Kupidura P., 2010. Semi-automatic method for a built-up area intensity survey using morphological granulometry. The Problems of Landscape Ecology, Vol. XXVIII. 271–277.

Semi-automatic method for a built-up area intensity survey using morphological granulometry

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Abstract: Built-up areas as a land-use type are easy to extract in a visual photo-interpretation process, however their heterogeneous character makes theirs automatic or semi-automatic extraction very complicated, even impossible using non-contextual, pixel-based methods of image classification. This paper concerns the application of the semi-automatic method of the extraction of built-up areas in satellite images. Granulometric maps, a mathematical morphology operator is used as a main tool for surveying a heterogeneity of particular parts of an aerial or satellite image. This function measures amount and size of objects in the determined neighborhood of each pixel of an image. Pixels representing built-up areas – a very heterogeneous land use type have generally higher values than other non-built-up areas. An image processed this way may be classified using traditional pixel-based algorithms and classes of image parts of different heterogeneity may be obtained. A multi-temporal set of aerial and satellite images of Łomianki municipality has been used. The research applied on the test area using a multi-temporal set of images proved a high quality of results built-up area changes obtained using the method described above. Granulometric maps seem to be an effective tool also for other purposes, where a heterogeneity of the object is an important characteristic.

Key words: *built-up area, digital image processing, mathematical morphology, remote sensing, multi-temporal analysis, change detection*

Introduction

Remote sensing is a tool providing us with accurate and relatively cheap data on vast area of land almost instantly. Aerial and satellite images are one of the most important data type used in Geographic Information Systems. However, in order to utilize such a data in GIS, it must be firstly processed to the form understandable by a computer software. Probably, the most accurate way to process an image is its visual interpretation on a screen of a computer. An experienced interpreter observing an image can notice different characteristics of the objects, relations between them etc. and, thank to his or her experience, intelligence and knowledge, can produce data in a way Geographic Information Systems need it. However, visual interpretation is costly and time-consuming, as it demands one's work-time. That is why we search for automatic or at least semi-automatic solutions, called classification of an image.

One of the most well-known and probably one of the simplest classification method is a classic pixel-based algorithm allowing to classify pixels depending on their digital numbers in different spectral bands. It is often a sufficient tool to extract such characteristics of the terrain as simple land cover types: water, different types of vegetation, bare soil etc. However, some classes of land cover or land use are complex and non-contextual approaches, like a pixel-based classification are not effective. The example of such a complex land-use class in the image is a built-up area. It is very easy to extract in a visual photo-interpretation process, but its heterogeneity makes its automatic or semi-automatic extraction using a pixel-based approach very difficult. As built-up areas include various of different objects: buidlings roofs, concrete, bare soil, grass, trees, shadows etc., they cannot be characterized by any specific color or tone of gray in the image, but rather by their heterogeneity, very often the biggest in the image. In order to extract such a contextual features from the image (semi) automatically, contextual methods are necessary. And contextual methods must include contextual digital image processing tools. One of the most powerful contextual digital image processing tools is mathematical morphology.

Mathematical morphology includes a big number of different operators. Simple, like erosion or dilation and more complex, like geodetic transformations or hit-and-miss transformations. Granulometry is the example of a complex morphological function. It allows to produce granulometric maps, presenting the amount of the objects of specified size in the specified parts of the image. It may be a very useful tool for helping an extraction such heterogeneous objects, as built-up areas.

This paper presents the research estimating the effectiveness of extraction of built-up areas in satellite and aerial images using granulometric maps. The multi-temporal image set was used for the research. The results of classification of the images using granulometric maps have been compared with the reference masks, created in the process of visual interpretation on a computer screen.

Mathematical morphology

Basics of mathematical morphology

Mathematical morphology is a set theory approach, developed by J.Serra and G. Matheron. It provides an approach to process digital images which is based on their geometrical shape.

Two fundamental morphological operations – erosion and dilation are based on Minkowski operations. There are two different types of notations for these operations: Serra/Matheron notation and Haralick/ /Sternberg notation. In this paper Haralick/Sternberg notation, which is probably more often used in practical applications, is used. In this notation erosion is defined as follows (Serra, 1982):

$$\varepsilon_B(X) = \bigcap_{y \in B} X_y$$

and dilation as:

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

where *B* is a structuring element,

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

and $\hat{B}$ is a symmetric opposition of *B*.

Two other principal operations called opening and closing are simple sequences of erosion and dilation operations. Opening is defined by the following equation:

$$\gamma_B(X) = \delta_B(\varepsilon_B(X))$$

and closing as:

$$\varphi_B(X) = \varepsilon_B(\delta_B(X))$$

Basics of granulometry

Below, only the basics of granulometry will be presented. Figure 1 illustrates the main idea of granulometry. It shows an image X and the set of results of sequential openings using a structuring element of a size growing with every step of the sequence. In this figure, X1 is an opening of X using an element $B1$, $X2$ is an opening of $X1$ using an element $B2$ etc. Granulometry is a function expressing a sizes of the images – differences between different steps of the sequence: $X - X1$, $X1 - X2$ etc.

Granulometric maps are images containing a granulometric data for different parts of the image. The neighborhood is specified for each pixel and a local granulometry is measured within this neighborhood for each pixel, so a local granulometric value becomes a pixel value in the granulometric map. Each step of the sequence ($X - X1$, $X1 - X2$ etc.) produces one granulometric map marked with different indices, so a map with index 1, shows the amount of small objects (of the size ca. 3×3 pixels – look figure 1) while a map with index 3 shows the amount of bigger objects (of the size ca. 7×7 pixels).

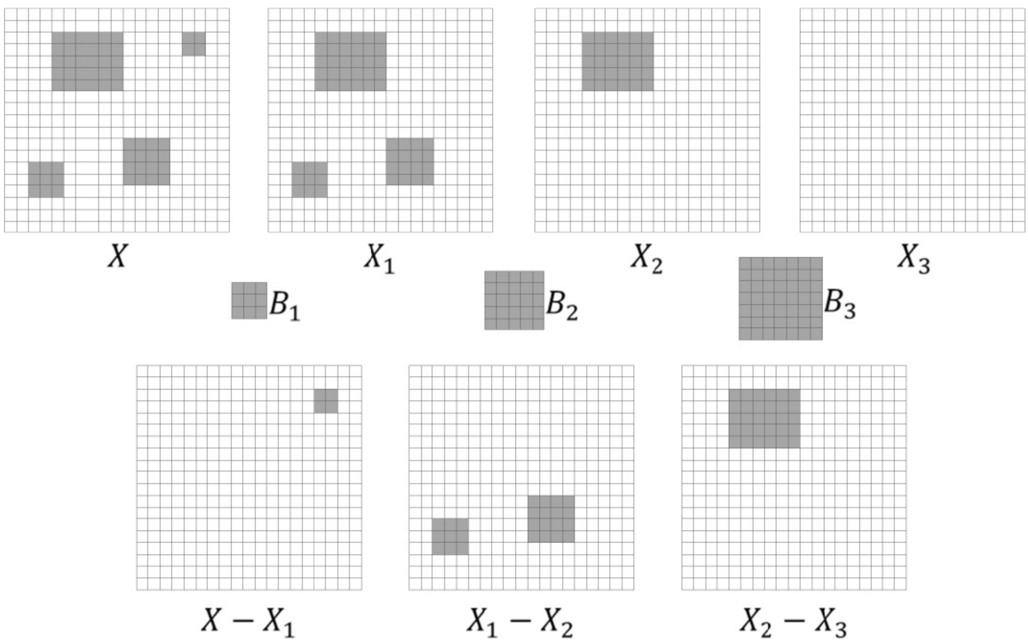

Fig. 1. A schematic of a granulometry

In the figure 2, a part of an original Quickbird image (infrared band) is presented together with extracted granulometric maps.

Readers are referred to the books and articles of mathematical morphology for an extended background to morphological operators, especially granulometry and granulometric maps (Serra, 1982, 1988; Haralick et al., 1987; Sternberg, 1986; Mering, Chopin, 2002; Nieniewski, 1998, 2005; Kupidura 2006).

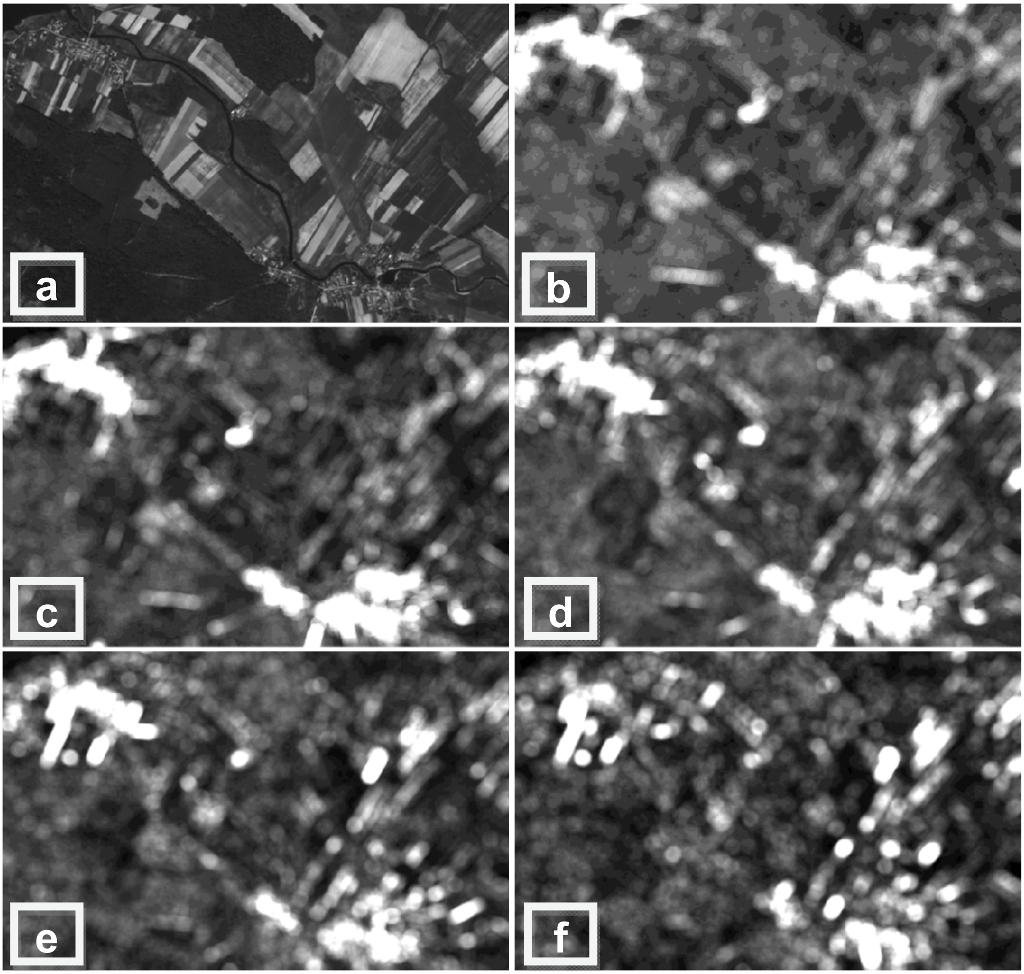

Fig. 2. Part of Quickbird satellte scene (a) and granulometric maps generated with circular granulometry window (20 pixel radius) and circular structuring element with radius: b) 1 pixel, c) 2 pixel, d) 3 pixel, e) 4 pixel, f) 5 pixel

Methodology and results

The multi-temporal set of aerial and Quickbird satellite images of Lomianki municipality has been used for the research presented in this paper. Lomianki municipality borders with Warsaw, capital of Poland so it is affected by urban sprawl phenomenon. Used images show Lomianki in the years 1987, 2001 and 2008.

All the images have been converted into 8-bit grayscale format to allow the application of the granulometry.

The images chosen to the process were of the very high spatial resolution (pixel size less than 1 m). Such a high resolution is not necessary to determine a heterogeneity seen in built-up area. That is why the spatial resolution of all the images has been degraded in ArcGIS software. This way, the sizes of the image files have been significantly reduced, together with time-consumption of the process of the calculation of granulometric maps and also allowed to unify the pixel sizes for all the images to simplify an interpretation of the results.

Granulometric maps have been calculated for each of the images. The parameters of the granulometric maps were:

- window of the granulometry: approximation of a circle of radius 25 pixel long,
- maximum size of a structuring element for an opening operation: approximation of a circle of radius 10 pixel long.

This way, ten granulometric maps for each of the images have been produced. These granulometric maps have been classified using Erdas Imagine software (ISODATA algorithm). 50 classes have been extracted. The results of the classification have been quickly interpreted comparing to the appropriate original (satellite or aerial) images. The classes representing built-up area have been extracted and the total built-up area have been calculated according to these extracted built-up classes. The results have been compared to the referential vector layers extracted in a process of a visual interpretation of the images.

The results obtained using the classified granulometric maps compared to the referential results are presented in the figures 3–5 and in the table 1.

Table 1. The results of classification of granulometric maps compared to the referential data

Date of acquisition	Built-up area according to granulometric maps [ha]	Real built-up area [ha]	Absolute difference [ha]	Relative difference [%]
1987	548.0	590.0	42,0	7
2001	900.1	938.3	38.2	4
2007	1010.0	1002.6	7.4	1

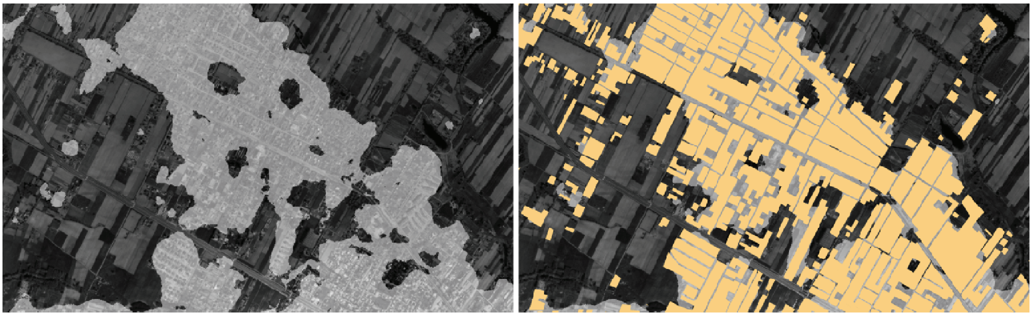

Fig. 3. Image from 1987. Built-up area extracted using classification of granulometric maps (left) and referential data (right)

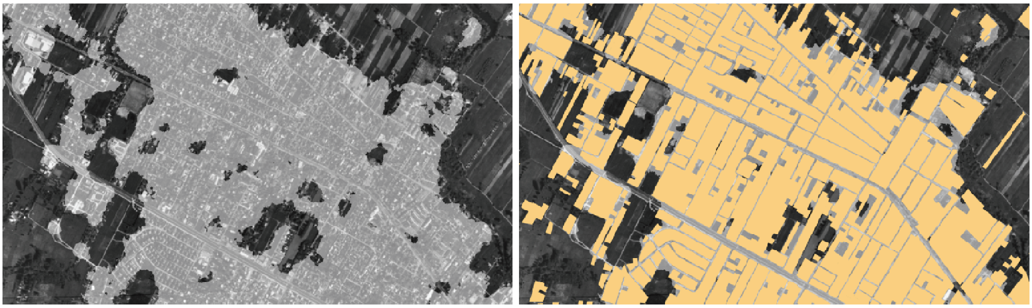

Fig. 4. Image from 2001. Built-up area extracted using classification of granulometric maps (left) and referential data (right)

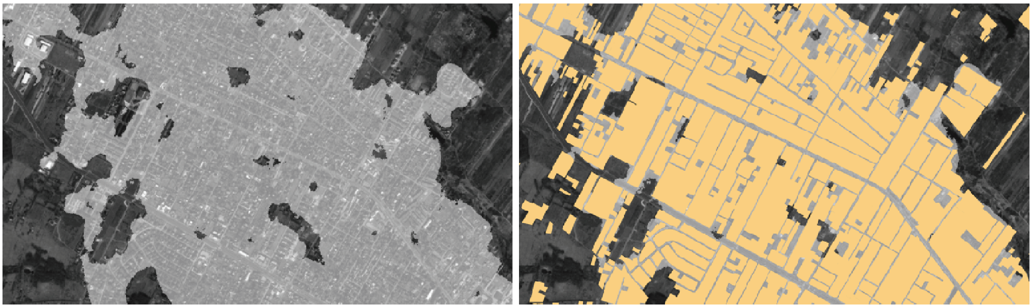

Fig. 5. Image from 2007. Built-up area extracted using classification of granulometric maps (left) and referential data (right)

Conclusions

Granulometry is the efficient tool, allowing to extract heterogeneous features form an image. Extraction of built-up areas using a pixel-based classification of the granulometric maps produced from the aerial and satellite images has relatively high accuracy, especially for one ortho-image from 2007, characterized by the best radiometric quality of all of the tested images.

What is also important, the process presented above may be executed using free software, downloadable from Internet, like BlueNote (http://telesip.gik.pw.edu.pl) for granulometric maps generation (and other morphological operations) and MultiSpec (www.ece.purdue.edu) for image classification.

Acknowledgment

The research was funded from the science research funding of Polish Ministry of Science for 2007–2008.

References

Haralick, R.M., Sternberg, S.R., Zhuang, X., 1987. Image Analysis using Mathematical Morphology. IEEE Transactions on Pattern Analysis and Machine Intelligence, 9(4), p. 532–550.

Kupidura P., 2006. Zastosowanie wybranych operacji morfologii matematycznej do wydzielania klas pokrycia terenu na zdjęciach satelitarnych, Ph.D. thesis, Warsaw University of Technology, Warsaw, 2006.

Merring, C. Chopin, F. Granulometric Maps From High Resolution Satellite Images, Image Analysis and Steorology, 2002, vol. 21, p. 19–24.

Nieniewski, M., 1998. Morfologia matematyczna w przetwarzaniu obrazów. Akademicka Oficyna Wydawnicza PLJ, Warszawa.

Nieniewski, M., 2005. Segmentacja obrazów cyfrowych. Akademicka Oficyna Wydawnicza EXIT, Warszawa

Serra, J., 1982. Image Analysis and Mathematical Morphology, Vol. 1. Academic Press, Londyn.

Serra, J., 1988. Image Analysis and Mathematical Morphology, Vol. 2 Theoretical Advances. Academic Press, Londyn.

Sternberg, S.R., (1986): Grayscale Morphology. Computer Vision Graphics and Image processing, 33(5), p. 333–355.

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