Segmentation Algorithms in Processing Satellite Images

Dmitry Pertsau
Faculty of Computer Systems and Networks
Belarusian State University
of Informatics and Radioelectronics
Minsk, Republic of Belarus
pertsev@bsuir.by

Artsemi Khatsianevich
Faculty of Computer Systems and Networks
Belarusian State University
of Informatics and Radioelectronics
Minsk, Republic of Belarus
khatenevicha@gmail.com

Abstract. **The problem of satellite image processing is specific and narrowly focused, but it is relevant in the context of active development of space technologies. This article analyzes the results of image segmentation by several algorithms, and then compares these results by selected metric: accuracy of the accordance of the boundaries of objects in the original images and images after processing. The results of the experiments reveal the most suitable segmentation algorithm for different starting conditions and different input data.**

Keywords: **segmentation, satellite images, watershed, flood fill, grayscale image, image processing**

I. Introduction

Segmentation in the context of image processing is the process of dividing a digital image into several segments, so-called superpixels (a set of pixels). The goal is to change the image in such a way as to simplify the analysis process and make it more efficient. The segmentation method is also used to highlight objects, boundaries, lines, curves in images. The result is a set of segments that together cover the entire image, or a set of contours extracted from the image. A distinctive property of a segment is the similarity of pixels in one or more specific characteristics (color, brightness, texture). Neighboring sets of pixels, in turn, have significant differences in these characteristics. The example of segmentation process is in Fig. 1.

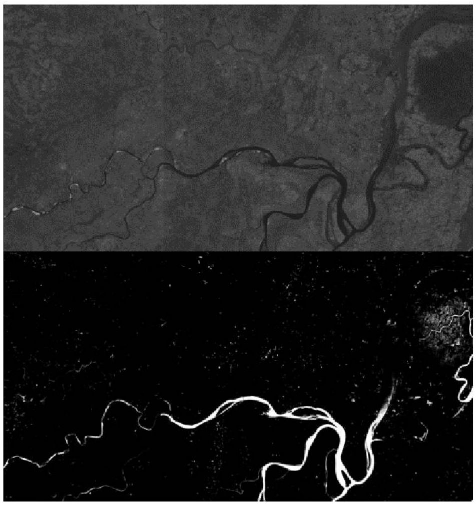

Fig. 1. Example of segmentation process

A number of algorithms and methods have been developed to implement the image segmentation process. Since there is no universal solution to the image segmentation problem, when working in a specific subject area, it is necessary to analyze existing methods and understand the specifics of the data in this area, on the basis of which a solution to the problem is developed.

The purpose of this article is to analyze existing methods in the context of solving the problem of segmentation of satellite images, select one or more metrics that will show the effectiveness of the algorithms, conduct comparative tests on real data and then compare the algorithms according to the selected metrics.

II. Experiment Description

A. Initial data

Real satellite images taken with equipment with a resolution of 2 meters (1 pixel reflects 2 meters of the earth's surface) provided by Peleng JSC were used as test data. The experiment involves 100 images of different surface areas.

The original images were made in grayscale, the bit depth was 10 bits/pixel, which allows for a more detailed image in terms of details. Two algorithms were selected for the experiment: the watershed and the flood fill.

The goal of the experiment is to highlight water bodies in images (rivers, lakes, etc.). The metric for evaluating the segmentation methods will be the accuracy of the correspondence between the boundaries of objects in the original images and the processed images. Based on this metric, the segmentation algorithms used in the experiment will be assessed in terms of their suitability for solving the task.

B. Watershed

This method is based on the representation of the image as a topographic surface, where the heights relative to a certain level are represented by the values of pixel brightness [1]. This analogy partitions the image into "peaks" and "plains". Plains are areas of the image where there are no differences in pixel brightness. Peaks appear in places where there is a difference in intensity, i.e. the absolute value of the brightness gradient is maximal. In the beginning the coordinates of the global minimum brightness in the image are determined and a gradual "water filling " begins, which implies the sequential addition of pixel layers to the segments. At the points where these segments touch (peaks), partitions are constructed, which are called watersheds and prevent individual sections from being merged into a single segment.

The above algorithm is a basic description of the watershed method, which works correctly only when there are a small number of local minima in the image, which implies a lack of fine detail. A large number of details leads to excessive segmentation in places where the processing result should look like a single segment.

Experiment starts with finding an approximate estimate of the water objects. For that, binarization can be used. Binarization is the process of setting a certain brightness threshold (in the example, the brightness threshold was 105) and then assigning each pixel either the value 0 (black) when the threshold is exceeded, or the value 255 (white) when the threshold is lower. Next step is removing any small noises in the image with using morphological opening (Erosion followed by Dilation) and removing any small holes in the object with using morphological closing (Dilation followed by Erosion). The kernel for erosion and dilation was in the form of a matrix of ones with a 3x3 size. The remaining regions are undetermined as either water objects or background. The watershed algorithm is employed to resolve these ambiguous zones. Initial data and results are in Fig. 2–5.

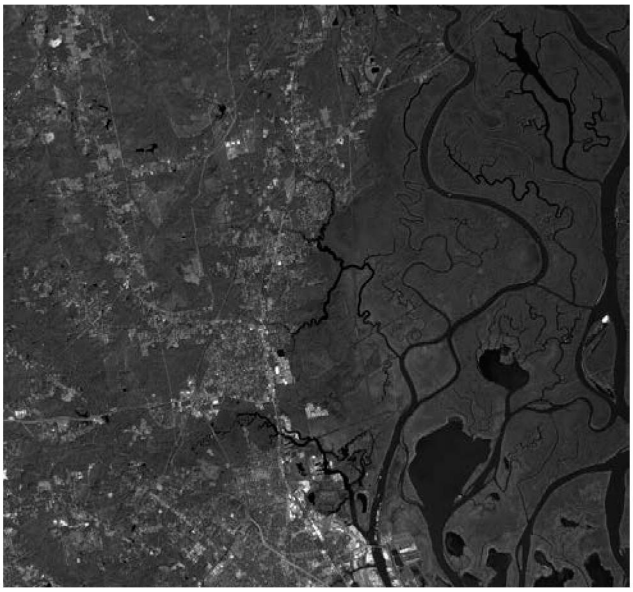

Fig. 2. Initial watershed method data № 1

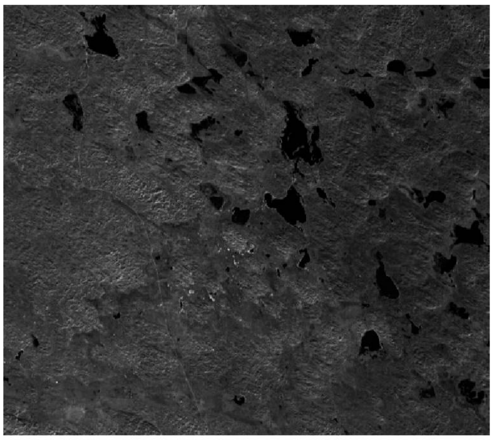

Fig. 3. Initial watershed method data № 2

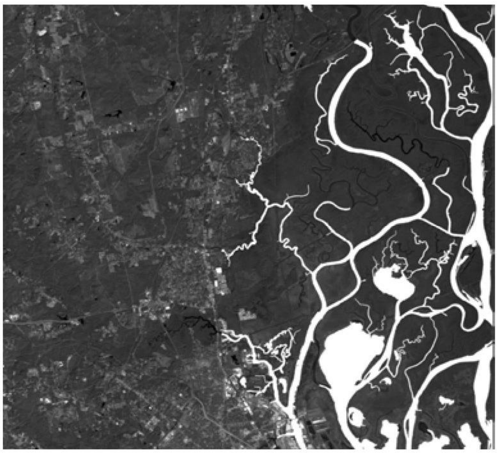

Fig. 4. The result of the watershed method № 1

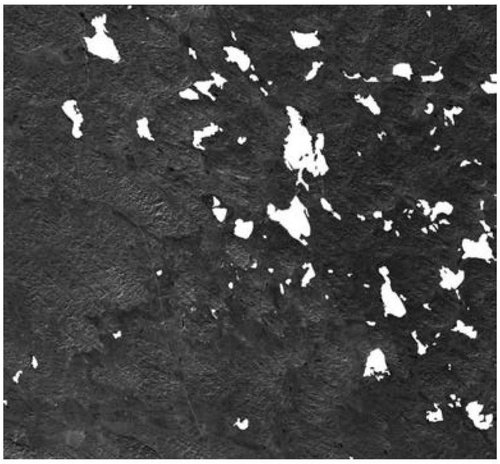

Fig. 5. The result of the watershed method № 2

C. Floodfill

Flood fill is an algorithm to identify and/or change adjacent values in an image based on their similarity to an initial seed point [2]. This method is used to highlight areas of uniform color. To perform this algorithm, an initial pixel is selected and the color change interval of neighboring pixels relative to the original is set.

The process combines pixels into one segment by filling them with one color, provided that they fall within the specified range. The result is a segment filled with a certain color.

This algorithm is useful for filling areas with a slight color difference and a uniform background. One way to use the flood fill method is to detect damage at the edges of an object. For example, when filling uniform areas with a certain color, the algorithm fills neighboring regions, this indicates that the integrity of the boundary between the two areas is damaged

When solving problems in the context of processing satellite images, this algorithm can be useful, for example, when determining the boundaries of lakes and finding contact points of several bodies of water on the map, since if there are intersections, they will be painted in one color. For flood fill to work correctly, it is necessary to transfer the coordinates of pixels located in the segments whose boundaries need to be found (Fig. 6–9). For this reason, to test this algorithm, the coordinates of points of only some areas were passed as input data.

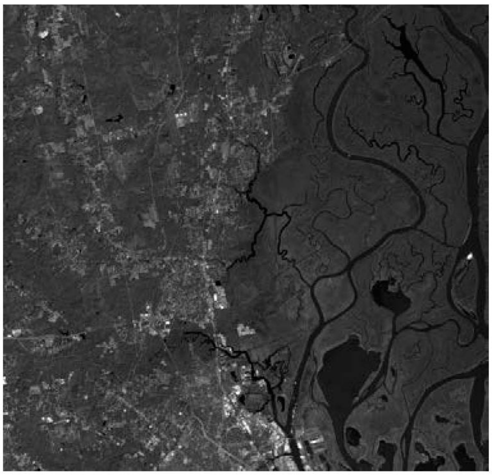

Fig. 6. Initial flood fill method data № 1

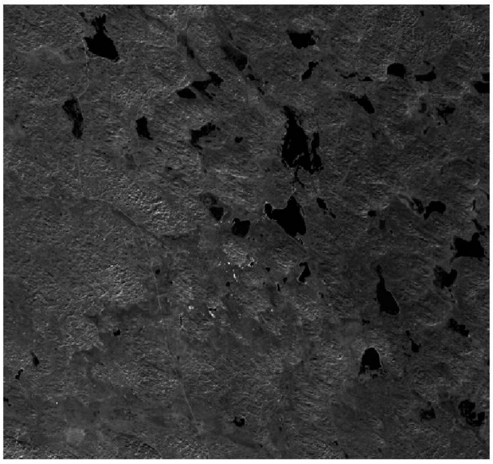

Fig. 7. Initial flood fill method data № 2

III. RESULTS ANALYSIS

The flood fill method satisfactorily solves the task of finding the boundaries of water bodies. The algorithm relatively accurately identifies small details such as land areas located in the middle of the segments being identified. When evaluating the results of the work, one can notice some noise on the identified clusters in the form of uncolored pixels in the middle of the cluster (Fig. 7). This noise is removed by slightly adjusting the initial parameters of the algorithm. In this case, the color range of pixels to be attached to the segment was changed from [-10, +10] to [-20, +20]. The main disadvantage of this method is the need to implement the search for the coordinates of pixels that will be located on the necessary clusters. The solution is either human intervention as an intermediary between the processes of data collection and their processing, or the introduction of an additional segmentation algorithm that will identify the necessary segments. Another disadvantage is that if this method encounters contrasting obstacles during its operation, then the cluster, which is one object in the original image, will be selected incorrectly.

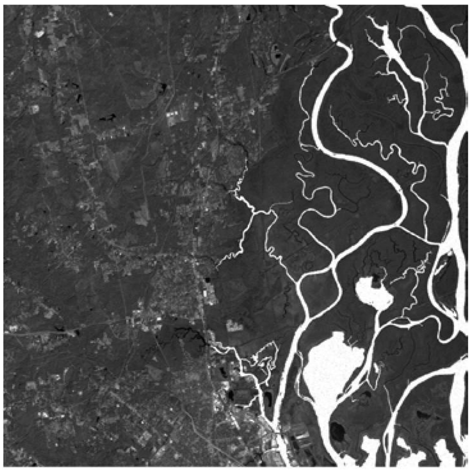

Fig. 8. The result of the flood fill method № 1

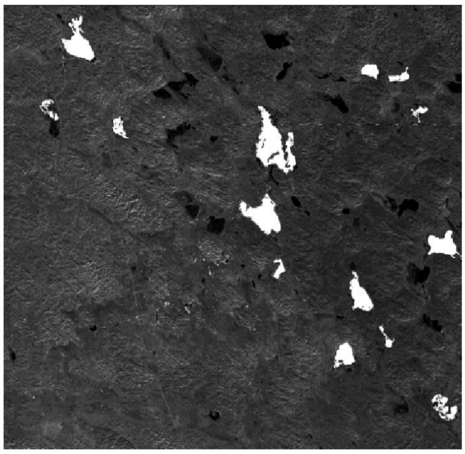

Fig. 9. The result of the flood fill method № 2

The watershed method can, under certain conditions, create redundant segmentation: places that should be a single cluster are divided into many smaller ones, which is hardly noticeable in the final results due to the density of these "subclusters". This defect can be detected by examining the image with markers (Fig. 10). But unlike the flood fill method, the watershed algorithm does not require an intermediate stage in the form of searching for the required coordinates on the image, and at the same time, this algorithm, with the correct choice of initial parameters, does not experience bigger losses in the accuracy of object selection in comparison with flood fill.

Fig. 10. Example of redundant segmentation

As mentioned earlier, the algorithms were compared according to the metric of the accuracy of the object boundaries in the original images and the images after processing. This implies that objects in the original image are taken as a reference, and the results of the algorithms are evaluated by the percentage of match reference objects with selected segments. Average level of accordance with the standard with using the flood fill algorithm is 85 percent, but during the experiment, additional assistance was required to find objects in the image and transfer their coordinates to the algorithm. On the other hand, the watershed algorithm showed a match rate of 80–82 percent without the need for additional assistance. The problem of additional assistance for flood fill algorithm will become critical if it becomes necessary to create a fully autonomous system for analyzing satellite images.

From the information obtained, it was concluded that when comparing according to the metric chosen at the beginning of the experiment, the watershed method would be preferable. This method has the advantage of not requiring additional image pre-processing while maintaining the same level of accuracy.

IV. Conclusuon

Having conducted a study of the algorithms in the context of the satellite imagery processing task, it was concluded that the watershed method is advantageous in the general case. It is also necessary to pay attention that space photography is a process with a large number of unstable conditions, to which it is constantly necessary to adapt and minimize their consequences. Therefore, the optimal choice when solving image segmentation problems is a combination of some algorithms for each of them to perform the segmentation stages in which they cope best. Thus, the decision on the use of each algorithm must be made based on the specifics of the task and the conditions for obtaining each image.

It is also worth noting that neural networks using in the analysis of satellite images could provide higher accuracy. This method of solving this problem will require much more computing power and time, and that condition may be unacceptable if it is necessary to integrate the system for analyzing satellite images into embedded systems.

References

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