

O.V. Spirintseva

PHOTOGRAMMETRIC IMAGE HOLDER EXPONENT BASED SEGMENTATION

Abstract. The aspects of photogrammetric images segmentation based on multifractal analysis are studied in this paper in order to extract the edges of the developed object optimally.

Keywords: photogrammetric image, fractal analysis, segmentation, Holder exponent.

Problem. The principle of multifractal based image segmentation is the following. It seems intuitively clear that points in an image can be classified according to their Holder exponent [1]. Let us take the example of points lying on contours. These points often correspond to discontinuities of the grey level map or of its derivative. They thus have in general "low" Holder regularity. However, the exact value of the exponent will depend on the characteristics of the image. In addition, the property of being an edge is not purely local, and one needs a global criterion in order to decide that a given point is an edge point. Indeed, points lying in textured regions also have in general a low regularity, and one has to find a way to distinguish them from contours.

Analysis of researches. As a powerful mathematic tool, fractal theory initiated by Mandelbrot [2] has been widely applied to many areas of natural sciences. The approach of Image Multifractal Segmentation is fully non parametric, and analyses the image through various features of its multifractal spectrum [3]. Although it is perfectly possible to use Weakly Self Affine functions [4] to model and segment images as well as to use multifractal tools for the segmentation of 1D signals. In fact this is really a modeling method used for segmentation purposes.

The aim of the work is to study the way of fractal analysis of photogrammetric images fixed in a number of spectrum ranges by iconic means of remote sensing.

Theoretical information. Since edges are by definition sets of points of dimension one, we shall declare a point to lie on a contour if it

has an exponent such that the associated value of the multifractal spectrum is one. Note that, in addition to this geometrical characterization of edge points, a statistical one is possible. Edge points may be defined through their probability of being hit when a pixel is randomly chosen in the image at a given resolution. The link between the geometrical and statistical characterizations is provided by the multifractal formalism. Starting again from the Holder exponents, one can decide to keep those points where the spectrum has any given value. One starts by computing the Holder exponent at each point. This yields the image of Holder exponents. The second step is to compute the multifractal spectrum. Finally, one chooses which kind of points to extract, i.e. points on smooth edges, textures, etc..., by specifying the corresponding value of the spectrum.

The analysis is performed with respect to the Lebesgue measure; exponents are computed by comparing the content of a region with its size.

The computation of the Pointwise Holder exponent is executed by different ways of measuring the content of a given region in the image:

- associating to each region the *sum* of the grey level of the pixels in it;
- computing the L_p norm, i.e. the $1/p$ -power of the sum of the p -powers of the individual grey levels (*lpsum* capacity);
- measuring the region content by the *minimum* of the grey levels of its pixels;
- measuring the region content by the *maximum* of the grey levels of its pixels;
- assigning to a region the cardinal of the largest subset of pixels having the same grey level (*iso* capacity).

For instance, if a region is composed of N pixels all having different grey levels, its *iso* capacity will be one. If all pixels have the same grey level, the *iso* capacity is N . The *adaptive iso* is a refinement of this taking into account a possible noise in the image.

At the next step the multifractal spectrum could be computed by one of the following three algorithms. The Hausdorff spectrum gives geometrical information pertaining to the dimension of sets of points in the image having a given exponent. This spectrum is a curve where abscissa represent all the Holder exponents that occur in your image, and the ordinate is the dimension of the sets of pixels with a given exponent.

The second spectrum is the large deviation spectrum. This spectrum yields a statistical information, related to the probability of finding a point with a given exponent in the image. The computation is based on techniques used in density estimation, and uses a kernel of optimal, signal dependent, size computed from some empirical statistical criterion. The third spectrum is called the Legendre spectrum. It is just a concave approximation to the large deviation spectrum. Its main interest is that it usually yields much more robust estimates, though at the expense of an information loss.

During segmentation those points the exponent of which have a corresponding value of spectrum that falls inside the definite range of dimensions are being extracted from the original image. The result is a binary image, where the extracted points are in white and everything else is black.

Results. As a testing image the Ikonos NIR multispectral image of urban area was kept. The resolution of this one is 4 meters and spectral range is 0.77 - 0.88 mkm.



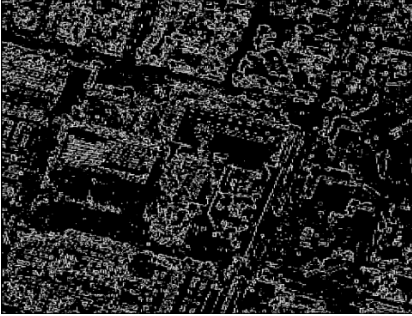
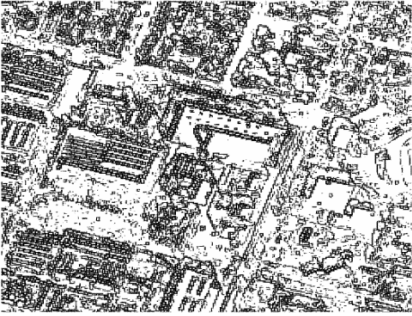


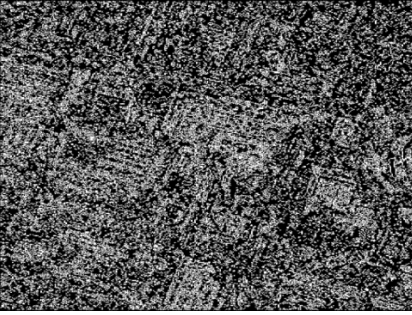
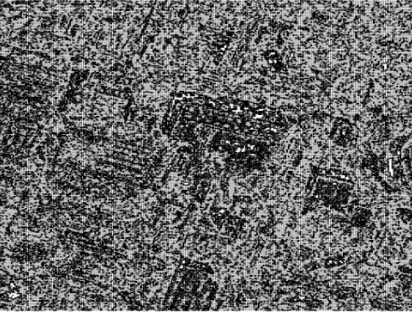
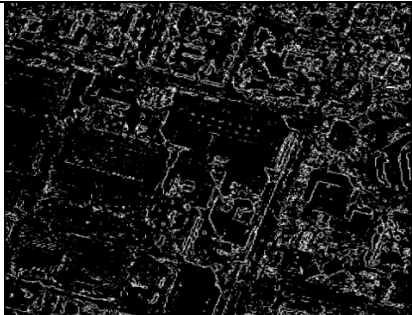

Figure 1 – Initial photogrammetric image

The images obtained after segmentation process are shown below in Table in accordance to Holder exponent capacity and Segmentation special parameter correspondence provided Hausdorff Spectrum was used.

The segmentation results were estimated by SSIM Index [5], which shows the result image geometrical structure similarity to initial one. The one is the maximum value of SSIM index which correspond to the maximum identity between two compared images. In this paper we estimate the efficiency of segmentation algorithm while applying it for photogrammetric images.

Table 1

Segmentation results and corresponding SSIM index value

Spectrum Holder exponent	[0.75, 1.25] for reasonable edge detection	[1.5, 2.0] for "fat" binary image containing smooth regions
Min	 0.0033	 0.0296
Max	 0.0267	 0.5051
Iso	 0.0084	 0.0883
Adoptive Iso	 0.1502	 0.0022

Conclusions. While computing the Holder Exponent It should be mentioned that the most important capacities are the *sum*, *max*, and *iso* ones. The choice of one capacity rather than another one should be performed on a trial and error basis. As a general rule, *max*, *min* and (*adaptive*) *iso* capacities give more robust and meaningful results. In any case, it should be experimented with different capacities and look at the result before you decide which one you choose: different capacities will often highlight different aspects of your image.

While computing the box dimensions for sets of points for Hausdorff spectrum be warned that excessive max boxes sizes (over 64) will result in long computation times. Increasing the min boxes yields smoother but less precise spectra.

The shape of the spectra for a typical image is very different depending on the capacity: for the *sum* capacity, it generally has an approximately bell shape. For the *max* capacity, it looks more like a segment of the form $y = 2 - ax$, with $a > 0$, as for the *iso* one, it would resemble $y = ax$, again with $a > 0$.

Further development of the photogrammetric image segmentation may hold towards small object detection in a number of parameter variations.

SOURCES

1. Trujillo L. The Estimation of Holderian Regularity using Genetic Programming / L. Trujillo, P. Legrand, J. Levy-Vehel. // GECCO'10. - 2010. - PP. 861-686.
2. Mandelbrot B.B. Fractional Brownian motions, fractional noises and applications / B.B. Mandelbrot, J.W. Van Ness. // SIAM Rev. 10 (4). - 1968. - PP. 422-437.
3. Levy-Vehel J. Thinking in Patterns / J. Levy-Vehel, P. Legrand // Signal and Image Processing with FRACLAB. - 2004. - PP. 321-322.
4. Levy-Vehel J. Weakly Self Affine Functions and Application in Signal Processing / J. Levy-Vehel // CUADERNOS del Instituto de Matematica "Beppo Levi", 30, ISSN 03260690, 2001.
5. Wang Z. Image quality assessment: From error visibility to structural similarity / Z. Wang, A. C. Bovik, H. R. Sheikh, E. P. Simoncelli // IEEE Trans. Image Processing. - 2004. - vol. 13. - PP. 600 - 612.