Successive Algorithm Using Discrete-Time Oscillator Network for Three-Dimensional Image Segmentation

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***Abstract*—**To extract three-dimensional (3D) image regions from a 2D sketch that we roughly draw the outline of target image regions in an image slice, we proposed an algorithm using a discrete-time oscillator network that we have developed. This oscillator network can produce the set of 2D fragments that corresponds to all combinations of 2D image regions. To improve the accuracy of 3D image segmentation, the parameter values of the oscillator network were optimized according to our analyzed results on responses from oscillators. For a 2D rough sketch of target image regions given as the initial reference image, the proposed algorithm successively provides the reference image for the neighbor slice as the fragment that is closest to the reference image for the current slice. Hence, a slice of 3D target image regions is extracted every slice. We also demonstrated that the proposed algorithm worked for 3D medical images.

***Keywords*—**Image segmentation, discrete-time oscillator network, successive algorithm, fragment

I. Motivation

IMAGE segmentation is a fundamental technique of medical image processing [1], [2]. For example, to design intensity-modulated radiation therapy (IMRT) plans, the regions of therapeutic targets and organs at risk must be exactly segmented from three-dimensional (3D) medical images of patients. In clinical situation, the medical staff carefully segments the 2D image regions every slice by mouse operation. Therefore, the development of high-accuracy 3D-image-segmentation techniques brings the lightening of workloads to them in the design of IMRT plans.

II. Problem Statement

We consider a method to extract 3D image regions from a 2D sketch that we roughly draw the outline of target image regions. To develop the method, we use a discrete-time oscillator network that we previously proposed [3], [4]. It can produce the set of connected components (image regions) with similar pixel values from a given 2D gray-scale image. Here, we call all combinations of image regions the set of fragments. The synchronization of responses from all oscillators produces fragments. This means that the number of generated fragments depends on the type of oscillatory responses. To improve the accuracy of 3D image segmentation, the use of an oscillator network that can produce more fragments is advisable. We also need an algorithm that extracts target image regions every slice.

III. Approach

First, we optimize the parameter values of our oscillator network so that it can generate more fragments. To find suitable parameter values, we analyze bifurcations of periodic points observed in a reduced model [5] of a large oscillator network. Second, we define the similarity between a fragment and a reference image using Kullback–Leibler divergence [6] and propose an algorithm to extract 2D target image regions successively from each slice of a given 3D image. In the algorithm, the initial reference image is given as a 2D rough sketch for a slice; the reference image for the neighbor slice is automatically provided as the fragment that is closest to the reference image for the current slice.

IV. Results

First, we analyzed bifurcations of periodic points observed in a reduced model that consists of only four discrete-time oscillators and an element coupled with all the oscillators. As the result, we found a parameter region that a chaotic attractor exists. From the conjecture that any large oscillator network has almost the same dynamical structure, we set the parameter values of oscillator networks we actually used according to the analyzed results. Second, we applied the successive algorithm to 3D images of the human head and abdomen. Our algorithm was able to fitly extract the 3D image regions of the skull bones and kidneys from their 2D rough sketches for a slice, respectively.

V. Conclusion

We proposed a new scheme of 3D image segmentation using a discrete-time oscillator network that can produce fragments for a given 2D reference image. The parameter values of our oscillator network were optimized as our analyzed results. We also demonstrated that the proposed algorithm using the

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optimized oscillator network was able to extract the 3D image regions of target tissues with high accuracy.

ACKNOWLEDGMENT

This work was supported by JSPS KAKENHI Grant Number 25330288.

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