THE NEW ORTHORECTIFICATION STRATEGY AS A WAY FOR VISUAL QUALITY IMPROVEMENT

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ABSTRACT:

In the paper a new orthorectification strategy of aerial images is presented. The strategy is focused on improvement of visual quality of orthoimage. The idea of proposed strategy relies on extraction of edges from the image and next special resampling is taken. The critical issue for edge detection is that the images usually includes some noise. The de-noising of an image has many solutions but none of them is perfect. Therefore in the paper the usefulness of wavelet transformation for image de-noising is tested.
The proposed orthorectification strategy gives a better image then the image from typical orthorectification. The visual quality of edges in orthoimage is comparable to the original image.

1. INTRODUCTION

The paper includes a proposal of a new orthorectification strategy of images.
The geometric transformation of images especially the transformation between the central perspective image and the orthoimage is performed in the same way for many years. The only changes that have been implemented, rely on the resignation from any simplification in the computing process. Now more often the exact transformation using collinearity is computed for all pixels and breaklines of the terrain are taken into account. These changes are sufficient to achieve the good geometric quality, but the visual quality of orthorectified image is always worse than the visual quality of the original image.
The reason why visual quality is reduced is that orthorectification is the same both for linear elements and for homogenous areas. In the typical rectification the intensity value of an orthoimage pixel is a result of interpolation of the intensity values of a group of image-pixels (from one to sixteen). Therefore on the intensity of pixel on the edges of a road is influenced by the intensity of a road surface and shoulder.
The proposed modification of orthorectification strategy is focused on the improvement of visual quality of an orthoimage. The main steps of the proposed strategy are: (1) image de-noising using wavelet transformation, (2) detection of edge using Laplace operator, (3) the execution of orthorectification with a special resampling method.

2. IMAGE DE-NOISING USING WAVELET TRANSFORMATION

Aerial and satellite images usually contain noise, due to image acquisition, transmission errors or compression side effects. The noise causes great problems to image processing algorithms. (Pitas, 2000). Only when the image de-noising is effective the edge detection is proper. In other case the edge detection is significantly noised.
De-noising is typically handled by smoothing filters. But smoothing can delete useful information or distort the input image. The mainly used smoothing method is the Gaussian 2-D filter. The Gaussian outputs are an average of each pixel's neighborhood weighted more towards the value of the central pixels. In comparison with a mean filter, the Gaussian provides a gentler smoothing and preserves the edges better. But the Gaussian filter works well only in isotropic spaces therefore when it is used for smoothing real images it removes both noise and detailed information.
An other solution to de-noise is the usage of the wavelet transformation. This transformation separates the smooth variations and details of the image much better than Fourier-based techniques.
Wavelet transformation is widely applied to image compression and is more often used for image de-noising (Rangarajan, 2002).
Wavelet transformation decomposes a discrete image into four sub-image where LL, HL, LH, HH represent average, vertical fluctuation, horizontal fluctuation and diagonal fluctuation respectively. The decomposition may be held on several levels (Walker, 1999). A sample of all the sub-images on the first level is shown in the figure 1b. As wavelet transformation the Haar function was used.
The basic method of image de-noising is thresholding. By choosing a correct threshold, it is possible to remove most of the random noise. In this research a soft thresholding adequate for each sub-image was tested:

$$f(i,j)=\begin{cases} f(i,j) & if\ |f(i,j)| \geq T1 \\ f(i,j) & if\ |f(i,j)| \geq T2 \ \text{AND (1a)} \\ 0 & if\ |f(i,j)| < T2 \end{cases} \quad (1)$$

the extra condition (1a) are as follow:

for LH: $if \quad |f(i,j-1)| \geq T1 \quad \text{OR} \quad |f(i,j+1)| \geq T1$

for HL: $if \quad |f(i-1,j)| \geq T1 \quad \text{OR} \quad |f(i+1,j)| \geq T1$

for HH: $if \quad |f(i-1,j-1)| \geq T1 \quad \text{OR} \quad |f(i-1,j+1)| \geq T1$
$\text{OR} \quad |f(i+1,j+1)| \geq T1 \quad \text{OR} \quad |f(i+1,j-1)| \geq T1$

where T1 > T2 = the threshold values

$f(i,j)$ = a value of source image wavelet transformation

The above given thresholding is applied for two set of detailed sub-images: LH1,HL1,HH1 which come from first decomposition of the whole image and LH2,HL2,HH2 which come from the second decomposition of the LL sub-image. This thresholding respects the properties of sub-images: non-directionality of the LL sub-image and the directionality of the detailed sub-images. The results shown in figure 1d is a evidence that wavelet transformation with the proposed thresholding is a useful method in de-noising.

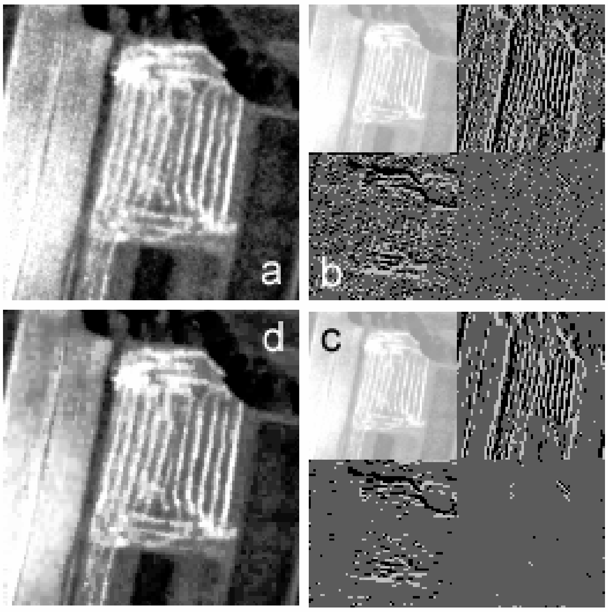

Figure 1. The way from original to de-noised image
a = the original image
b = the decomposition into four sub-images (first level)
c = the result of the soft thresholding
d = the de-noised image

3. EDGE DETECTION USING LAPLACE OPERATOR

Edge detection is the process of extracting out locations of high contrast in an image.

The most popular methods of this process use high-pass filters of a specific size. The image convolution with a small filtering mask approximates the first or second derivative of the image intensity function. There are two detectors applied (Pitas, 2000):

- first order derivative – so called intensity gradient – i.e. Roberts, Sobel - result is a vector,
- second order derivative - Laplace operator (laplacian) - result is a scalar:

$$\Delta g(i,j) = \frac{\partial^2 g}{\partial x^2} + \frac{\partial^2 g}{\partial y^2} \quad (2)$$

The intensity gradient is easy to perform but it gives very little control over smoothing and edge localization. The Laplace operator gives better results but it is very sensitive to noise, more than the intensity gradient method. Therefore it is often applied together with the Gaussian smoothing and they form so called the Laplacian of Gaussian (LoG) operator. But the LoG operator provides that the image intensity function operates in the same way in any direction from each pixel. This is the reason why both noise and detailed information are removed.

In this work the Laplace operator is used as the next step after image de-noising.. The approximation of the equation (2) is realized as a result of image convolution with the Laplace mask and we obtain a laplassian image:

$$l(i,j) = g(i,j) * L_{mask} \quad (3)$$

where $l(i,j)$ = laplasian image

$g(i,j)$ = the intensity value of de-noised image

$$L_{mask} = \begin{bmatrix} 1 & 1 & 1 \\ 1 & -8 & 1 \\ 1 & 1 & 1 \end{bmatrix}$$

4. THE EXECUTION OF ORTHORECTIFICATION WITH A SPECIAL RESAMPLING

The orthorectification is the process of removing geometric errors inherent within aerial and satellite images due to a orientation of cameras and the influence on projection of ground surfaces. In the indirect way of orthorectification for the position on orthoimage the equivalent location in the source image is calculated by using a projecting equations and by applying a DEM and exterior orientation parameters of a camera (Kraus, 1997). The procedure starts from ground position (X,Y) and projects it towards to a coordinate system of the source image and the position (x,y) is received. The source image is a array where the position of pixels is represented thrugh an integer row-columns coordinate system. Therefore the orthorectification process comprises a digital resampling procedure. This resampling relies on an assessment of the intensity values of a group of pixels from source image to assign a value to the position (x,y). Three algorithms of resampling are normally employed in orthorectification software packages: the nearest neighbor method uses the intensity of one source pixel, the bicubic method interpolates a new value from four pixels and the cubic convolution method - from sixteen source pixels.

The Bilinear Interpolation and the Cubic Convolution often produces similar results, however the Cubic Convolution method generally produces a smoother output raster. But these methods have the effect of a low-frequency convolution. Most of the edges are smoothed, and some extremes of the data file values are lost. Only the nearest neighbor method insures that the extremes and subtleties of the data values are not lost. But this method causes usually a stair-stepped effect around edges (Erdas, 1999).

In the work described in this paper a special resampling method was tested – see formula (4). The result is shown in the figure 2.

$$g(x,y)=\begin{cases} g(i_n,j_n) & if \quad d \le 0.1 \\ g(i_n,j_n) & if \quad d \le 0.2 \quad AND \quad |l(i_n,j_n)| \ge L1 \\ g(i_n,j_n) & if \quad d \le 0.3 \quad AND \quad |l(i_n,j_n)| \ge L2 \\ \text{interpolation} & \text{otherwise} \end{cases} \tag{4}$$

where

$g(i_n, j_n)$ = intensity value of the nearest neighbor pixel to position (x,y) respectively

$l(i_n, j_n)$ = laplasian value of the nearest neighbor pixel to position (x,y) respectively

d = distance from position (x,y) to center of nearest pixel (in pixels)

L2 > L1 = the threshold values

interpolation = Bicubic Interpolation

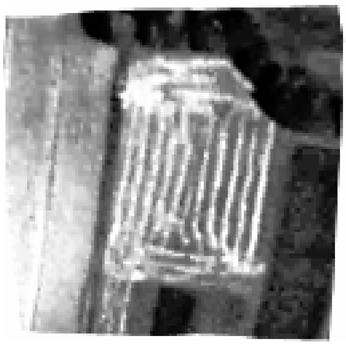

Figure 2. The result of orthorectification

5. DISCUSION OF THE RESULTS

In the typical orthorectification, the intensity value of an orthoimage pixel is a result of a interpolation of the intensity values of a group of source image-pixels independently of the fact they are the pixels on linear elements or the inner pixels in a homogenous area.

The proposed orthorectification strategy includes de-nosing by using wavelets and resampling which protects the edges. In the described research the usefulness of wavelet transformation for image de-noising was proved. The best result gives the soft thresholding but the critical issue is the proper selection of threshold value.

The proposed strategy of orthorectification gives promising results. The visual quality of edges is almost the same both in an orthoimage and in original image. A longer computation time in comparison with a typical rectification strategy will be insignificant because of quick development in computing technology.

The strategy has been implemented in GRASS GIS environment with applying the R statistic package, both of them represents the Open Source Initiative.

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