Water Extraction in High Resolution Remote Sensing Image Based on Hierarchical Spectrum and Shape Features

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Abstract. This paper addresses the problem of water extraction from high resolution remote sensing images (including R, G, B, and NIR channels), which draws considerable attention in recent years. Previous work on water extraction mainly faced two difficulties. 1) It is difficult to obtain accurate position of water boundary because of using low resolution images. 2) Like all other image based object classification problems, the phenomena of “different objects same image” or “different images same object” affects the water extraction. Shadow of elevated objects (e.g. buildings, bridges, towers and trees) scattered in the remote sensing image is a typical noise objects for water extraction. In many cases, it is difficult to discriminate between water and shadow in a remote sensing image, especially in the urban region. We propose a water extraction method with two hierarchies: the statistical feature of spectral characteristic based on image segmentation and the shape feature based on shadow removing. In the first hierarchy, the Statistical Region Merging (SRM) algorithm is adopted for image segmentation. The SRM includes two key steps: one is sorting adjacent regions according to a pre-ascertained sort function, and the other one is merging adjacent regions based on a pre-ascertained merging predicate. The sort step is done one time during the whole processing without considering changes caused by merging which may cause imprecise results. Therefore, we modify the SRM with dynamic sort processing, which conducts sorting step repetitively when there is large adjacent region changes after doing merging. To achieve robust segmentation, we apply the merging region with six features (four remote sensing image bands, Normalized Difference Water Index (NDWI), and Normalized Saturation-value Difference Index (NSVDI)). All these features contribute to segment image into region of object. NDWI and NSVDI are discriminate between water and some shadows. In the second hierarchy, we adopt the shape features to remove more shadows. The water polygons are generated by vectorization algorithm after water segmentation, and then some shape parameters (Compact, Critical Point and Symmetry) are considered to remove shadow. To evaluate the performance of the proposed method, we collect several Quick Bird images at 0.61-m resolution which are acquired in May 2009 at GUANGZHOU province of China. The proposed method is compared with four other methods in water extraction, including pixel-based segmentation by NDWI, Mean-sift segmentation by NDWI, and SVM with different channels. Experimental results show that the proposed method can increase extraction accuracy and reduce the influence of shadows.

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1. Introduction
In the recent years, remote sensing imagery makes the monitoring of the earth surface and atmosphere possible with fast developments of remote sensing technology. The object recognition based on remote sensing images becomes an important issue which draws a lot of attention from both research and industry field. Extracting water body information accurately from remotely sensed imagery is a crucial issue for surveying, planning and protecting water resources, and particularly flood disaster management.

Recently, a number of new approaches to water extraction for remote sensing images of different sources have been proposed. The object-oriented technique is a new technology which appeared recent years, rather than in pixel-level, it classifies remote sensing images in patch-level. Afterwards, various features such as textural features, shape, spatial relations and reflectance statistics were applied into water extraction. Zhou developed a descriptive model for automatic extraction of water based on special spectral characteristic [1]. Du proposed an approach for water extraction from SPOT-5 based on decision tree algorithm [2]. Furthermore Deng extracted water information in plain regions using the decision tree model. Cao established decision tree model of water automatic extraction and using object-oriented method in urban areas based on SPOT5 image [3] [4]. Mcfeeters proposed the normalized water index (NDWI), which largely restrains vegetation information, and highlight the water body information [5]. Based the improvement on NDWI, Xu developed a new water index, MNDWI (Modified NDWI), which works especially well on extracting water body in urban areas [6]. In addition, for different optical data, like RVI (Ratio Vegetation Index), MNDWI (Modified Normalized Difference Water Index), and NDSI (Normalized Difference Snow Index) etc can all be used respectively in the extraction of water area [7]. Luo represented an accurate extraction model with the “whole-local” step-by-step iterative method [8]. Xue proposed the method by image segmentation, segment merging, spectral and spatial features analyses to extract aquaculture water [9]. Li took various spectral features by using Adaboost algorithm to extract water [10].

Obviously, previous work on water extraction mainly faces two difficulties: (1) It is difficult to obtain accurate position of water boundary because of the low image resolution and different sensors; (2) Shadows are usually cast by elevated objects such as buildings, bridges, and towers, especially in urban region, it is difficult to discriminate water and shadow in certain condition.

In this paper we address the problem of water extraction from Quick bird images (including 4 channels: R, G, B, and NIR). The proposed method operates at two hierarchies: (1) Statistical information of spectral characteristic is used in image segmentation; (2) Shape feature is used to remove the shadow. In the first hierarchy, we combine NDWI (Normalized Difference Water Index) and NSVDI (Normalized Saturation-value Difference Index) [11] and (R, G, B, and NIR) to segment image and rough classification of water by NDVI and NSVDI. In the second hierarchy, we use shape features to remove shadow.

2. Water Extraction
From the above outline of the existing work on water extraction, one can see that the work on water extraction is rather limited. Water extraction is one of the important measures to protect and monitor water resources on the earth. We feel that there is a clear need for more efforts in water extraction for effectively maintaining the water resources.

The process of water extraction includes two hierarchies: (1) image segmentation process and water extraction; (2) shadow removal process, as shown in Figure 1. Firstly, we use Statistical Region Merging (SRM) techniques [12] to segment image, and take NDWI and NSVDI to extract water. Secondly, object shape features, generated by vectorization algorithm, are computed to remove shadow and other noises [13]. Finally, we get satisfied water result.

2.1. Water Segmentation based NDWI and NSVDI
The SRM algorithm belongs to the family of region growing techniques with statistical test for region fusion. The two key steps of the algorithm are as follows. 1) Ascertain a sort function. According to
the size of the function, the adjacent regions are sorted. 2) Ascertain a merging predicate. The merging predicate decides whether the adjacent regions are merged or not [14]. We modify sorted method with dynamic processing, sorting will change while the adjacent regions changes. At same time, we improved and applied it in remote sensing imagery with many features (R,G,B,NIR and NDWI and NSVDI) to predicate whether the adjacent regions are merged or not. NDWI is expressed as follows:

$$NDWI = \frac{GREEN - NIR}{GREEN + NIR}$$

where GREEN is Quick-bird band 2 and NIR is band 4. NSVDI is expressed as follows:

$$NSVDI = \frac{Saturation - Value}{Saturation + Value}$$

where Saturation and Value are HSV color space parameter.

**Figure 1.** The flow chart of water extraction.

### 2.2. Shape Features

Water polygons are generated by vectorization algorithm after water segmentation. Then the shape information such as Compact, Critical Point and Symmetry are considered.

**Compactness:** We simple define the compactness as follow:

$$Compactness = \frac{S}{L}$$

Compactness is a useful index in removing shadow of some irregular buildings. S is area of object and L is perimeter of object.

**Critical points:** Critical points angle exceed fixed threshold value characterize the curvature (inflexion) of contours. The critical point to Segment water polygon can help to remove irregular object in image.

**Symmetry:** Polygon is partition two parts by the major axis of the object, Symmetry is defined ratio of two parts. Irregular shape of shadow by segmentation is removed by symmetry.
3. Experimental Result and Discussion
To evaluate the performance of the proposed water extraction method, we collect five panchromatic Quick Bird images at 0.61-m resolution which were acquired in May 2009 at GUANGZHOU province of China.

![Image](image.png)

Figure 2. Results of water extraction by using different method (red is results of water body).

We compare five water extraction methods. Figure 2 shows results of different methods in water extraction. Figure 2 (a) shows original resolution remote sensing image. Figure 2 (b) shows results of water in NDWI by each pixel before segmentation which produce incorrect boundary of water and include many shadows. Figure 2 (c) shows result of using the mean-shift segmentation method which use OTB open source. This method considers water extracted by NDWI before mean-shift segmentation. Changing the threshold for NDWI will increase the amount of detected shadows,
missing water region in dark region. Figure 2 (d) and (e) shows results of using OTB (open source, adopting the SVM as classifier) based on the (R, G, and B) channels and (R, G, B and NIR) channels respectively. These two methods show similar results, and not only need training samples but also increase the time cost, which make the water extraction accuracy depends on same source data and the number of samples.

Fig 2 (f) shows result of our proposed method which reduces incorrect boundary of water body and improve the performance of water extraction. The proposed method adopts a hierarchical structure in spectrum and shape features that aims to overcome large deviation drawback of methods based on the pixel segmentation. Firstly, we segment image by spectrum attribute (R, G, B, and NIR), water index (NDWI) and shadow index (NSVDI) to control the homogeneity region boundary of water. A merging predicate is ascertained, and is used to confirm whether the adjacent regions are merged or not. Secondly, getting local spatial attribute by the shape of segmentation, we extract shape and spectrum features for water extraction. Because of different form of shadow, we use the NSVDI to remove vegetation shadow, and shape features to remove build shadow.

The proposed method effectively uses spectrum features to segmentation water region and shape features to remove shadow without using train samples which make the method is easy to use and easy to transplant to different systems.

4. Conclusions
In this paper, we have proposed a novel method based on hierarchical structure of spectrum and shape features for water extraction. Firstly, in segmentation and merge, we extracted water information under NDVI and NSVDI parameter based on spectrum attributes. Secondly, we use shape feature to remove different influence including shadow and incorrectness of segmentation. Finally, experimental results show that our method can increase extraction accuracy and reduce the shadow. Future work would involve considering spectrum features and topology of spatial features, and developing more effective segmentation method to enhance the performance of water extraction.

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