Surface Water Information Extraction Based on High-Resolution Image

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Abstract. Remote sensing image is an important information source for fast acquisition of information on the earth's surface. The extraction of high-resolution satellite remote sensing image information has also gradually increased. Based on high resolution image, this paper discusses its main characteristics, current research progress, main interpretation methods and similarities and differences with traditional interpretation methods, and further research is discussed. An example of surface water information extraction for Miyun Reservoir, China based on Landsat-7 image is preliminary explored. It provides a good reference for choosing different interpretation methods for different research purposes or situations.

1. Introduction
Remote sensing image is an important information source for fast acquisition of information on the earth's surface. With the development of remote sensing technology, the resolution of remote sensing image is getting higher and higher, which can reach 1-2 m or even tens of centimetres[1]. Since the launch of the first commercial high-resolution satellite IKONOS in the United States in 1999, high-resolution remote sensing satellites have attracted worldwide attention in the civilian and military fields because of the enormous military and economic benefits they bring. Governments and scientific research institutions are competing to study high-resolution remote sensing satellite and its application technology[2]. The extraction of high-resolution satellite remote sensing image information has also gradually increased. These high-resolution remote sensing images provide favourable conditions for the updating and application of surface data. Surface water information is an important part of the earth's surface information, the main source of water for human life, and also an important part of water resources in various countries. Extracting water body information based on high resolution images is fast and efficient. This paper comprehensively analyses the extraction of surface water information based on high resolution images. At the same time, the existing methods are analysed and summarized, and further research is discussed.

2. Basic ideas of surface water information extraction.

2.1. Basic characteristics of surface water
In high resolution remote sensing images, water body can be easily distinguished by eyes based on people's existing knowledge. To interpret water information through software, it is necessary to provide the computer with relevant features of the water body information. Physical and geometric features of objects change the grayscale values of local areas in the image, which results in image features. The basic characteristics of water bodies are as follows:
(1) Spectral characteristics. Without pollution, the water absorbs more light, especially in the near infrared band. Relatively speaking, the reflectivity of blue and green light is higher and the image is dark.

(2) Shape features and topological features. The river is linear and has a large curvature. Rivers are generally connected to form a river network. Lakes, reservoirs, etc. are irregular polygons and are often connected to rivers.

(3) Contextual characteristics. The water body has related image features such as dams and vegetation. There are differences between the main river, small rivers, lakes, and reservoirs.

2.2. Basic situation of high-resolution images

In recent years, the development of Chinese high-resolution remote sensing satellites has advanced by leaps and bounds. Mapping series satellites, Resources satellite three (ZY-3) satellites, Gaofen-1 (GF-1) and Gaofen-2 (GF-2) satellites are widely used in all walks of life for their ever-increasing spatial resolution, progressively enhanced image acquisition capabilities, and better image visibility. Foreign high-resolution satellites include: the American Quick Bird satellite, the French SPOT Satellite, the Indian Cartosat satellite, and so on (Table 1).

Table 1. Main high-resolution satellite (less than 10m).

| Satellite          | Country       | Launch Time (mm/dd/yy) | Full Color Resolution (m) | Multispectral Resolution (m) |
|--------------------|---------------|-------------------------|---------------------------|------------------------------|
| GF-1               | China         | 04/26/13                | 2                         | 8                            |
| GF-2               | China         | 08/19/14                | 1                         | 4                            |
| Mapping Satellite-1| China         | 08/24/10                | 2.5                       | 10                           |
| ZY-3               | China         | 01/09/12                | 2.1                       | 5.8                          |
| ALOS               | Japan         | 01/24/06                | 2.5                       | 10                           |
| Cartosat 1         | India         | 05/05/05                | 2.5                       |                              |
| CBERS-3            | China/Brazil  | 05/01/08                | 5                         | 20                           |
| CBERS-4            | China/Brazil  | 06/01/10                | 5                         | 20                           |
| EROS A1            | Israel        | 12/05/00                | 1.8                       |                              |
| EROS C             | Israel        | 03/01/08                | 0.7                       | 2.5                          |
| IKONOS-2           | US            | 09/24/99                | 1                         | 4                            |
| IRS Cartosat 2     | India         | 12/10/06                | 1                         |                              |
| IRS IC             | India         | 12/28/95                | 6                         | 23                           |
| IRS ID             | India         | 09/29/97                | 6                         | 23                           |
| IRS ResourceSat-1  | India         | 10/17/03                | 6                         | 6,23,56                      |
| IRS ResourceSat-2  | India         | 01/15/06                | 6                         | 6,23,56                      |
| KOMPSAT-1          | Korea         | 12/20/99                | 6.6                       |                              |
| KOMPSAT-2          | Korea         | 12/20/04                | 1                         | 4                            |
| OrbView 3          | US            | 06/26/03                | 1                         | 4                            |
| OrbView 5          | US            | 07/01/07                | 0.41                      | 1.64                         |
| Pleiades-1         | France        | 07/01/08                | 0.7                       | 2.8                          |
| Pleiades-2         | France        | 07/01/09                | 0.7                       | 2.8                          |
| QuickBird-2        | US            | 10/18/01                | 0.6                       | 2.5                          |
| SPOT-2             | France        | 01/22/90                | 10                        | 20                           |
| SPOT-4             | France        | 03/24/98                | 10                        | 20                           |
| SPOT-5             | France        | 05/04/02                | 2.5                       | 10                           |
| Rapid-eye (5 in total) | Germany    | 06/01/07                | 6.5                       |                              |
Currently, the largest users of commercial high-resolution satellite imagery are still military and government departments. However, with the increasing availability of high-resolution satellite imagery resources, image acquisition is more convenient. The application of high-resolution remote sensing satellite imagery in the civilian field has developed rapidly. In addition to traditional mapping applications, new application areas continue to expand. High spatial resolution images generally have the characteristics of rich texture information.

2.3. Basic process of surface water extraction
The remote sensing image is pre-processed to remove other information interference. Then the image is processed as follows: First, the image is initially processed by image binarization, grayscale segmentation, and the like. Secondly, comprehensive analysis of the specificity of water information, to find extraction rules, knowledge and so on. Thirdly, it is learned and extracted by computer. Next, Post-classification is performed to eliminate misclassified noise points, especially plaques in non-aqueous parts, and to eliminate holes in water bodies. Finally, the extraction results are verified.

3. Research status of water body information extraction

3.1. Research direction
With the expansion of civil use, research on surface water extraction based on high-resolution images has three main directions: Based on high-resolution images, local water bodies were extracted for analysis. Research and comparison of surface water extraction methods based on high resolution images. Compare the surface water extraction effects of different high spatial resolution remote sensing images.

3.2. Research application
The high-precision extraction of water resources information is of great significance for the prevention and control of natural disasters such as droughts and floods and the sustainable development of agriculture[3]. Such as the rapid extraction of flooding information[4]. It is also suitable for studying the core hot issues of transnational water use, water monitoring and emergency monitoring. Similarly, it plays an important role in the geographic national conditions’ census. Carrying out a survey of geographical conditions and forming an authoritative, objective and accurate census result is an important basis for formulating and implementing national development strategies and plans, optimizing the development pattern of national land space and allocating various resources. It is also an important basis for the investigation and application of related industries. It is worth noting that the waters are an important part of the survey of geographical conditions.

4. Method of water body information extraction
With the acquisition of high-resolution remote sensing images more convenient, there are more and more methods for extracting water information based on hyperspectral remote sensing images[5-8]. This paper summarizes the following five methods.

4.1. Spectral analysis method
Spectral analysis methods mainly include image classification and index method. The image classification method distinguishes ground objects according to different spectral characteristics of the reflectivity of the ground objects in different bands. However, this method requires artificial thresholding, which is subjective and not universal. The index method is a method of multi-spectral image band calculation and decision tree classification. Its principle is similar to the image classification method. But mathematical methods are used to increase the difference between the water and other features. Based on high-resolution optical images, the index method can intuitively extract water bodies. For example, based on GF-2 remote sensing imagery, a comprehensive water body index (NCWI) is used to enhance water body information, and then the improved OSTU (Named after Nobuyuki Otsu.)
combined with clustering algorithm (CSO) is used to quickly and adaptively determine the optimal segmentation threshold to extract water bodies[9].

4.2. Supervised classification
Supervised classification is a technique based on the establishment of statistical recognition functions and classification based on typical sample training methods. That is to say, according to the samples provided by the known training area, the characteristic parameters are obtained as decision rules. Then the discriminant function is established to classify the images to be classified. It is a method of pattern recognition. The concrete steps are as follows: First, training samples are obtained through field collection or screen selection. Then calculate the basic statistical value of the sample and the separation between the samples to determine whether the sample is good or bad, and adjust the sample to get a better value. Next, select the appropriate classification algorithm to classify. Finally, classification accuracy evaluation and post-classification processing are performed.

4.3. Object-oriented extraction method
The object-oriented analysis process is a geographical object that expresses space by dividing the pixels in the image into image objects. It mainly consists of two processes: image segmentation and object classification. Firstly, scale segmentation is carried out. In the process of segmentation, image is segmented according to several adjustable mean or heterogeneity criteria of shape and spectrum, and image objects are generated. Considerations include heterogeneity criteria, spectral criteria, shape criteria and so on. The size of the scale parameter indirectly affects the size of the generated object. The larger the segmentation scale, the larger the polygon area and the smaller the number of polygons in the generated object layer, and vice versa. After the image is segmented, a classification system is established, samples are selected, and an object knowledge base is established, and then classified. For example, the optimal segmentation scale and segmentation parameters are selected to segment the experimental area, the object knowledge base is established, and the appropriate threshold parameters are selected for water extraction[10].

4.4. Water body contour extraction method
At present, there are three kinds of water body contour extraction methods commonly used: the inter-spectral relationship method based on multi-band images[11]. A method based on edge detection algorithms[12]. Edge extraction algorithm based on active contour model[13]. The first two methods are easy to generate quadratic errors in the calculation process, and it is difficult to accurately obtain the water body boundary. The latter directly extracts the water body of the original image, and can directly acquire the target vector contour line, but there is also the problem that the boundary of the deep concave water body cannot be extracted. On this basis, many scholars have proposed many new improved algorithms[14]. Effectively extract water boundary, and then obtain water information.

4.5. Machine Learning Method
The water sample data is selected artificially on the image. After setting the kernel function type and the kernel function diffusion range, the partitioning problem of the sample feature space is transformed into the linear classification problem of the high-dimensional feature space. The classification decision function is established by linear combination of finite support vector points for classification. The advantages of this method are small sample learning, excellent anti-noise performance, high learning efficiency, and good generalization. However, there are also problems of large sample demand and high sample accuracy requirements. Existing researches such as support vector machine (SVM), Gauss Markov random field (GMRF) model combined with SVM method to form GMRF-SVM classification method[15], and high-resolution remote sensing image water body information extraction method based on case-based reasoning. For example, the spectral features and texture features of the water on the image are extracted to construct the case library, the normalized case similarity calculation method and the case matching strategy are used to match the case feature, regional growth method and
Morphological closed operation are combined to match post-processing, the water bodies information of the image is extracted[16]. Based on LiDAR data and aerial images, combined with image matching, computer graphics and digital image processing technology, a perfect water body automatic extraction scheme is constructed[17].

5. Example of surface water information extraction for Miyun Reservoir
Miyun Reservoir (40°29.0’N-40°30.5’N, 116°50.0’E-117°3.5’E) is located in the north of Beijing and was completed in September 1960. The rivers in the reservoir include Baihe River, Chaohe River, Baimaguan River and Qingshui River. Based on the Landsat image (medium resolution), the water body area of the reservoir is extracted by the index method, and the effect is better (Figure 1). However, it can be clearly seen that there are rivers in the upper left and south of the reservoir. River information is not interpreted by images with lower resolution.

![Figure 1. The extracted water body surface information of Miyun Reservoir based on the Landsat-7 image in 2016.](image)

6. Conclusion
Due to the limitation of spatial resolution, the surface water information extraction of traditional remote sensing images can only rely on the spectral information of the image and is classified at the pixel level. The high spatial resolution image, although the structure, texture and other information is very prominent, the spectral information is insufficient (small band). Therefore, relying solely on the spectral information of the pixels for classification, focusing on the local pixels and ignoring the texture, structure and other information of the adjacent whole pattern, will inevitably lead to a reduction in classification accuracy[18-19]. The improvement of image resolution enhances the difference in land use types on the one hand, but also causes the spectral characteristics of similar features to be unstable. The resolvability between categories is reduced, which increases the difficulty of automatic information extraction[20].

This paper preliminary explores surface water information extraction for Miyun Reservoir based on Landsat (medium resolution image). In order to improve the experiment and extract more detailed water information, the surface water extraction based on high resolution images is analysed.

With the development of science and technology, the combination of high-resolution remote sensing image processing and computer technology is getting closer. Focus on the cross-disciplinary application of disciplines, so that high-resolution data sources can play the greatest possible role for the benefit of human society.
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