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# THE CONCEPT OF THE ISLANDS EXTRACTION IN SATELLITE IMAGES USING MATHEMATICAL MORPHOLOGY

# PROPOZYCJA ALGORYTMU DO WYODRĘBNIANIA WYSP NA ZDJĘCIACH SATELITARNYCH Z WYKORZYSTANIEM MORFOLOGII MATEMATYCZNEJ

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## Introduction

The neighborhood is one of the indirect features of the object which may be used in the interpretation of an image. Sometimes, this feature may be essential, as can be shown using an example of islands. According to the Oxford Dictionary (Internet edition) island is „a piece of land surrounded by water" so, as we can see, this element of landscape is defined by its neighborhood. The traditional, pixel-based classification is useless in such a case, taking into account only digital numbers of individual pixels. It is impossible to classify islands properly, using this kind of non-contextual algorithm.

This paper proposes a mathematical morphology, with the potential to change the structure of an image depending on the different contextual features of the objects presented to it to resolve such a problem. The proposition is based on a relatively simple application of the close-hole operation presented in (Angulo, Flandrin. 2003). Although the application is simple, the operation itself is quite complicated, so its presentation in this article is essential for its understanding.

## Close-hole operation

The close-hole operation is a sequence of morphological and simple non-morphological operations. It is important to present some basic morphological operations before presenting the close-hole operation itself.

One of the two fundamental operations of mathematical morphology is a dilation. According to the Haralick/Sternberg (Sternberg, 1986; Haralick et al., 1987) notation we can define a dilation of the set $X$ using a structuring element $B$ as below:

$$\delta_B(X) = \bigcup_{y \in B} X_y$$

where

$$X_y = \{x + y : x \in X\}$$

The dilation is then a logical sum of all shifts of the set X by vectors defined by elements of the structuring element $B$. The size and shape of structuring element may differ, affecting the result of the process. An example of the dilation is shown in Figure 1.

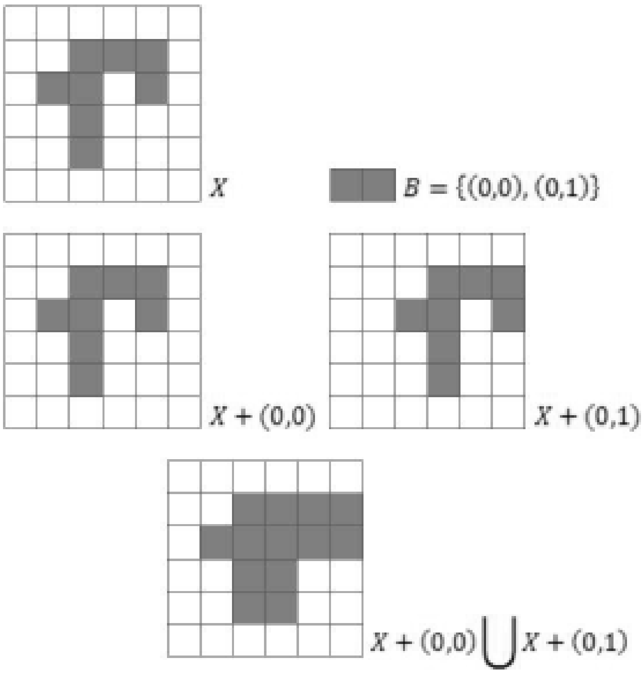


**Figure 1.** Dilation

The second operation crucial for the close-hole operation is a reconstruction by dilation. The morphological reconstruction is called a geodesic transformation because it is based on the idea of geodesic distance. Normally, geodesic distance is the length of the shortest path between two points along the surface of the earth model. In our case, geodesic distance means the shortest path between two points (pixels) in the image called a marker, along the space defined by another image called a mask. The morphological reconstruction may be based on geodesic dilation. According to (Lantuejoul, Maisonneuve, 1984) we can define this operation as below:

$$\delta_g^{(1)}(X) = \min\left(\delta_{B^{(1)}}(X), (M)\right)$$

where $B^{(1)}$ is a structuring element of the size 1 (3 pixels x 3 pixels), $X$ is a marker image and $M$ is a mask image. The simple dilation of the marker is then restricted by the mask image. What is important, when processing a geodesic dilation, is that only structuring elements of size 1 may be used. To increase the range of the operation one may iterate it. It is easy to imagine that repetitive use of this operation leads to the state in which no further change may be done by a geodesic dilation. Such a sequence is called a reconstruction and we may define it as below:

$$\mathrm{R}_{\delta}(X) = \delta_{g}^{(i)}(X)$$

where $i$ is the smallest number for which $\delta_{g}^{(i)}(X) = \delta_{g}^{(i+1)}(X)$

Knowing these operations we can present now a close hole operation. According to (Angulo, Flandrin, 2003) we can define it as:

$$\psi^{ch}(X) = \left[R_{\delta k}(X)^{C}\right]^{C}$$

where $k$ is a border of the marker image.

Because, according to (Nieniewski, 2005), the marker image $k$ must be anti-extensive compared to the mask image (digital numbers of pixels of the marker must be smaller than relative mask pixels) we can modify the formula, by changing the meaning of the marker $k$ (Kupidura, 2006):

$$k = (X)^{C} \wedge X\vartheta$$

where $X\vartheta$ is a border of the image.

The idea of this operation is that the image $k$ is dilated just to the reconstruction of the $(X)^C$ image, but *holes* in the image $X$ are isolated in the image $(X)^C$ so they are not reconstructed. Inverting the result of the reconstruction enables the closing of these holes.

The close-hole operation is presented in the Figure 2.

For an extended discussion on mathematical morphology and morphological operators, see the literature (particularly: Serra, 1982; Haralick et al., 1987; Nieniewski, 1998; Kupidura, 2006).

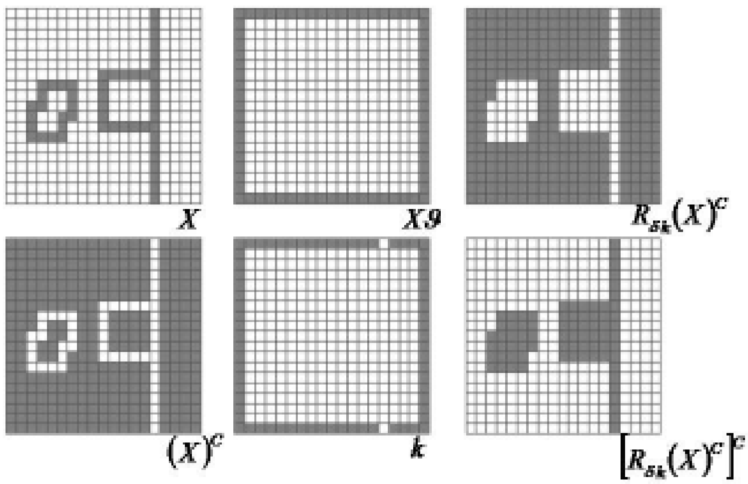


**Figure 2.** Close-hole operation

## Extraction of islands

The proposed algorithm consists of three major steps:

1. Extraction of water mask using non-contextual algorithms (classification or thresholding).
2. Close-hole process on the water mask.
3. Extraction of islands by subtracting the water mask from *closed* water mask.

This sequence may be modified by additional filtration of the result, so erroneous pixels caused by an imperfect water mask extraction can be deleted.

Two examples of the application of the algorithm are presented in the Figures 3 and 4.

The first of these figures shows an example of the application of the proposed algorithm. Its first part is a part of a SPOT 5 scene (RGB 432). The water mask shown on the right was obtained using a minimum distance classification of this image. Islands, by definition „surrounded by water" are the *holes* in this image, closed using the close-hole operation (third part of the Figure 3) and extracted in the fourth part of the figure by subtracting two water mask – original and *closed* one (the last image is also filtered using a morphological filter.

It is important to note that the accuracy of the algorithm depends completely on the accuracy of the water mask extraction. Figure 4, shows part of a Landsat ETM+ scene (RGB 453) with an error of the islands mask. One of the islands visible in the image (pointed with a flash) is simply connected with the rest of the land so it does not satisfy a condition of being surrounded by water in the image. The reason is a low resolution compared to the width of the river at this place. The dimension of Landsat ETM+ pixel: 30m x 30m is, in that case, insufficient. The distance between the indicated island and the rest of land is to small to be classified as water and that is the reason of this error.

## Morphological software

When considering mathematical morphology operations, digital image processing software is a very important issue. Despite its potential, mathematical morphology is not very well known, nor is morphological software. There are, however, some examples of software with some basic morphological functions implied, such as Matlab (used for the morphological processing in the examples above), Erdas Imagine or freeware: ImageJ, ScionImage etc. however, most of these offer only fundamental operations (except Matlab but this one is not a free software) and even where it is possible to build almost every morphological function using two fundamental operations: erosion and dilation (and other, non-morphological operations as well) it is sometimes difficult and time consuming.

One solution is a new, free, open source software named BlueNote, created in the Department of Photogrammetry, Remote Sensing and GIS in Warsaw University of Technology. In addition to the basic morphological functions, it also provides complex operations with some potential for digital processing of a remote sensing data, such as morphological filters, operations with multiple structuring elements, morphological granulometry and, of course, the close-hole operation. Beta versions of BlueNote are available on sourceforge.net for download and testing. Please do not hesitate to give the author any suggestions or propositions about this software.

## Conclusions

The algorithm described above is based on the use of a complex morphological operation named close-hole. This operation itself is error-free, however the whole algorithm is not, because the first step of water mask creation may be imperfect and may affect the accuracy of the algorithm.

The islands extraction algorithm is relatively easy, even trivial, but it shows the potential of the mathematical morphology in image processing. Mathematical morphology allows to take into account different contextual features of the objects in the image such as neighborhood, as presented in this paper, but also size, shape, texture etc. It is important because non-contextual algorithms, such as like pixel-based classification, are often insufficient. Mathematical morphology, as shown in this article, may be an important and useful tool for digital processing of remote sensing data.

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### *Streszczenie*


*Artykuł przedstawia przykład zastosowania morfologii matematycznej w przetwarzaniu danych teledetekcyjnych. Wyspy, element krajobrazu definiowany wyłącznie przez swoje sąsiedztwo stanowi nierozwiązywalny problem dla bezkontekstowych przetworzeń cyfrowych typu tradycyjnej pikselowej klasyfikacji. Zastosowanie morfologicznej operacji wypełniania dziur pozwala stworzyć algorytm, który, bazując na cesze sąsiedztwa, umożliwia automatyczne wykrywanie wysp na zdjęciach satelitarnych. To stosunkowo proste zastosowanie morfologii matematycznej ukazuje jej duży potencjał w przetwarzaniu obrazów, również zdjęć lotniczych i satelitarnych.*



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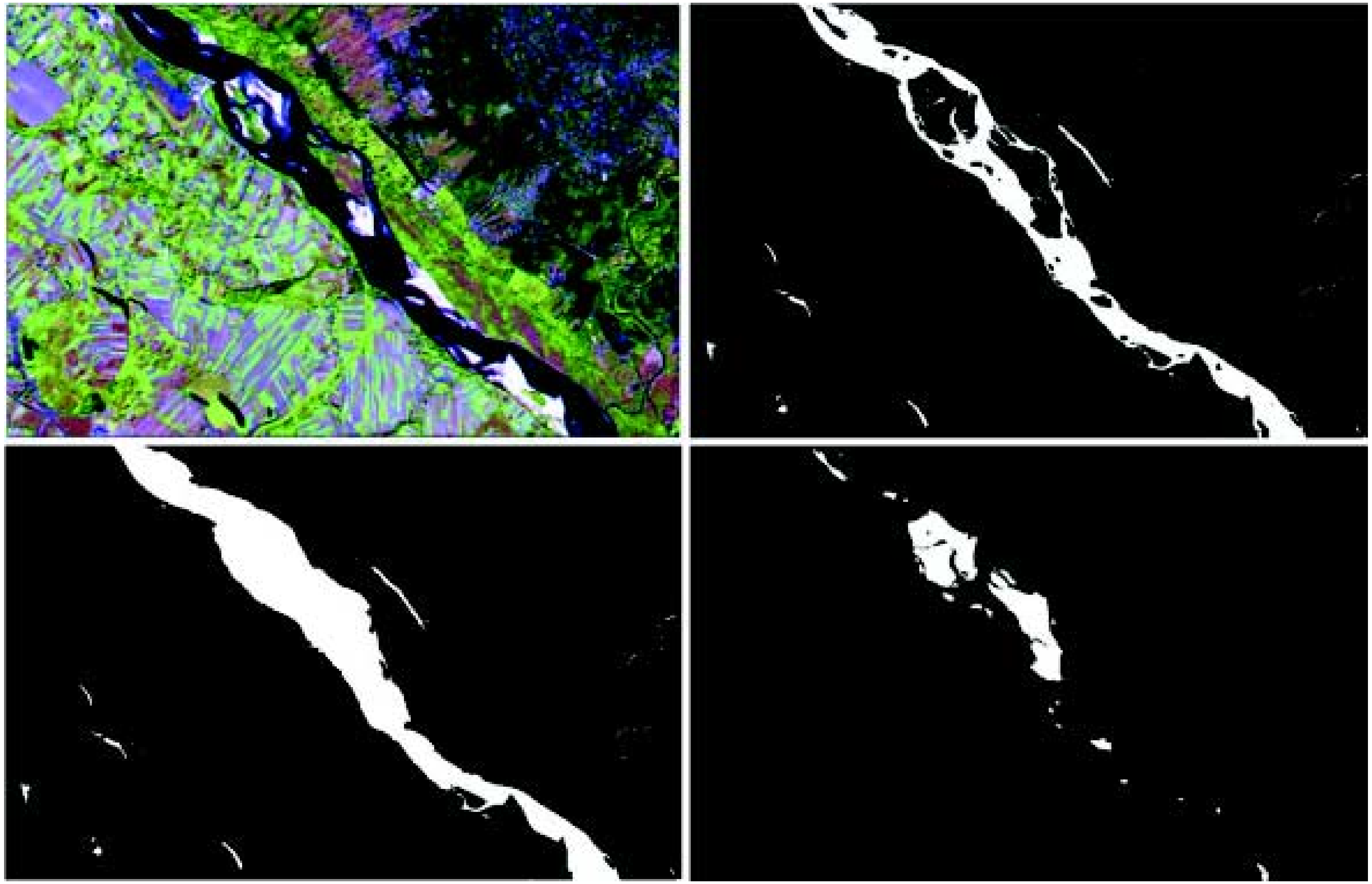

**Figure 3.** The first example of the application of the islands extraction algorithm

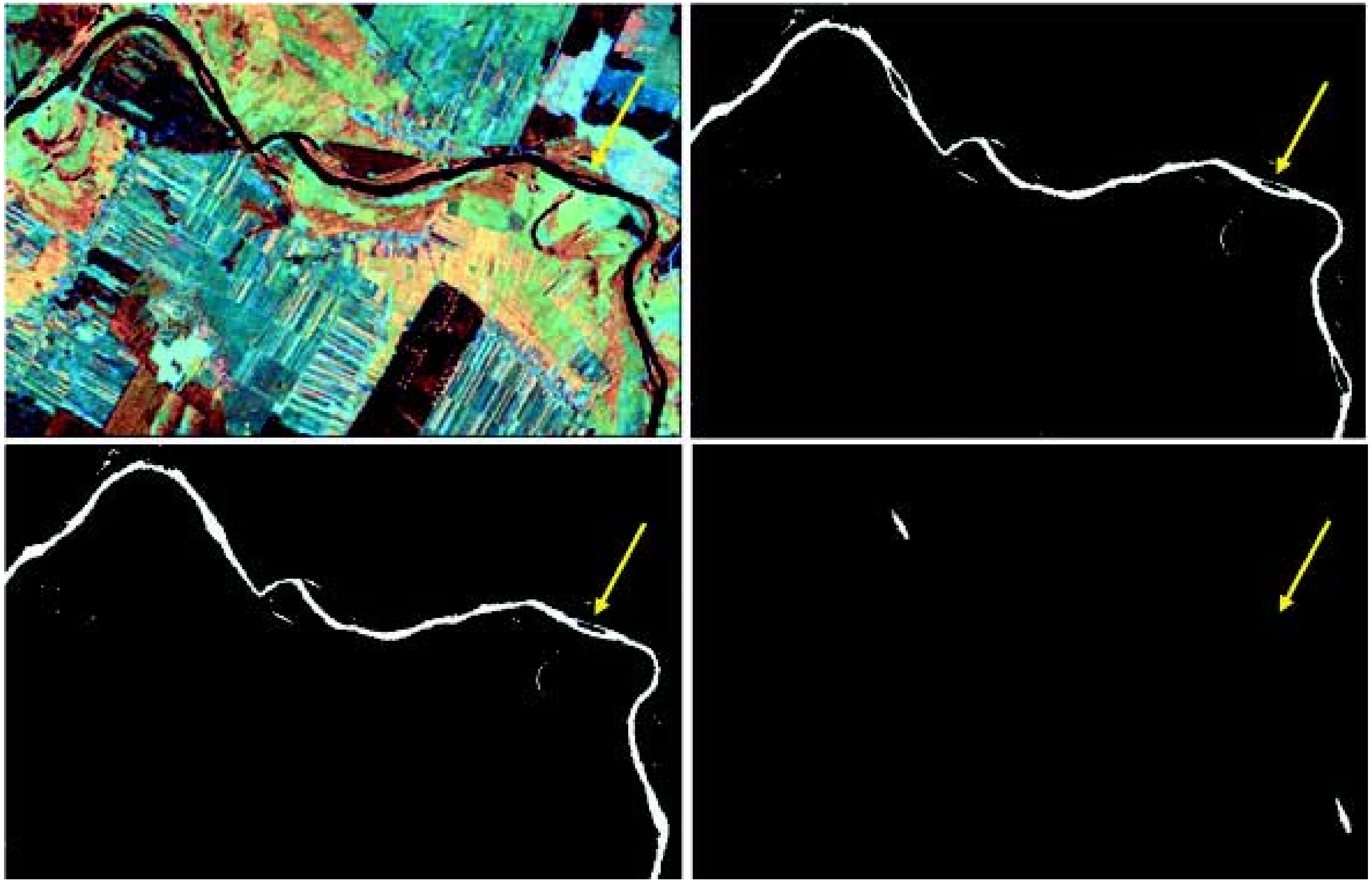

**Figure 4.** The second example of the application of the islands extraction algorithm