# Watershed Segmentation of High-Resolution Remotely Sensed Imagery

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**Abstract:** High-resolution remotely sensed data such as SPOT-5 imagery are employed to study the effectiveness of the watershed segmentation algorithm. Existing problems in this approach are identified and appropriate solutions are proposed. As a case study, the panchromatic SPOT-5 image of part of Beijing urban areas has been segmented by using the MATLAB software. In segmentation, the structuring element has been firstly created, then the gaps between objects have been exaggerated and the objects of interest are converted. After that, the intensity valleys have been detected and the watershed segmentation have been conducted. Through this process, the objects in an image are divided into separate objects. Finally, the effectiveness of the watershed segmentation approach for high-resolution imagery has been summarized. The approach to solve the problems such as over-segmentation has been proposed.

**Keywords:** Watershed Segmentation, High-Resolution Remotely Sensed Data.

## 1. Introduction

Image objects are commonly homogenous and image segmentation means the grouping of neighboring pixels into separate segments. Meanwhile, a variety of algorithms for image segmentation have been employed in the field of the Pattern Recognition for more than 20 years (see [1]).

In the processing of remotely sensed data, segmentation algorithms have already been recognized as a valuable approach. Through this approach, more meaningful information has been effectively extracted. With the availability of high-resolution remotely sensed data, image segmentation has become popular in data interpretation. Segmentation techniques have not only shown their higher accuracy but also demonstrated their faster efficiency than the pixel-based analysis of such high-resolution imagery.

However, image segmentation is probably the most complicated and challenging problem in image processing. Generally speaking, image segmentation is the merge of image elements based on homogeneity of the same segment and the heterogeneity to the neighboring regions. The difficulty in the identifying of such homogeneity and heterogeneity turns out to be the key factor leading to the complex of the image segmentation. A variety of methods, such as thresholding, edge detection and clustering algorithms, have been developed in the image processing (see [2,3]).

Among the various approach for image segmentation, the watershed segmentation algorithm has been actively regarded as the extensively employed morphological tool (see [4,5,6,7]). In this algorithm, the gray level image is regarded as a relief with dark image objects as valleys and light objects as peaks. The original data are firstly transformed into a gradient image and then separated into two separate parts: "the catchment basins" and "the watershed lines". The local "minima" are regarded as "catchment basins" and all points that "flow" into the same "catchment basin" are divided into the same watershed (see [8]). This paper is to test the applicability of the watershed segmentation for high-resolution imagery. It is rather a more application-oriented analysis based on SPOT-5 remotely sensed imagery. The quality and suitability of this approach for very high-resolution image segmentation have been evaluated.

## 2. Watershed Method

The idea of the watershed approach for image segmentation comes from the natural real watershed.

Two procedures are necessary for this method: preselection of the minima and segmenting.

In the process of the minima preselection, each seeds are marked with a unique identifier, which will be applied for segmenting the regions that will be generated from these seeds.

In the process of segmenting, the regions surrounding the seeds become "flooded" and many regions grow out to a point where they can contact with each other (see [9]). Finally, the image will be classified into separate "catchments" bordered by the watershed lines.

In this approach, the number of "catchments" is equal to the number of these seeds. Otherwise, errors may occur in the region growing process from the seeds. Therefore, the selection of optimal seeds is of importance. Generally, using any point of the relief probably results in the over-segmentation while too few seeds possibly lead to under-segmentation.

The immersion-based algorithm to calculate the watersheds was developed by Vincent and Soille (see [8]). In this method, holes are described to pierce in each local minimum. The "catchment basins" are filled and the surface is gradually immersed into a "lake". A watershed is identified at the point where the two "catchment basins" merge (see [10]).

## 3. Experimental Results

As a case study, the selected area lies in the north of Beijing and covers a part of the planning Olympic Games Cottage. Most of the study areas were occupied by building, road and agricultural land. The available SPOT-5 PAN image was acquired in August of 2002 and the spatial resolution is 2.5m (Fig.1). As a matter of fact, a variety of segmentation methods have been employed for the land survey in this area. The result of this study can be compared with the previous research.

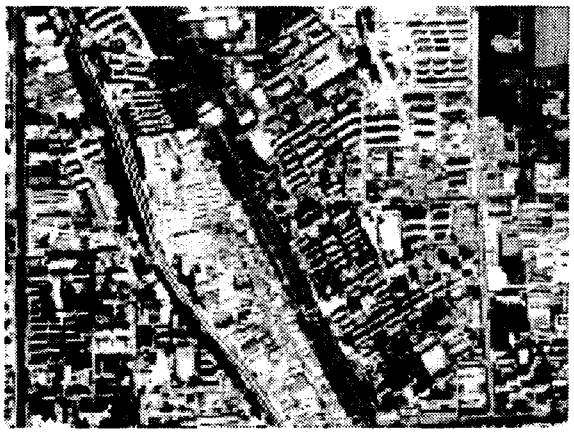

**Fig. 1. Original SPOT-5 PAN image.**

In this study, the watershed algorithm is based on Becher & Meyer's method of image segmentation, a marker-controlled watershed segmentation approach (see [4,11]). In the image processing, the structuring element has been firstly created, then the gaps between objects have been exaggerated and the objects of interest are converted. After that, the intensity valleys have been detected and the watershed segmentation have been conducted. Through this process, the objects in an image are divided into separate objects. The segmentation process can be accomplished by the MATLAB software (see [12]).

In this approach, image contrast is enhanced by maximizing the contrast of the areas of interest while minimizing the number of valleys. In the process, a usually employed method for contrast enhancement is applied by combining the difference between the original image and its foreground with the difference between the background and the original image. The study detects those intensity valleys deeper than a particular threshold. The watershed function was employed to conduct the watershed segmentation in the MATLAB software (Fig.2).

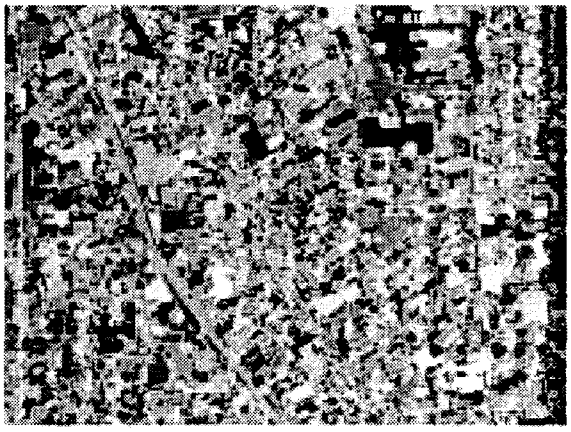

**Fig. 2. Watershed segmentation result**

## 4. Discussion and Conclusions

In this study, only SPOT-5 PAN imagery is available for the project. From the result for the gray level image, the building, road and farmland have demonstrated different segmentation accuracy. The images for buildings are fragmentary and the profiles are clearly segmented. The roads separating different images with strong contrast are effectively segmented. In contrary, the roads dividing the regions with approximate gray level are poorly segmented. For the farmland, the segmentation result demonstrates the obvious over-segmentation although the outlines are delineated clearly.

Over-segmentation and under-segmentation are common problem in the image segmentation (See [13,14,15]. In this study, the segmentation result

demonstrates the obvious over-segmentation. The problems of over-segmentation mainly result from the multiple markers generating from the maxima within the same image object. In the marker-constrained algorithm, distance transform has been employed to generate marks. The distance transform provides a standard for measuring the space in different points in the image. One feasible solution to overcome the over-segmentation is to connect all those maxima to ensure that one unique marker generates from an object (see [10]).

The goal of this study is to test the efficiency of the watershed image segmentation approach. The image segmentation work is with the guidance of the MATLAB help. The primary result demonstrates that it is one optional approach for gray level images. Indeed, the conventional watershed segmentation approaches are to be improved to process the high-resolution imagery. Although many exiting problems such as over-segmentation are to be solved in watershed image segmentation, it has been proven that the approach is promising to separate the image objects containing little noise and having strong contrast.

Indeed, much better methods have been proposed in this field (see [16,17,18,19,20,21,22]). Our future research and development will focus on the algorithms of the watershed image segmentation to improve the segmentation accuracy. For the remotely sensed imagery with different resolution, a variety of specific segmentation algorithms will be studied.

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