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APPLICATION OF WATERSHED ALGORITHM TO IMAGE HIERARCHICAL SEGMENTATION

ZASTOSOWANIE ALGORYTMU DZIAŁÓW WODNYCH DO HIERARCHICZNEJ SEGMENTACJI OBRAZU

A b s t r a c t

The existing image segmentation algorithms do not always give expected results. Very often dedicated algorithms or tools are created for specific groups of images. An alternative solution could be to introduce a manual control over the algorithm operation. The article discusses how to use watershed algorithm for fast and hierarchical separation of large objects into smaller ones. This is implemented by using appropriate markers to define initial areas of occurrence of individual objects.

Keywords: image segmentation, watershed algorithm with marker, object hierarchical separation

S t r e s z c z e n i e

Istniejące algorytmy segmentacji obrazu nie zawsze dają pożądane rezultaty. Aby poprawić ich działanie często konstruuje się dedykowane narzędzia dla konkretnych grup obrazów. Alternatywnym rozwiązaniem może być wprowadzenie manualnego sterowania działaniem algorytmu przez użytkownika. W artykule omówiono sposoby użycia algorytmu działów wodnych do szybkiego i hierarchicznego rozdzielania dużych obiektów na mniejsze. Udaje się to realizować poprzez właściwe definiowanie kolejnych znaczników początkowych określających obszary występowania poszczególnych obiektów.

Słowa kluczowe: segmentacja obrazu, algorytm działów wodnych ze znacznikiem, hierarchiczny rozdział obiektów

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1. Introduction

The discussion in the paper there will cover the issue of objects separation on raster images using computer image analysis. Solving tasks of this type, called image segmentation, even if it is not a problem to humans, it is still a big challenge for a machine. One of the more advanced algorithm giving satisfying results in various types of images is the watershed algorithm [1]. The paper will present the use of the algorithm in hierarchical separation of larger objects into smaller ones, and will analyze the process supervised by the user.

2. Watershed segmentation algorithm

To understand the operation of the watershed segmentation algorithm we might look at an image as it was a map of some mountain region. Then the brightness of each pixel determines the elevation relative to a particular point of reference – for the map to the level of the sea. In addition, we assume that the ground structure is like a sponge. Now we can imagine the process of flooding the entire area, from bottom to top. It seems obvious that the lowest areas are soaked first, and water will be filling them up until it merges with adjacent basins. Introducing nomenclature associated with image analysis, we can say that the points of connection between basins are watershed lines, and basins itself determine independent segments on the image. Points (pixels) that are the first flooded are treated as local minimums.

If we used the above described concept of watershed algorithm, we would quickly notice that it does not always give desired results in edge detection. The reason for this is that one object may have brightness different from another object and different from the background. First, the darkest places are filled, then the background, and at last objects brighter than the background. Thus, some objects (e.g. the darkest ones) could be omitted. The analysis of heterogeneous objects where the lighting is different in different parts of the object may cause even greater problems. Taking into account these problems it is suggested that, first, the gradient image be prepared, which highlights the edges of objects and then run the watershed algorithm. On the gradient image local minimums are situated in the areas of uniform color saturation, while being closer to the edges, gradient values are higher and they are treated as a merger of two segments.

The following pictures (Fig. 1) are effects of the watershed algorithm operation on the image with the neck of a hip bone.

The number of segments which we received (Fig. 1c) far exceeds the number of objects that we would appoint manually. In this case, the problem is related to the presence of noise throughout the image, which introduces a significant excess of local minimums. In this situation a good approach is to use a noise removal algorithm and restart the whole procedure. The results shown below (Fig. 2) are better than the previous ones.

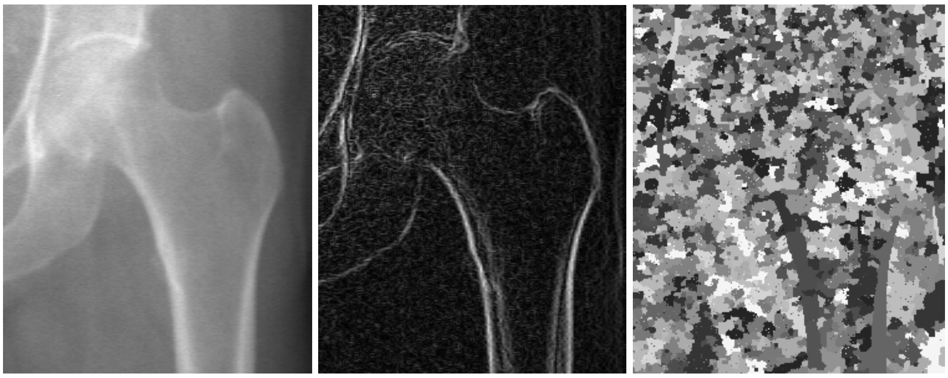

Fig. 1. Results of segmentation by watersheds algorithm on the image with the neck of a hip bone (1a – input image, 1b – gradient image, 1c – results)

Rys. 1. Wyniki segmentacji kości biodrowej z wykorzystaniem algorytmu działów wodnych (1a – obraz oryginalny, 1b – gradient, 1c – obraz wynikowy)

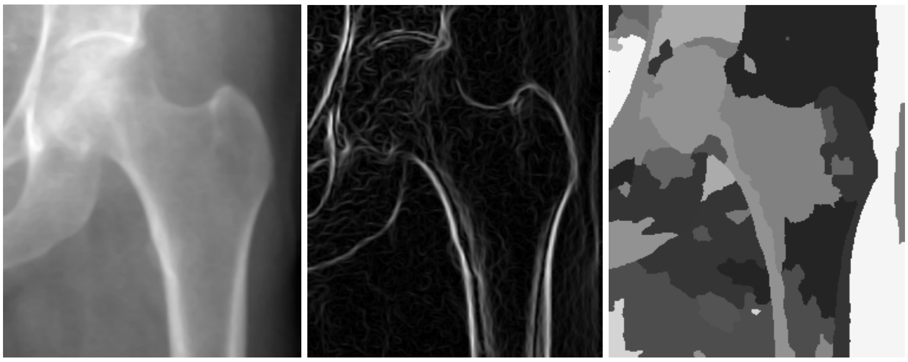

Fig. 2. Watershed segmentation algorithm on the image with removed noise (2a – input image with removed noise, 2b – gradient image, 2c – results)

Rys. 2. Segmentacja wododziałowa obrazu po uprzednim usunięciu szumu (2a – obraz oryginalny po usunięciu szumu, 2b – gradient, 2c – obraz wynikowy)

To extract real objects from the output image (Fig. 2c), it is necessary to define criteria for the similarity of these objects and start merging similar segments into objects [2].

3. Applying markers

The standard procedure of watershed algorithm starts from local minimums and spilling in their range sets limits of sections [3]. Further in the article, a modified version of the algorithm will be described. This modification allows the omission of some local minimums, and even determining any starting points. Such algorithm will be the base for preparing an interactive tool for hierarchical segmentation of the image.

In order to explain changes made to the algorithm, we will use the example of re-flooding the land by water. But this time we assume that the ground is completely impenetrable for water. To make flooding possible in places indicated by the new starting points we drill holes in the ground until the level of the sea. Water which is located there starts to emerge on the surface and flood local valleys at first. Then, if the neighboring valley is empty, the water begins to transfer there, but if it is not empty, watershed line will be determined. This approach is known in literature as marker-based watershed segmentation [4]. The main advantage of the approach is the certainty that the number of segments which we receive is the same as the number of starting points. In this case the key thing is to define starting points properly. But this may require preparation of complex algorithms for starting points detection. What is more, each procedure must be created for each case separately (different detection for femur neck, and another to detect two elephants on savannah). Still, we do not have confidence that we will get the correct result (too many or too few starting points). In this case, the best way could be just asking the user to identify them. Although automation is lost, general rules of the algorithm work and control over the number of starting points is held.

Here we can see the operation of the watershed algorithm with markers (Fig. 3). Using the interactive program, starting points of both – background and object are indicated, and the program automatically determines the proper segments.

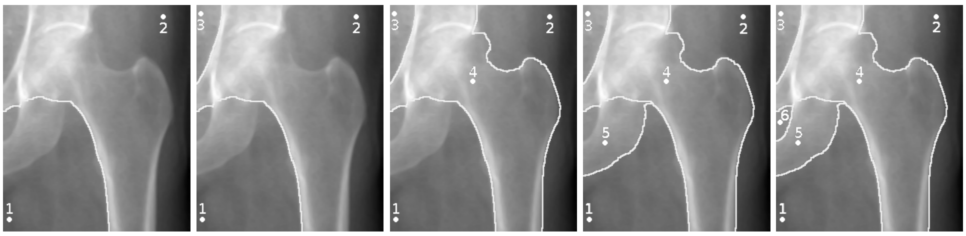

Fig. 3. Watershed algorithm with marker defined by the user

Rys. 3. Algorytm działów wodnych ze znacznikiem definiowanym przez użytkownika

4. Hierarchical segmentation of the image

When we analyze the above example in more detail (Fig. 3), we will notice that identifying the next point does not change the line of watershed previously defined. Moreover, the process of segmentation applies only to the area in which the starting point is selected. This enables us to divide larger objects into smaller ones, without changing the boundaries already established. Such approach allows the user to hierarchically separate objects into smaller components, depending on the required level of details.

In order to understand better how to use this algorithm to achieve the desired results, we will carefully review its method of operation for an artificial image (Fig. 4). On Fig. 4a we can see a gray square in which there are smaller pieces drawn – a black rectangle, and a dark grey square (Fig. 4a) shows a corresponding gradient image. The first two starting points were selected to separate the object (marked with no. 2) from its background (marked as no.1) (Fig. 4b). Despite a strong boundary between the black rectangle and the outer gray square, this rectangle was properly included in the square area. It happens this way because after the watershed line between the first and the second area was defined, black rectangle could be flooded only from the area which borders directly with it, which is the gray square. A similar situation takes place for the next two starting points (Fig. 4c and 4d). As we can see, the addition of further points does not alter pre-determined boundaries, and divides only the segments, which were already marked with the starting point. Referring again to the analogy with the re-flooding land, it is easy to notice that drilling another hole in an already flooded area can not change the area of flooding, but only introduce a further division within local flooded area.

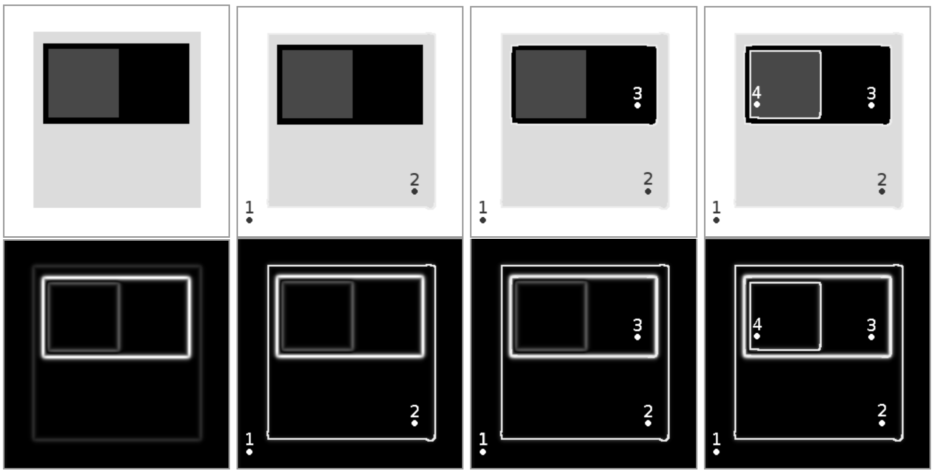

Fig. 4. The process of hierarchical segmentation using watershed algorithm on an artificial image (second row presents gradient image)

Rys. 4. Proces hierarchicznej segmentacji obrazu z wykorzystaniem algorytmu działów wodnych na sztucznym obrazie (w dolnym wierszu obraz gradientowy)

5. Applying continuous markers

The described method of watershed segmentation with marker and its application to hierarchical segmentation of the image, despite its advantages not always gives required effects. In some cases, the obtained results may be far from expected. There may be several reasons for the wrong detection. One of the obstacles is a high level of noise, which is difficult to remove by means of smoothing filters. The results are also affected by a large heterogeneity of structures and the presence of strong internal boundaries cutting through an object. Another reason, not related to the quality of an image, is a problem with the interpretation of information on the image. Even the best image segmentation algorithm is not able to detect objects without an error, based only on some residual information (e.g. indicating one point may not be sufficient). We can not expect that the algorithm will guess intentions of the user, especially when detection object is not clear (e.g. several identical objects are attached to each other).

To eliminate mentioned problems, we should describe objects in more detail. This can be achieved by asking the user to define not only the starting points, but also draw a line cutting through an object. This way the algorithm will be modified again by adding so called continuous markers. Referring again to the example with the re-flooded land, this time a hole will not be drilled, but a long row will be excavated. Water pouring out from it will flood adjacent valleys and will immediately connect them with each other into a channel cutting through the hills. This approach is illustrated on Fig. 5. Comparing these results with the results presented on Fig. 4 we can see that this time segmentation of bones in the left part of the image went well and we received one area associated with the bone, not two - as was before.

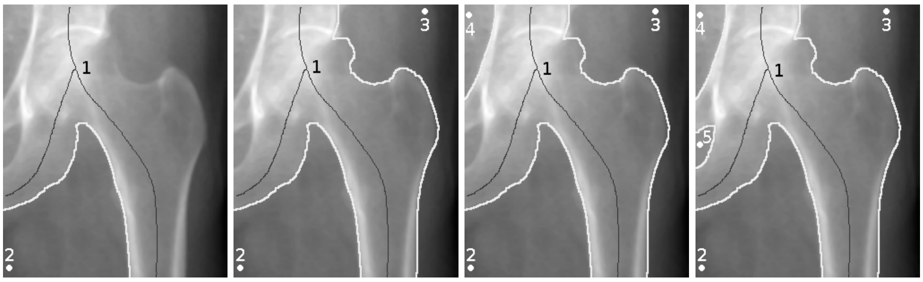

Fig. 5. Applying continuous markers in watershed segmentation

Rys. 5. Zastosowanie znaczników ciągłych w segmentacji wododziałowej

6. Conclusions

Modifications to the watershed algorithm described in the paper allow constructing software that can greatly facilitate and speed up the process of correct segmentation of the image. By identifying markers (starting points and lines) interactively by the user we hold control over the correctness of results. What is more, the user can freely define the level of details for detection. On the following images (Fig. 6) we can see more examples of detection using methods discussed in the paper.

Fig. 6. Examples of applying markers to watershed segmentation

Rys. 6. Przykłady działania algorytmu działów wodnych ze znacznikiem

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