Three Dimensional Segmentation in PCNN

Naoya NISHI[1] and Masaru TANAKA[1] and Takio KURITA[2]
[1]Information and Computer Science, Faculty of Engineering
Saitama University, Japan
Simo-Ookubo255, Saitama-shi, Saitama, 338-8570 Japan
Tel. +81-48-858-3957.
[2]The National Institute of Advanced Industrial Science and Technology
Umezono1-1-1, Tukuba-shi, Ibaraki, 305-8568 Japan

Abstract: In the three-dimensional domain image expressed with two-dimensional slice images, such as fMRI images and multi-slice CT images, we propose the three-dimensional domain automatic segmentation for the purpose of extracting region.

In this paper, we segmented each domain from the fMRI images of the head of people and monkey. We used the neural network "Pulse-Coupled Neural Network" which is one of the models of visual cortex of the brain based on the knowledge from neurophysiology as the technique. By using this technique, we can segment the region without any learning.

Then, we reported the result of division of each domain and extraction to the fMRI slice images of human's head using "three-dimensional Pulse-Coupled Neural Network" which is arranged and created the neuron in the shape of a three-dimensional lattice.

1. Introduction

In the three-dimensional image which consists of two-dimensional fMRI images, multi-slice CT images, and slice images as shown in the sectional view of a stratum, segmenting each domain or object in images makes easy an understanding of the form of the domain, or a position and a size. Moreover, the segmented images can be used and applied to other processing.

For example, in the medical field, it is used as visualization of a three-dimensional domain. It can be used for capaticy presumption, comparision of a specific domain and so on.

Although there are many researches, an epoch-making technique is not establised.

In image segmentation, people are dividing the image by one sheet and one-sheet handmade business in the present condition. If only a few two-dimensional images is given, the segmentation task can be performed by hands with some efforts. However, if it becomes a three-dimensional image, a great labor and a lot of time will still be required.

Then, this research proposes the technique of dividing each domain in three dimensions to the three-dimensional image which consists of two-dimensional slice images. If a single two-dimensional image is divided, we have to consider the relation of the upper and lower sides between images. However, it can be expected that the output taken into consideration is obtained maintaining relation of the upper and lower sides by dividing a domain in three dimensions. Moreover, it is more nearly expectable to perform in three dimension for more short time rather than performing one sheet by one sheet at a time. Here, we proposal to use "Pulse-Coupled Neural Network" which is one of the models of the cerebral visual cortex as the technique of three-dimensional segmentation. As the reason, the "Pulse-Coupled Neural Network" adopt the pulse coded neuron as the basic element.

On the other hand, the common neural network is using the McCulloch-Pitts neuron as the basic element. Although a neuron of this coding is not change at all about time, even when a pulse coded neuron has a fixed input, in order that a threshold value may change with time dynamically, an output changes for every time. By this difference, the pulse coded neuron has higher power of expression. Now, our brain is working by the neuron group by which pulse coding was carried out. About how the pulse sequence generated from these neurons is used as information, although there are also many still unknown portions, these pulse sequences are considered to have played the important role.

Moreover, "Pulse-Coupled Neural Network" has the feature of not needing learning. It is not necessary to consider prior samples and time to need learning, and by this, whether or not it will be wit images, it can be treated.

From the above reason, we use "Pulse-Coupled Neural Network", to the images of a three-dimensional domain, and checked the validity of the segmentation by this research.

2. Pulse-Coupled Neural Network

"Pulse-Coupled Neural Network(PCNN)" is the model into which Lindblad and Kinser (1998) developed the model which Eckhorn (1990) proposed, in order to explain the synchronous burst phenomenon which happens by the neuron group in the visual cortex of the brain of the cat. Then, pioneering work in the implementation of the algorithms which is used easy to image processing was done by Johnson and his colleagues.

"Pulse-Coupled Neural Network" is known as one of the techniques which performs segmentation of edge detection or an object effectively.

It is the feature of PCNN that the pulse coded neuron is being used.

Unlike other common neuron, "Pulse-Coupled Neural

Network" perform coding to the time domain.

That is, even when a pulse coded neuron has a fixed input, an output changes as time goes on. Thereby, a pulse coding type neuron can have high power of expression. Moreover, it is one of the features that it is not necessary to use learning. The samples used for learning is unnecessary by this reason, and the result in a short time can be searched for.

2.1 Neuron model

There are three parts to the model neuron: the dendritic tree, the linking modulation, the pulse generator. Each parts will be described separately, and then the operation of the complete model will be discussed.

The dendritic tree is divided into two principal branches in order to make two distinct inputs to the linking part of the jth neuron. They are the primary input, termed the feeding input F_j, and the secondary input, which is the linking input L_j. The linking and feeding inputs are given by

$$L_j(i) = L_j(i-1)e^{-\alpha_L} + V_L(K * Y(i-1))_{jk} \quad (1)$$

$$F_j(i) = S_j + F_j(i-1)e^{-\alpha_F} + F_L(M * Y(i-1))_{jk} \quad (2)$$

where K and M are the synaptic gain strengths, or weights, for the kth synapse of the linking and feeding receptive fields, respectively, to the jth neuron. Y is the input pulse from kth neuron. α_F and α_L are the time constants, and $f1 * f2$ denotes the convolution integral operation for any two functions $f1$ and $f2$. S is an analog feeding input to the jth neuron.

The linking modulation is obtained by adding a constant positive bias to the linking input and multiplying that by the feeding input. The linking input cannot drive the internal activity to zero. The total internal activity U of the neuron is

$$U_j(i) = F_j(i)(1 + \beta L_j(i)) \quad (3)$$

where β is the linking strength.

The pulse generator uses a threshold discriminator followed by a pulse former, and a variable threshold that is dependent upon the prior pulse output of the generator itself. The output Y and threshold Θ are given by

$$Y_j(i) = \begin{cases} 1 & \text{if } U_j(i) > \Theta_j(i) \\ 0 & \text{otherwise} \end{cases} \quad (4)$$

$$\Theta_j(i) = \Theta_j(i-1)e^{-\alpha_\Theta} + V_\Theta Y_j(i-1) \quad (5)$$

where α_Θ is the time constant. The pulse generator makes use of the step function so that the output of the system is to binary(0 or 1). In this paper, the receptive field of a neuron is globosity. The linking strength is in inverse proportion to distance of neurons.

3. Experience

We performed domain segmentation to a three-dimensional image using "three-dimensional Pulse-Coupled Neural Network" which has arranged the pulse coded neuron described in the top in the shape of a three-dimensional lattice.

The receptive field of this "three-dimensional Pulse-Coupled Neural Network" is the shape of a three-dimensional sphere, and is not only including front and rear, right and left but an receptive field including an up-and-down relation. This receptive field is applying the weight in inverse proportion to the square power of the distance between neurons. The situation of this receptive field is shown in Fig.1.

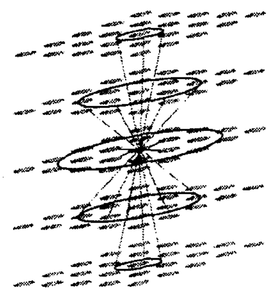

Figure 1. the receptive field on a PCNN neuron. The receptive field is the shape of a sphere.

Moreover, The input to this "Pulse-Coupled Neural Network" treats images as an input. To 1 pixel of pixels, one neuron is assigned, and a network is operated. As a image inputted into a network, the fMRI images which took human head in the shape of level section form was used. This is shown in Fig.2 and Fig.3. The parts of input images into the network is shown Fig.2. As shown in Fig. 3, the group of two-dimensional slice images were inputted into "three-dimensional Pulse-Coupled Neural Network" as a three-dimensional image in piles in layers. However, we never use a nature of the voxel data about fMRI images, and use as common images. The by means, we can use three-dimensional images which consists of two-dimensional slice images except of fMRI images.

Moreover, "Pulse-Coupled Neural Network" has some parameters, and according to the purpose or the use, it had to be given and also did this research using the group of some parameters.

The output obtained from "Pulse-Coupled Neural Network" is shown in Fig.4, Fig.5 and Fig.6.

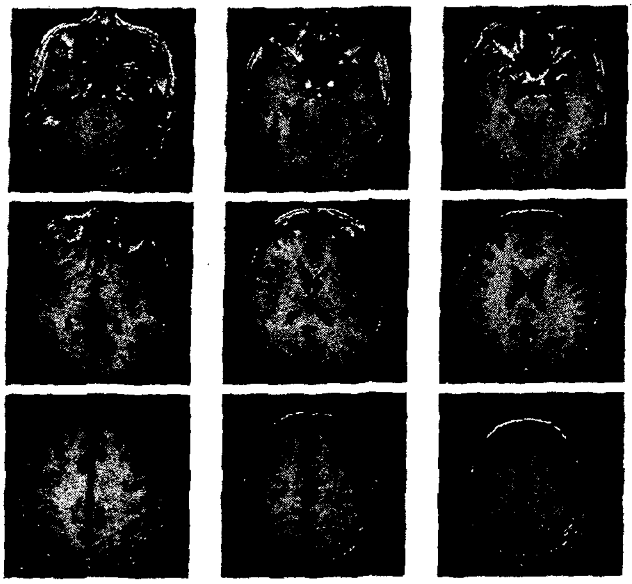

Figure 2. The parts of input images into "Pulse-Coupled *Neural Network*"

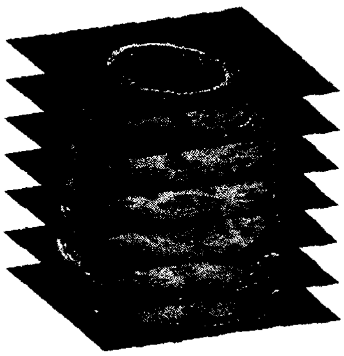

Figure 3. This show that the input images are piled up in layers.

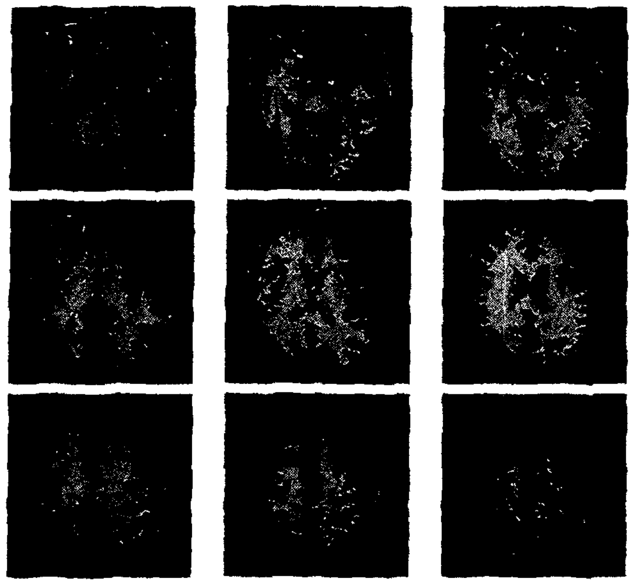

Figure 4. PCNN's output plot on the input images in the case of one time.

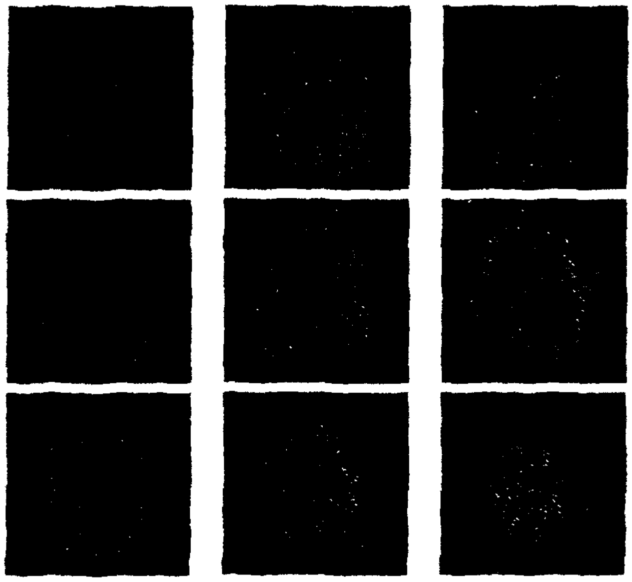

Figure 5. PCNN's output plot on the input images in the case of other time.

4. result

The output obtained when a certain parameter is used is shown in Fig.4, Fig.5 and Fig.6.

Fig.4 shows that the portion inside cerebral, i.e., white matter, and it is obtained. As compared with input images, I understand that the a little bit white part and form of the brain of the input image overlap.

In Fig.5, the outside somewhat dark portion is outputted by contraries. It is gray matter of the brain. I understand that is approximating with the form of the a little bit dark part of the outside of the brain as compared with input images.

Figs.4 and 5 show that the whole domain to extract are firing. However, the output which takes edge is also obtained along the domain to segment in Fig.6.

Moreover, Figs. 4, 5, and 6 don't extract only a specific portion like white matter and gray matter, and two or more domains are extracted. Since it does not adjoin even if this has two or more domains currently extracted, it is considered that it can divide easily by subsequent image processing. Moreover, it is considered that the output divided one by one is obtained, using the images obtained from this output for the network as input once again.

It could be judged that the output with a certain amount of accuracy is obtained from this result. Moreover, the output from the network not only what was described in the top but that from which various domains are extracted arealso obtained.

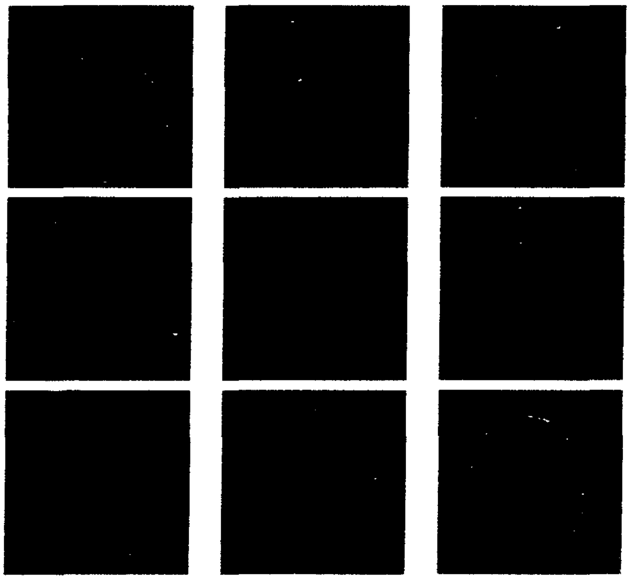

Figure 6. PCNN's output plot on the input images in the case of other time.

5. conclusion

Using the neural network, the three-dimensional image was segmented and the result which can be judged to be in general good was able to be obtained. By using a pulse coded neuron, two or more outputs in a short time were obtained. Moreover, in the segmentation of a three-dimensional domain using "three-dimensional Pulse-Coupled Neural Network", selection of a parameter is comparatively easy and can divide various domains in three dimensions only by operating one cycle of "three-dimensional Pulse-Coupled Neural Network". The good result also from an experiment here has been obtained.

The improvement of accuracy of segmentation and extraction of the domain in details are now going on.

This study was performed through Special Coordination Funds for Promoting Science and Technology from the Ministry of Education, Culture, Sports, Science and Technology, the Japanese Government.

References

[1] T.Watanabe, M.Tanaka, T.Kurita and T.Mishima, "Autonomous foveating system based on the Pulse-Coupled Neural Network", International Technical Conference on Circuits/Systems, Computers and Communications (ITC-CSCC'99), Vol.1, pp.197-200, July, 1999.

[2] Daniel D. Lee and H. Sebastian Seung, "Learning the parts of objects by non-negative matrix factorization", NATURE, Vol.401, pp.788-791, October 1999.

[3] J. L. Johnson, H. Ranganath, G. Kuntimad and H. J. Caulfield, "Pulse-Coupled Neural Networks", pp.1-56.

[4] Vlatko Beanovic, "Wavelet Preprocessing and Pulse Coupled Neural Networks.", pp.14-20, September 1996.

[5] R.Eckhorn, H.J.Reitboeck, M.Arndt, P.Dicke, "Feature Linking via Synchronizetion among DistributedAssemblies: Simulationsof Result from Cat Visual Cortex", Neural Computation, Vol.2, pp.293-307,1990.

[6] T.Lindblad, J.M.Kinser, "Image Processing using Pulse-Coupled Neural Networks", pp.101-130, Springer, London, UK, 1998.