm improvement, conducting experiments, comparing with existing algorithms, processing and analysing results, and formulating conclusions.

Testing and implementation of results

The main provisions and results of the dissertation work were reported and discussed at:2023 7th International Conference on Data Mining, Communications and Information Technology (DMCIT 2023) and Engineering Letters, 2022.

Author’s publications

According to the results of the research presented in the dissertation, 2 author’s works was published, including:1 EI conferences and 1 EI journal.

Structure and size of the work

The dissertation work includes an introduction, an overview of related work, proposed algorithms, experimental results, conclusion, and bibliography.

The total volume of the thesis work is 81 pages, including 68 pages of text, 39 Figures, 6 tables, a list of bibliographic sources used, and a list of author's publications on the topic of the thesis.

Plagiarism

An examination of the dissertation «AN IMPROVED ADAPTIVE THINNING FRAMEWORK» by Author’s Full Name 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 22.05.2023. As a result of the verification, the correctness of the use of borrowed materials was established (the originality of the thesis is 77.39 %)

SUMMARY OF WORK

In the first chapter, this paper introduces related concepts: in section 1.1, this paper introduces the original skeletonization algorithm and its types. In addition, it also briefly describes different types of skeletonization algorithms and compares their advantages and disadvantages. In section 1.2, this paper gives a detailed introduction to a classic algorithm among different types of skeletonization algorithms and analyzes its advantages and disadvantages. In Section 1.3, this paper introduces the existing skeletonized noise reduction algorithms in detail, and analyzes their advantages and disadvantages.

In the second chapter, the improved algorithm of this paper is introduced: in section 2.1, the general structure of the algorithm is first introduced, and then the various parts of the algorithm are introduced, as follows:

Gaussian Filter Procedure. The value of the element whose coordinates are (x, y) in the Gaussian kernel can be expressed as $G_n(x, y, \delta)$, which can be calculated according to Equation. By changing the value of σ, from the initial σ_{init} to σ_{max}, its value is a multiple of σ_{init}, and with the step size of σ_{init}, a series of different Gaussian kernels can be obtained.

$$G(x, y, \delta) = \frac{1}{2\pi\delta^2} e^{-\frac{(x+y)^2}{2\delta^2}} \quad (1)$$

Binarization Procedure. These kernels are then applied to the original input grayscale image to produce a sequence of filtered images. After binarizing the filtered grayscale image through the formula [1], we can get different binary images. The input of this procedure is the blurred image that is obtained from the previous procedure. The output is the binary image. Here we adopt an adaptive binarization, using the average of non-white grayscale intensities as the threshold for binarization th:

$$th = \frac{1}{N_b} \sum_{i=0}^{N} \sum_{j=0}^{M} f(i, j) \tag{2}$$

where N_b is the number of foreground pixels in the image, M and N are the dimensions of image I, and function f is defined as follows:

$$f(i, j) = \begin{cases} 0, if\ I_{G(i)}(i, j) = 255 \\ I_{G(i)}(i, j), otherwise \end{cases} \tag{3}$$

where $I_{G(i)}$ denotes a pixel in the grayscale image that filtered by the gaussian filters, whose smoothing parameter is i. (i, j) denotes the coordinates.

Thinning Procedure. In this procedure, the skeletons I_{th} are extracted from the input binary images. There are many methods to realize this function. Among them, the FPSA method has both good performance in terms of the thinning speed and thinning rate. It is also able to suppress slight border noise. In additional, the ability of topology preservation of the FPSA has been proved in their paper by introducing three Ronse's conditions. Therefore, we decide to use the FPSA algorithm to realize the thinning procedure.

Evaluation Procedure. The evaluation procedure was used to evaluate skeletons obtained from previous procedures. A suitable σ produces a suitable binary image and a suitable skeleton with as few noise branches as possible and as large a necessary branch as possible. To choose a suitable σ, we modify the sensitivity measure S_{m} used in the Houssem framework to preserve the connectivity and topology of the original patterns. A wrong σ may produce excessively large values, while a suitable σ may produce small values.

$$S_{\mathrm{m}}(\mathrm{I}_{th}) = \frac{1}{n} \sum_{i=1}^{N} \sum_{j=1}^{M} S_1(\mathrm{i}, \mathrm{j}) \tag{4}$$

$$S_1(\mathrm{i,\,j}) = \begin{cases} 1,\ T_{BW}(i,\,j) > 2 \text{ OR } (I(i,j)=0) \\ 5,\ F_{BD}(i,j) = 1 \text{ AND } \ T_{BW}(i,\,j) > 1 \\ 10,\ \dfrac{|Area(I_{B(i)})\text{-}Area(I_{B0})|}{Area(I_{B0})} > 0.02 \\ \qquad \text{OR Region}(I_{B(i)}) \neq \text{Region}(I_{B0}) \\ 0,\ \text{Otherwise} \end{cases} \tag{5}$$

Where, n is the total number of the foreground pixels that exist in the skeleton. N and M are still the dimensions of image I that mentioned in the former section. T_{BW} is the number of conversions from white pixels to black pixels in the 8-neighborhood window of (i, j) The definition is the same as mentioned above.

In this formula, the first condition is same with the condition used in the Houssem framework. The second condition is used to avoid the connection of two separative but with limited distance objects, which can preserve the original connectivity, where F_{BD} consists of all the background pixels that are not enclosed by the contour of the foreground pattern. Next, the $Area$ function is used to count the area of the foreground object in a given binary image, which can be used to limit the great changes of the binary images in two consecutive iterations. Function Region is used to count the number of existing foreground objects. The third condition is used to preserve the topology.

In the third chapter, this paper conducts experiments on the algorithm, and summarizes, as shown in Figure 1.

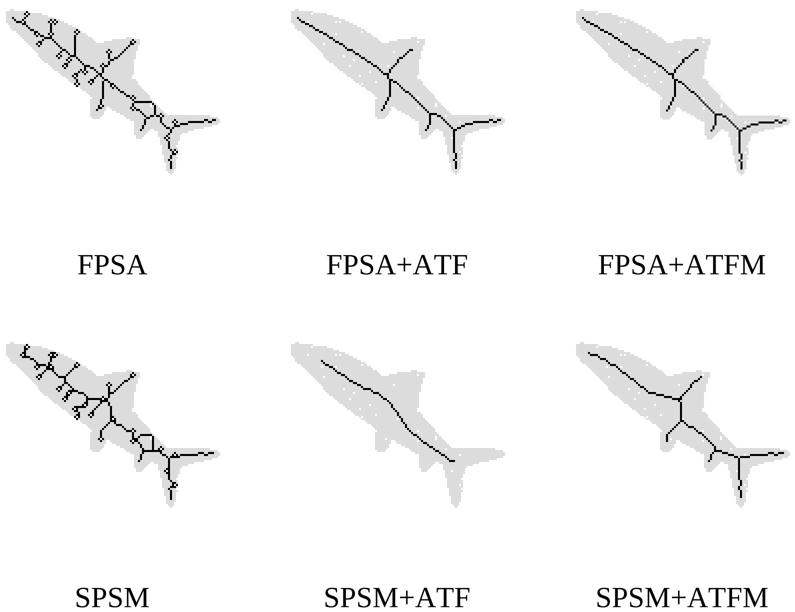

Figure 1 – Skeletons extracted from bonefishes with 2% internal noise using six different methods

From the experimental results, it can be found that for the FPSA method and the SPSM method, due to the influence of internal noise, there will be many pseudo-skeleton rings in the skeletons extracted by them, and the number of pseudo-skeleton rings will increase significantly with the increase of noise. In contrast, the other four methods do not have pseudo-skeletal rings due to the use of a refinement framework. Comparing the two methods combined with the ATF framework and the two methods combined with the ATFM framework, we can find that the skeleton extracted by the ATF method has a skeleton loss, while the method combined with the ATFM method has no . phenomenon. In addition, it can also be found that under the internal noise pollution, the skeleton extracted by the method combined with ATFM is almost the same as that extracted by the noise-free case, while the skeleton of other methods changes significantly.

CONCLUSION

Skeletonized noise reduction processing is a key research direction at present. As a shape descriptor representing the topological structure of objects, skeletons are widely used in various fields such as object recognition and shape retrieval. The skeleton simplifies the representation of the object shape while expressing the main visual features of the object shape as much as possible, and has rotation, translation and scale invariance. However, most of the current skeleton extraction methods are very sensitive to object shape contour noise and deformation, prone to redundant branches and skeleton loops, affecting the topology of the shape skeleton, resulting in a large amount of computation. The application of skeletons is often highly dependent on a complete and clean skeleton, so skeleton denoising is an essential step. There are many denoising methods at present, but most of them cannot obtain a complete and clean skeleton at the same time. Aiming at the problems existing in bone noise reduction, this paper focuses on several aspects of research, and achieved the following results:

1 Eliminate the internal noise of the image very well, making the skeleton cleaner and tidier

2 Elimination of skeleton loops in the skeleton

3 Save the topological structure of the image very well.

4 Avoid the occurrence of skeleton loss.

Since the skeleton only considers the topology of the shape, features such as the color of the shape are not considered. Therefore, the future research work of this paper mainly includes the following aspects.

LIST OF POSTGRADUATE PUBLICATIONS

1–A Liu, Y. A Modified Thinning Framework Against Noise / J. Ma, X. Ren // 7th International Conference on Communication, Image and Signal Processing – 2022. – P. 145–149.

2–A Ma, J. An Improved Adaptive Thinning Framework / X. Ren, Y. Liu, V. Y. Tsviatkou, V. K. Kanapelka // Engineering Letters – 2022. – Vol. 30(3) – P. 1138–1145.

3–A Liu, Y. Survey of Noise-Against Techniques for Extracting Stable Skeleton / J. Ma, X. Ren // 7th International Conference on Data Mining, Communications, and Information Technology. (In publish)