Abstract—Based on locally excitatory globally inhibitory oscillator networks (LEGION), an object extraction method was proposed. The oscillation network can segment image and extracted objects by the scene and object feature. In this paper, the normalized difference water index (NDWI) was used as the feature of water body to segment remote sensing image. Because of the good coherence of spectrum property of water body, the NDWI of the water body would have strong couple weight on NDWI. The special spectrum property of water was also considered as a feature in this paper. Because the proposed method can extract object with their features instead of the pixel intensity, it was robust to noise and advantage to keep the detail information of object. The results of experiment validate the effective of the proposed method.

Index Terms—image segmentation; object extraction; neural network

I. INTRODUCTION

Image segmentation and object extraction had important significant for Remote sensing. The remote sensing data can be used to analyze, detect and monitor earth surface globally. Especially for the water area, remote sensing data supplied for the macroscopically and nondestructively descriptions. There have been plentiful achievements for remote sensing technology on water quality retrievals, water body extraction, coastline changes detection, the area of water body change detection and so on.

The mostly used methods for extraction of water body were threshold method and multi-bands method. The threshold method was based on the ground object spectra characteristic of every single band, chose an appropriate threshold to extraction the water body. Multi-band method was to construct an index to enlarge the distance between water and other ground objects. Such as spectrum property method [1], normalized difference vegetation index (NDVI) [2], normalized difference water index (NDWI) [3, 4] and improved indices (MNDWI) [4, 5]. Beside above methods, such as decision tree, step iterative method [6-8]and so on. Beside those, the spectrum value of objects is affect by the surrounding environment and noise [9].

There are mainly four disadvantages of the pixel-wise methods: Firstly this kind of method is depended on the resolution, the luminance condition and the content of the image; secondly the water bodies extracted by the pixel-wise methods are lack of integrity; thirdly it is easy to be disturbed by noise and other ground object; fourthly the result of these methods can’t supply the available input to the higher process.

Differing from the pixel-wise method, the object-wise method is based on the macroscopic analysis of the image. At 2000, Baatz M. et al [10] had proposed an local mutual best fitting area increasing strategy which was an object-oriented optimum segmentation method of the remote sensing image. This method had been used in a remote sensing classification software eCongnition. And Gamanya R. et al [11] improved the method of Baatz. M. and proposed an auto-segmentation method. Both of these methods cut the object body from object-level.

This paper would construct the couple weight based on NDWI instead of the lumina nce of pixels to extract the water body by oscillation network. The couple weight of water body areas should be larger. In order to inhibit other ground objects which have the same spectrum characters of water, this paper also brings the special spectrum property into the oscillation network. Combining these two methods offset the shortages of each other.

II. THE INTRODUCTION OF LEGION

Inspired by biological visual system and brain, Wang and Terman et.al [12] proposed the locally exciting globally inhibition oscillation network (LEGION). This neural model is originated from correlation theory of Von Der Malsburg et al [13-15] proposed at 1994. They assert that the brain can bind the similar features of objects by firing activities the scattered cells from different cortex areas. Won Der Malsburg [13] considered this integrated perceive function of brain as the temporal correlation theory. At 1989 Eckhorn [16] and Gray [17] point out that oscillation correlation is the special form of temporal correlation. The model of LEGION is described as follows:

\[ x_{i,j}^{t+1} = 3x_{i,j}^{t} - x_{i,j}^{3} + 2 - y_{i,j}^{t} + I_{i,j} + S_{i,j} + \rho \]  

(1)
\[ y_{i,j}' = \epsilon(1 + \tanh\left(\frac{x_{i,j}}{\beta}\right)) - y_{i,j} \]  
\[ S_{i,j} = \sum_{k,l \in N(i,j)} W_{ij,k,l} H(x_{k,l}) + W_p H(P_{i,j} - \theta_p) - W_H(z - \theta_z) \]  
\[ P_{i,j}' = (1 - P_{i,j}) H\left[\sum_{k,l \in N_p(i,j)} H(x_{k,l}) - \theta_p\right] - \epsilon P_{i,j} \]  
\[ z' = H\left[\sum_{k,l} H(x_{k,l}) - 1\right] - z \]

where \( l_{i,j} \) is the stimulate input of pixel \((i,j)\), \( x_{i,j} \) and \( y_{i,j} \) are two oscillators on different temporal scale. And \( \rho \) is the variance of Gaussian noise. \( S_{i,j} \) was the couple equation. \( W_{ij,k,l} \) is the couple weight of pixel \((i,j)\) and pixel \((k,l)\). \( H \) is the step function. \( W_p, W_z \) are the weight coefficient correspond to \( P_{i,j} \) and \( z \) is the globally inhibition. \( P_{i,j} \) is the later potential of pixel \((i,j)\), and \( \theta_p, \theta_z \) are the threshold of \( P_{i,j} \) and \( z \).

Equation (1), (2), (3) and (4) are differential equations. The physical significance of these equations had been analyzed particularly and comprehensively by Terman and Wang in [12]. They had proposed a simplified LEGION method in [18]. The couple weight coefficient \( W_{ij,k,l} \) was the important factor, it decided what feature will be chosen to cut the image.

### III. THE LEGION BASE ON NDWI

#### A. The model of NDWI

The NDWI was defined as follow:

\[ \text{NDWI} = \frac{\text{Green} - \text{NIR}}{\text{Green} + \text{NIR}} \]  

Based on the NDWI, the distance between water and other ground objects was enlarged. But because of the pollution and the magnitude of sandiness, the coherence on the water surface will be reduced and the NDWI fluctuated above zero.

Fig.1 shows the spectrum change trend of water area, vegetation area and building area around the river. Like paper [5], the spectrum of building on the forth band (TM4) and the second band (TM2) had the similarity change trend, but with the different mean. Fifteen sample points of NDWI were plotted in Fig. 2. The variance within the water body and the building body were smaller, and the variance between water and building was larger.

#### B. The couple weight based on NDWI

From the above analysis, construct one couple weight based on NDWI to describe the relationship of pixels:

\[ W_{\text{NDWI}}(i,j;k,l) = \frac{N(i,j) + N(k,l)}{N(i,j) - N(k,l) + \epsilon} \]  

Where \( N(i,j) \) was the NDWI value of pixel \( I(i,j) \). The equation (2) could be rewritten as follow:

\[ S_{i,j} = \sum_{k,l \in N(i,j)} W_{\text{NDWI}}(i,j;k,l) H(N(i,j))H((I_4(k,l)+I_2(k,l)) > (I_4(l,k) + I_2(l,k))) + W_p H(P_{i,j} - 0.5) - W_H(z - 0.5) \]

- **C. LEGION based on NDWI**

The special spectrum property was introduced into the proposed extraction method which was found by Zhou. The special spectrum property of water is:

\[ B_3(\text{green}) > B_4(\text{SW}) & B_2(\text{red}) > B_4(\text{IR}) \]

So the equation (8) could be rewritten as follow:

\[ S_{i,j} = \sum_{k,l \in N(i,j)} W_{\text{NDWI}}(i,j;k,l) H(N(i,j))H((I_4(k,l)+I_2(k,l)) > (I_4(l,k) + I_2(l,k))) + W_p H(P_{i,j} - 0.5) - W_H(z - 0.5) \]

Where \( I_4(k,l) \) represent the spectrum luminance of pixel \( I(k,l) \) of the first band. \( H(x) \) was the step function, and \( H(N(i,j)) \) compared the NDWI value of pixel \( I(i,j) \) with zero. Adding \( H(N(i,j)) \) onto the second term was to make the object to be remained which was with the NDWI larger than zero.
IV. Experiments and Analysis

A. Experiment Data

In this paper, we chose the Landsat 7 TM image date to complete the experiments. This remote image contains the area of Tai lake and the part of Chang Jiang River which was cut on the north of the lake.

This cut part contains Yangzhou city and other small towns. The size of image was 800×810 pixels.

Fig. 3 showed the water body extraction results based on NDWI method and the spectrum property. Fig. 4 was the two enlarged parts of original image. This paper used the enlarged part of fifth band (TM5) to show the detail. Fig. 4(a) was the enlarged yellow block. And the Fig. 4(b) was the enlarged red block. Fig. 5 shows the results of the LEGION method. Fig. 5 could extract the water body with vivid edge on the transition part and the integrity bridge body. At the same time the edge and coherency of Fig. 5(b) was better than Fig. 5(a).

B. The convergence of the proposed Method

The areas of water body were enlarged as the LEGION iterated. This section talked about the convergence of LEGION method based on the river body. Fig. 6 showed the change of increase magnitude between two adjacent iteration times, red line represented the area increase of LEGION method and the blue line represented the area increase of LEGION method with spectrum property. From this figure, 40 times were an optimum iterative time and the areas of water body stay on a stable value.

![Figure 3](image1)
(a) The result based on NDWI method
(b) The result based on special spectrum properties

Figure 3  The results based on NDWI method and the spectrum properties $\theta_w = 30; \theta_p = 1100$, and the iterative time was 80.

![Figure 4](image2)
(a) Enlarged yellow bridge
(b) Enlarged red block

Figure 4  The enlarged parts of original image

![Figure 5](image3)
(a) The output based on LEGION (NDWI) method
(b) The result of LEGION with the spectrum property

Figure 5  The results of LEGION with NDWI
V. CONCLUSION

This paper presents a water body extraction method based on LEGION (NDWI). The experiment results indicated that the proposed method could extract the coherent water body with smooth and clear edge accurately. Because the oscillation network was dependent on the feature function, it was important to construct an appropriate feature function which can bind the object tightly.

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REFERENCES


Min Li is a PhD student of Hohai University, and received the B.S. degree in Communication Engineering from Hohai University, Nanjing, P. R. China in 2005 and 2007 respectively. Her main research interest is remote sensing images processing, bionic vision computation and analysis.

Lizhong Xu is a Professor at College of Computer and Information, as well as the Director of Institute of Communication and Information System Engineering, Hohai University, Nanjing, P. R. China. He received the Ph.D. degree in Control Science and Engineering from China University of Mining and Technology, Xuzhou, P. R. China in 1997. He is a Senior Member of IEEE, Chinese Institute of Electronic, and China Computer Federation. His current research areas include signal processing in remote sensing and remote control, information processing system and its applications, system modeling and system simulation. He is the corresponding author of this paper, his email: lizhxu@hhu.edu.cn, hhice@126.com

Min Tang received PhD degrees from Nanjing University of Science and Technology in 2006. Currently, she is a lecturer at the Hohai University. Her research interests include computer vision and computer graphics.