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ORCID
Kyungjae Lee: orcid.org/0000-0002-1529-3120
Junhyeop Lee: orcid.org/0000-0001-8325-4097
Sangwon Hwang: orcid.org/0000-0001-8666-7479
Sangyoun Lee: orcid.org/0000-0003-0394-6777

Inversion of Spread-Direction and Alternate Neighborhood System for Cellular Automata-Based Image Segmentation Framework

Kyungjae Lee, Junhyeop Lee, Sangwon Hwang, Sangyoun Lee

Department of Electrical and Electronic Engineering, Yonsei University, Seoul, Korea

Purpose In this paper, we proposed alternate neighborhood system and reverse spread-direction approach for accurate and fast cellular automata-based image segmentation method.

Materials and Methods On the basis of a simple but effective interactive image segmentation technique based on a cellular automaton, we propose an efficient algorithm by using Moore and designed neighborhood system alternately and reversing the direction of the reference pixels for spreading out to the surrounding pixels.

Results In our experiments, the GrabCut database were used for evaluation. According to our experimental results, the proposed method allows cellular automata-based image segmentation method to faster while maintaining the segmentation quality.

Conclusion Our results proved that proposed method improved accuracy and reduce d computation time, and also could be applied to a large range of applications.

Key Words Image segmentation · Cellular Automata · Medical Image.

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Address for correspondence: Sangyoun Lee
Department of Electrical and Electronic Engineering, 50-1 Yonsei-ro, Seodaemun-gu, Seoul 03722, Korea
Tel: 82-2-2123-5768, **Fax:** 82-2-362-5563, **E-mail:** syleee@yonsei.ac.kr

Introduction

Image segmentation method is a technique that divides the background and object that we want to extract. Extracting object areas from an input image is necessary for many practical applications. A lot of image segmentation method is developed based on the color information. The image segmentation method has been utilized in a wide range of fields such as graphics, design, biometric and medical imaging (1, 2). Among the approaches, Intelligent Scissors (5) and Active Contours (6) use the boundaries of the object. On the other hand, in the interactive image segmentation methods, GrowCut (3) and Graph Cut (4) methods need the seed pixels of the object and the background selected by the user. Likewise, in order to use the interactive image segmentation method, it requires seed pixels of the foreground and seed pixels of the background, respectively. At result section of this paper, we present image segmentation results based on these seed points.

In this paper, we designed the combined neighborhood system to improve the segmentation performance and reverse direction scheme to reduce computation time, on the basis of cellular automata-based on image segmentation algorithm called GrowCut that have a low computation cost and easy to extend.

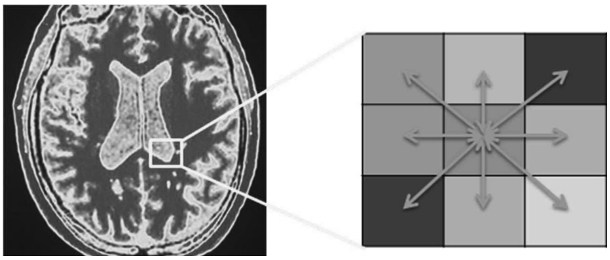

Fig. 1. Input Image and neighborhood system.

Materials and Methods

The proposed method is derived from simple but effective interactive image segmentation technique (3) that is based on a cellular automaton. The cellular automaton, A, has a triplet term as below.

$$A=(S, N, \delta) \tag{1}$$

This equation (1) reflects the discrete model in both space and time. The cell is considered as a pixel in a input image. For each cell, S indicates a state set and N is pre-designed neighborhood system that is defined as a relationship between the seed cell and the surrounding cells as shown in Fig 1. δ indicates a local transition function that defines the rules for calculating the next state of each cell. The next state of the cells is determined by calculation of the cell's current state and its neighboring cells.

According to the cellular automata-based image segmentation framework, each pixel in an image is considered as a cell in a grid of the cellular automata that is discrete in both space and time.

In the proposed, a supervised method is used for image segmentation. After the user sets seeds of the object and the background to identify the cell state that has a label and strength, the seed cells spreads to the surrounding cells. We changed the manner in which a reference cell let the labels of surrounding cell changed opposed to the conventional way, called as inversion of spread direction (ISD). Based on the seeds, a distance value is computed by calculating feature vectors between the current cell and its neighboring cells, where Moore neighborhood is generally used as the neighborhood system. In addition, we added another neighborhood system that is designed to skip the cell next to it. We call this method as alternate neighborhood system (ANS). By adapting these two neighborhood systems alternately, it is possible to perform robust performance by calculating not only near cells but also distant cells. An attack force is defined by the product of the value obtained from the equation as

$$g(x) = 1 - \frac{x}{m\,ax\|\vec{C}\|} \tag{2}$$

where x is the distance value between feature vectors of two cells, and $\vec{C}$ is the feature vector. This g (x) is a function of the monotonous decreasing with a minimum value of 0 and a maximum value of 1. And the equation (2) is a function having the distance value between the current cell and its neighboring cells as a variable x.

We let the seed cell have the strength value as 1. If the attack force is greater than the strength of the current cell, its label and strength are changed to those of the neighboring cell at the next step. This method is based on synchronous cellular automata, which uses the states of cells that are the same at the current time and updates all the states of the cells simultaneously before proceeding to the next time. It repeatedly performs these operations and spreads to neighboring pixels until there is no change in the state of the cells.

Results

In order to evaluate foreground performance, evaluation metrics have been calculated based on true and false positives and negatives (TP, FP, TN, FN). These measures are defined as follows: recall is the true positive rate, R=TP/ (TP+FN); precision is the ratio between the number of correct segmented pixels and the total number of ground truth pixels, P=TP/ (TP+FP); finally, F-score is used to measure a test's accuracy. F-score combines precision and recall measurements to evaluate the quality of the segmentation. F- measure is defined as follows.

$$F_1 = 2 \cdot \frac{P \cdot R}{P+R} \tag{3}$$

The higher value of F-score is the better of the performance.

To evaluate the proposed method, we use the GrabCut database (7) with 3.3 GHz CPU and 16.00 GB RAM. The GrabCut dataset consists of 50 test images. The seeds of foreground and background are selected by a tri-map from lasso image. Table 1 shows the comparisons of the performance conducted on (7). Fig. 2 illustrates the results of the object segmentation through our method conducted on (7, 8)

Discussion

According to our experimental results, the proposed method

Table 1. Performance evaluation

Method	F-Score	Iteration	Time (sec)
Original	0.981	96.78	1.69
ANS	0.984	67.06	1.15
ISD	0.982	49.2	0.78
ANS+ISD	0.984	50.92	0.84

Fig. 2. Examples of the image segmentation results on various environments.

make cellular automata-based image segmentation method more efficiently. From the evaluation at the results section, our approaches show more accurate. Interestingly, compared to the original method, performance is better and execution speed is decreased.

Conclusion

In this paper, we propose an efficient algorithm by using basic and designed neighborhood system alternately and reversing the direction of the reference pixels for spreading out to the surrounding pixels. The experimental results show that the proposed method has improvement in terms of accuracy and computation time. Our proposed method can be applied to a large range of computer vision applications such as medical image segmentation.

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