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Time-series processing of large scale remote sensing data with extreme learning machine

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ABSTRACT

Nowadays, land-cover change detection plays a more and more important role in environment protection and many other fields. However, the current land-cover change detection methods encounter the problems of low accuracy and low efficiency, especially in dealing with large scale remote sensing (RS) data. This paper presents a novel extreme learning machine (ELM) based land-cover change detection method with high testing accuracy and fast processing speed. The evaluation results show that ELM outperforms the traditional methods, e.g., SVM and BP network, in terms of training speed and generalization performance, when applied in land-cover classification. In our experiments, we apply our method to the analysis of rapid land use change in Taihu Lake region over the past decade.

1. Introduction

In this section, three aspects of land-cover change detection with time-series RS images are firstly introduced: definition, application and challenges. Secondly, our work of ELM based land-cover change detection method is briefly described and contributions are listed.

1.1. Land-cover change detection with time-series RS imageries

Change detection is the process of identifying differences of the status of an object or phenomenon by observing it at different time [1]. Currently, a popular method for land-cover change detection method is through the digital analysis of time-series RS images. Time-series RS images are taken of the same area at different time. We can manually compare time-series images and find the difference by view, but RS image digital processing can provide an automatic way. Briefly, land-cover change detection method based on time-series RS images is to identify the interesting land-cover changes between before time image and after time image.

Recently, land-cover change detection technology plays a more and more important role in various applications, such as land usage analysis, disaster monitoring, and snow-melt measurements. Various papers [2–4] have presented their work of applying change detection technology to the analysis of land-use and land-cover. Lunetta [4] performed the change detection experiment in the biologically complex landscape of the Neuse River Basin, North Carolina using Landsat5 and Landsat7 image collected in May of 1993 and 2000. Weng [2] analyzed the rapid land use change taken place in Zhujiang Delta over the past decades with the help of change detection technology.

Traditionally, the main challenge to land-cover change detection methods is the detection accuracy. However, RS data is rapidly growing and the image's resolution has become much higher. Therefore, the methods' processing speed and scalability have become another two major challenges.

1.2. Major contributions

This paper's major contribution is to propose a novel ELM-based land-cover change detection method. In detail, it can be described in three aspects:

(i) First, our land-cover change detection method is the first work of applying ELM to time-series RS image processing. The application successfully analyzed the rapid land use change in Taihu Lake region over the past decade. This proves that ELM can be applied in time-series RS data processing with high accuracy and high efficiency.
(ii) Second, ELM-based land-cover classifier is proved to have fast training speed. In our application, it is trained much faster than both SVM and BP based classifiers, especially when the training data set is large.
(iii) Third, ELM-based land-cover classifier has high generalization performance. When compared with SVM and BP based land-cover classifiers, it has higher testing accuracy.

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In conclusion, ELM is firstly applied to time-series RS data intelligent processing. And the evaluation proves that ELM outperforms the traditional classifiers, in terms of training speed and generalization performance. With high testing accuracy training efficiency, our ELM-based land-cover change detection method is successfully applied in land usage analysis.

2. Related work

2.1. Methods for land-cover change detection

In the field of land usage analysis, a wide range of methods [1] have been explored. Here, we classify the current land-cover change detection methods into two categories: classification mapping based and none classification mapping based.

(i) First, classification mapping based methods, like post-classification and cross-correlation, determine land-cover change through the comparison of before time and after time classification mappings.
(ii) Second, the none classification mapping based methods, like image differencing, image ratioing and principal components analysis, involve transformations of the original spectral bands so as to enhance the land cover changes.

Among the classifiers used in change detection, both supervised and unsupervised algorithms have made progress. The supervised methods provide more information about the kinds of transitions that occurred on the ground. They are less affected by different atmospheric conditions, sensor calibration, and ground conditions [5,6]. Demir [5] presents a novel iterative active learning technique aimed at defining effective multitemporal training sets. It can be used for the supervised detection of land-cover transitions.

In comparison, unsupervised approaches require fewer manual intervention [7–9]. Therefor, they are quite suitable in the situations that the ground-truth is always unavailable. However, the testing accuracy of unsupervised approaches is much lower than the supervised ones. The supervised methods with various traditional machine learning algorithms are also not perfect. They need more human interventions and are less scalable. Moreover, the traditional land-cover classifiers are not accuracy enough for real application and have low efficiency in dealing with large training data set.

2.2. ELM for remote sensing application

ELM is a recently proposed machine learning method with the capability of multiclass classification and universal approximation [10–13]. It has been widely applied in various applications, such as sales forecasting in fashion retailing [14]. However, only a little work of applying ELM to RS image processing has been done until now.

Pal [15] did the supervised land-cover classification experiment with ELM using remote sensing image. However, only the classification accuracy and computational cost of ELM are tested and compared with BP network. And ELM is applied to no real application. Jun [16] indicates that ELM can be used for training the positive and negative fuzzy rule system quickly for specific image classification. Although ELM network is adopted for RS image classification, no time-series image processing work are introduced. Briefly, ELM has not been applied to the applications of land-cover change detection or time-series RS image processing until now.

3. ELM-based method for land-cover change detection

In this section, we describe the ELM-based land-cover change detection method in detail. The method mainly contains two components: training unit and detection unit. The following contents describe four aspects of the method: the whole method framework, preparatory work, training unit and detection unit.

3.1. Framework of land-cover change detection method

The whole land-cover change detection method can be divided into two components: training unit and detection unit. The framework is shown in Fig. 1. Training unit is to build an ELM network for RS image classification. Through adjusting the hidden nodes number and activation function, the classifier can achieve enough high generalization performance. Detection unit is responsible for time-series land-cover mapping's calculation and comparison.

3.1.1. Preparatory work: land-cover categories and samples

According to different terrains area and RS images, the types of land-cover can be determined. In our application, according to the investigation of Taihu Lake region's terrains and the chosen Landsat7 images, we classify the land-cover into five types. Image features and ground object description of each category are described in Table 1.

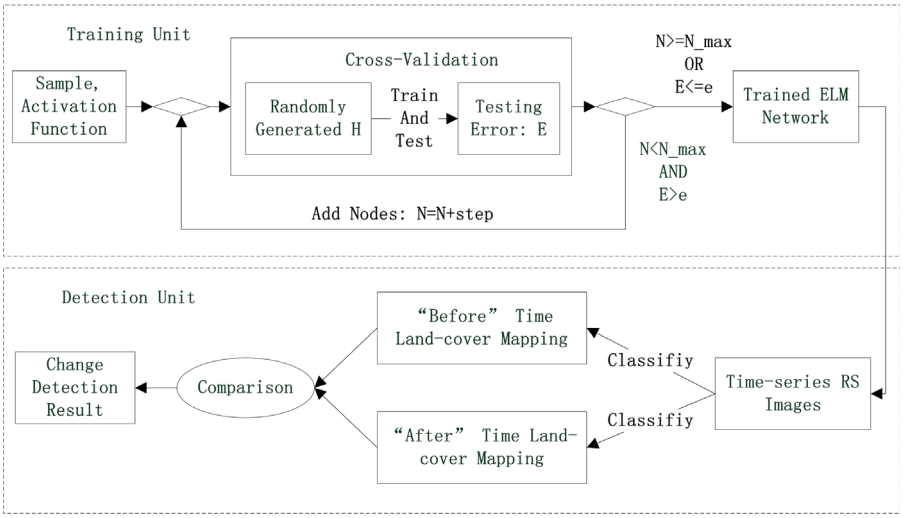

Fig. 1. Framework of ELM-based land-cover change detection method.