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RESEARCH OF SATELLITE IMAGES PREPROCESSING METHODS FOR QUALITY IMPROVEMENT OF NATURAL OBJECTS EDGES DETECTION

Abstract. Application efficiency of satellite images preprocessing methods for quality improvement of natural objects edges detection is investigated. It is experimentally set that the increase in selected integral and extensive edges quantity is reached by contrast-limited adaptive histogram equalization method images preprocessing.

Keywords: satellite images, edges, image processing, Canny edge detector.

Problem definition

Nowadays a lot of technical tasks are solved with use of Earth surface satellite images. Technical constructions monitoring (roads, pipelines, buildings, and industrial facilities), farmland monitoring, subsoil investigation and maintenance, property and territories control, and many others belong to such tasks. One of standard image processing stages is so-called edge detection – area feature contours and linear feature axes. They can be accurate and objectively existing (for example, the building contour or the highway), and indistinct or only conditionally existing (for example, an ancient geological fault axis or bog edge). As a rule, second type edges correspond to natural objects therefore their detection is executed less successfully (they are detected only partially and are represented discontinuous, fragmentary), in comparison with the technogenic objects, that have simpler and accurate contours.

There are a number of approaches to automatic natural objects edge detection. One of them is used more often. It consists in preliminary detection of the narrow drawn-out zones of sharp overfall image brightness values (phototone) – so-called edges. Various shadow-mask algorithms are used for this purpose. The most acceptable algorithm is considered the Canny edge detector [1]. It transforms the initial picture to a bitmap. On this image single pixels correspond to edge existence, and zero – to edge absence.

Preliminary researches showed that edge detection quality improvement can be reached by additional satellite image processing. Traditionally, a row of simple methods – contrasting, brightness correction, satellite image histogram equalization – is put into practice. At the same time, in the digital image processing theory [2] there is a large number of methods which weren't applied to the specified purposes so far.

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Work purpose – the experimental assessment of image processing methods and finding the most effective edges detection methods on the synthesized and panchromatic satellite images.

Input data and research tools

20 synthesized satellite images appear as input data. These are different spatial and spectral resolution images. They are made the equipment Landsat-7, Terra MODIS, Spot-4, and also Google images are used. Satellite images represent different sections of the Globe which are in different geological and landscape conditions.

Input satellite images processing made in the MatLab environment by the researched methods. Processed images edges detection execute in the specialized GIS RAPID environment, developed on Geoinformation Systems Department of the State HEI "National Mining University" [3].

The conditional names and short images characteristic are provided in table 1.

Table 1 – Input data for experiments

Image name	Image characteristic
Zarmitan field (Uzbekistan)	gold field Zarmitan synthesized SPOT-4 satellite image (resolution - 20 m)
Ziaetdin field (Uzbekistan)	gold field Ziaetdin panchromatic Landsat-5 satellite image (resolution - 15 m)
China territory fragment	fragment of mountain terrain Sichuan Province (China) territory synthesized Landsat-5 satellite image (resolution - 30 m)
Farmland, Ukraine	Magdalinovsky district (Dnepropetrovsk area) territory parts synthesized Landsat-5 satellite image (resolution - 30 m; channels 1,2,4)
Afghanistan territory fragment	Google image of a part Afghanistan mountain territory
Mexico territory fragment	Google image of a part Mexico mountain territory
Norway territory fragment	Google image of Norway northern part fragment
Peru territory fragment	Google image of Peru east part fragment
Sultanuizdag field (Uzbekistan)	gold fiel Sultanuizdag Google image (Uzbekistan)
Tibet territory fragment	Google image of a part Tibet mountain territory
Finland territory fragment	Google image of the parts Finland mid-mountain territory
Scotland territory fragment	Google image of Scotland northern part fragment (break Glenmore region)
Rain wood, Malaysia	Google image of Malaysia territory fragment
Popigai meteoric crater	Popigai meteoric crater Landsat-7 satellite image (Russia)
Sumatra island territory fragment	Google image of Sumatra island coast territory, Indonesia (resolution ~ 10 m)
Transbaikalia territory fragment	Google image including northern part of the Baikal water area and Transbaikalia territory (resolution ~ 250 m)
Australia territory fragment	снимок Terra Modis (resolution ~ 500 м) of Australia east part
Morocco territory fragment	Terra Modis image (resolution ~ 250 м) of Morocco western part
Asia territory fragment	survey satellite image of the Asia territory (resolution ~ 10000 м)
Central Carpathians	Terra Modis image (resolution ~ 250 м) of the Carpathians central part

Technique and research results

Such image processing methods are researched [2, 4-6]:

- counter-harmonic filter;
- indistinct masking method;
- contrast-limited adaptive histogram equalization (CLAHE);
- Lucy-Richardson method;
- finite difference method;
- mean squared deviations method of local neighborhoods pixels intensity;
- based on the sectional average filter;
- based on the Kuwahara filter;
- based on the linear Winer filter;
- based on the median point filter.

Experiments are made by the following technique.

1. Each input images is processed by above-mentioned methods in the MatLab environment. As a result, 200 images are received, which underwent later processing.

2. In the GIS RAPID environment on the input and transformed images the Canny method detected edges. As a result, 210 bitmaps are received on which units correspond to edges. Some of the received bitmaps are given in a picture 1 (which relating to the Transbaikalia territory). Note high concentration and detected edges curvilinearity. It is caused by their natural origin and a difficult land relief figure.

3. The assessment of edge quality detected is executed before and after researched image processing methods use.

Detection quality assessment is usually based on intuitive-clear use of edges detection quality heuristic criteria:

a) detected edges shall be most integral and doesn`t have a lot of gaps; this condition execution in practice carries to growth of boundary pixels carried number.

b) only the main edges shall be selected, having sufficient expansion and definition. Otherwise there can be a situation, when the received bitmap is overloaded 1-2-pixel fragments. In practice, this condition execution carries to reduction of boundary pixels carried number.

Thus, the specified requirements are mutually exclusive in practice – the maximum satisfaction of one carries to the minimum satisfaction of another. Therefore approach to detection quality assessment, which is based on two merit figures use of edges detection is represented to the most

productive. They are easily calculated and make simple geometrical meaning. Their sharing doesn't require multicriteria optimization procedures application.

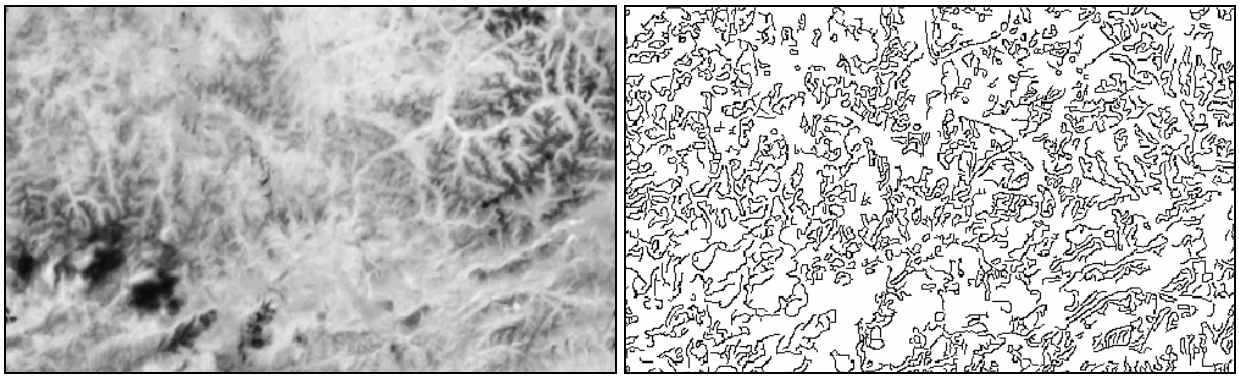
It is offered the following indexes use:

N – single (nonzero) pixels number corresponding to edges on a bitmap. Characterizes total detecting edges quantity and calculated by summing of pixels with single values.

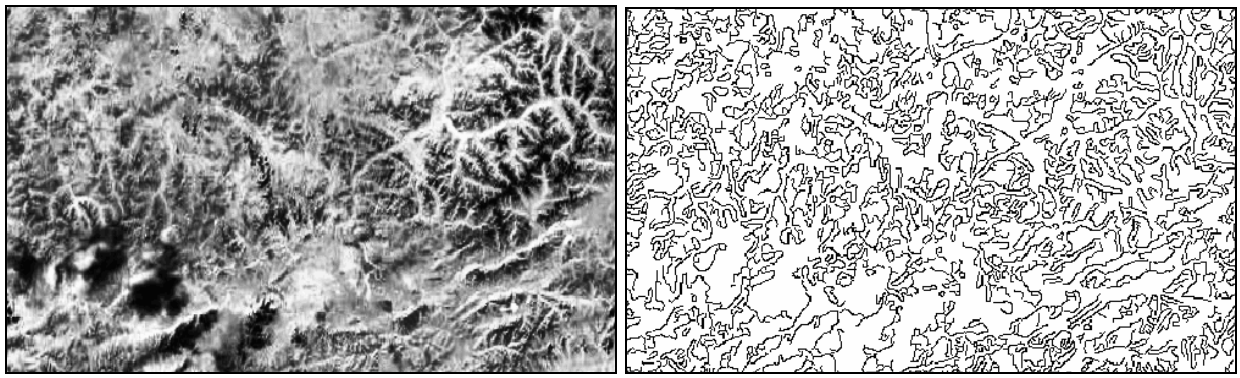
F = K/N, where K – edges continuous fragments quantity on the image. This index characterizes a level of edges integrity. Than it is lower, especially safely and surely edges are detected.

Measure N and F values automatically are calculated for all initial and processed by different images methods and are entered in tables. N and F indexes given in each tables are arranged on increase and, depending on their got sequence number, the rank from 1 (the smallest value) to 11 (the greatest value) is appropriated to them.

a)



b)



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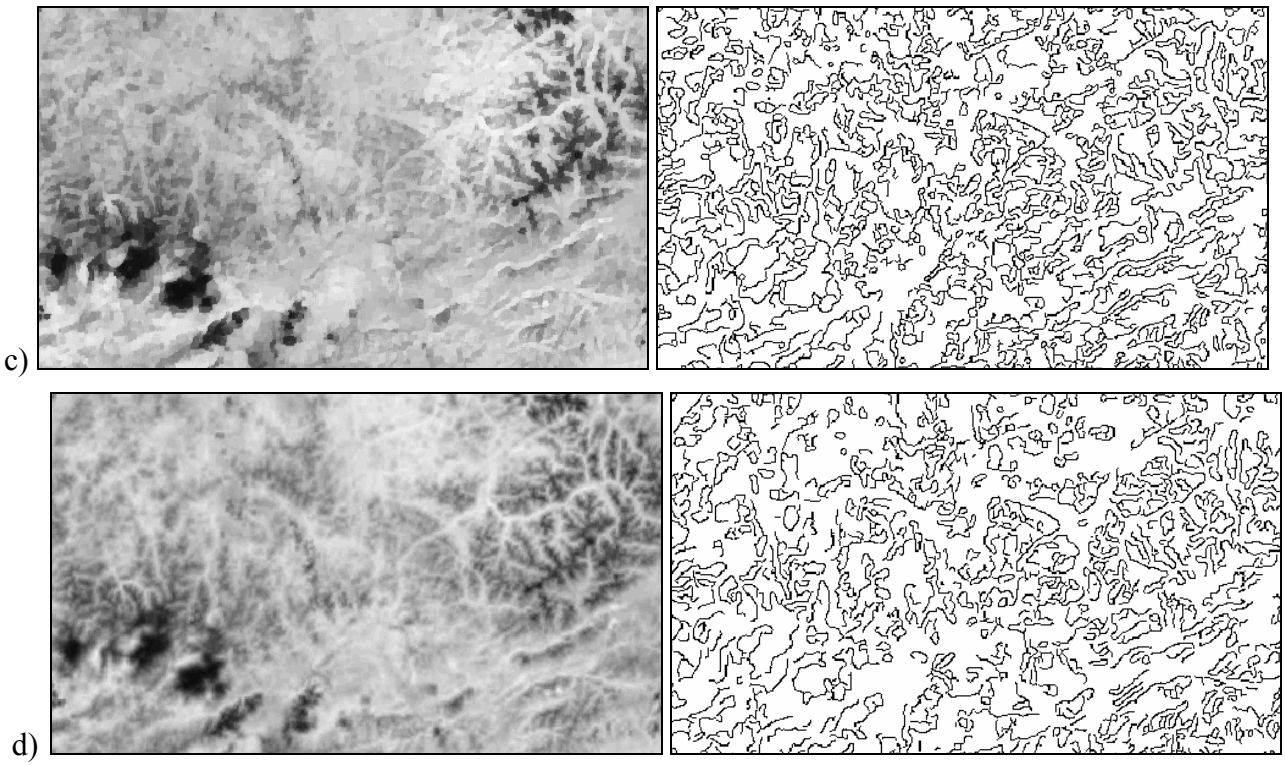

Picture 1 – Transbaikalia image fragment processing results and edges binary cards, corresponding to them: a) input image; the histograms processed by methods of contrasting and limited adaptive alignment (b), the Kuwahara filter (c), the median point filter (d).

Tables 2 and 3 are built by results of N and F indexes ranging. Tables contain the indexes ranks for the researched methods calculated for each image. They form a basis for conclusions formulation and recommendations concerning applicability of probed methods in satellite images processing procedures and lineament detection.

The summary N and F indexes ranks ranged on increase for different methods are provided in table 4. They allow estimate efficiency each of ten application used images preprocessing methods.

Similar actions are executed separately for high and low resolution images. Received results are similar with provided in tables 2-4.

Results analysis and practical conclusions

Received results analysis allows approve following:

1. Contrast-limited adaptive histogram equalization method, finite difference method and mean squared deviations method of local neighborhoods pixels intensity increase N measure value in comparison with the input image. It means that use any of these methods allows to increase

detected edges quantity on the processed image in comparison with the input.

2. Increase of detected edges quantity carries to significant manifestation amount of unessential details (short, discontinuous edges fragments) which significantly complicate solution of many practical tasks. Therefore, the measure F value has great importance. It is a peculiar received edges integrity measure. Low F values testify that the detected edges are integral, extensive, surely detected.

3. From the practical use point of view, the best results can be reached when using such processing methods which provide detection of large edges number (N value increase), in comparison with the raw image, but detected edges shall be extensive, integral (F value lowering).

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Table 2 – N index ranks for the used satellite images

Image processing methods:	Afghanistan territory fragment	Transbaikalia territory fragment	Zarmitan field (Uzbekistan)	Ziaetdin field (Uzbekistan)	China territory fragment	Farmland, Ukraine	Mexico territory fragment	Norway territory fragment	Peru territory fragment	Sultanuizdag field (Uzbekistan)	Tibet territory fragment	Finland territory fragment	Scotland territory fragment	Australia territory fragment	Popigai meteoric crater	Sumatra island territory fragment	Morocco territory fragment	Rain wood, Malaysia	Asia territory fragment	Central Carpathians	Summary rank
Input image	8	9	8	6	8	6	8	9	10	7	9	8	9	6	9	6	10	9	6	7	158
Sectional average filter	3	3	5	5	4	3	3	5	3	4	3	3	3	5	4	2	1	3	4	2	68
CLAHE	4	11	11	11	11	11	7	10	9	10	10	11	6	11	11	9	4	6	10	11	184
Counter-harmonic filter	2	2	3	2	2	2	2	3	2	2	2	4	2	4	2	1	3	2	2	3	47
Kuwahara filter	6	5	1	4	6	4	6	6	5	6	5	5	5	2	1	4	7	5	9	1	93
Lucy-Richardson method	9	7	6	7	9	7	10	7	7	8	7	6	7	7	7	7	8	10	7	8	151
Indistinct masking method	7	6	9	9	3	9	5	1	6	5	6	10	10	1	6	11	6	7	5	9	131
Mean squared deviations intensity method	11	10	10	10	10	10	11	11	11	11	11	9	11	10	10	10	11	8	11	6	202
Finite difference method	10	8	7	8	7	8	9	8	8	9	8	7	8	8	8	8	9	11	8	10	167
Median point filter	1	1	2	1	1	1	1	2	1	1	1	1	1	3	3	3	2	1	1	5	33
Linear Winer filter	5	5	4	3	5	5	4	4	4	3	4	2	4	9	5	5	5	4	3	4	87

Table 3 – F index ranks for the used satellite images

Image processing methods:	Afghanistan territory fragment	Transbaikalia territory fragment	Zarmitan field (Uzbekistan)	Ziaetdin field (Uzbekistan)	China territory fragment	Farmland, Ukraine	Mexico territory fragment	Norway territory fragment	Peru territory fragment	Sultanuizdag field (Uzbekistan)	Tibet territory fragment	Finland territory fragment	Scotland territory fragment	Australia territory fragment	Popigai meteoric crater	Sumatra island territory fragment	Morocco territory fragment	Rain wood, Malaysia	Asia territory fragment	Central Carpathians	Summary rank
Input image	10	11	9	8	10	7	8	10	11	8	10	10	10	8	8	8	9	8	9	8	180
Sectional average filter	3	3	4	5	5	1	2	4	5	6	6	3	4	2	6	2	1	2	5	2	71
CLAHE	4	5	10	7	6	6	7	7	6	3	5	7	5	11	5	7	4	5	3	6	119
Counter-harmonic filter	2	2	6	6	4	4	4	5	3	4	3	5	3	5	3	4	2	4	2	3	74
Kuwahara filter	1	1	2	1	2	2	1	1	1	1	1	1	1	1	2	1	5	1	1	1	28
Lucy-Richardson method	8	9	7	9	11	9	10	8	9	9	8	8	8	9	9	9	10	9	10	9	178
Indistinct masking method	6	4	1	2	1	5	3	2	2	2	2	6	7	3	1	11	7	7	6	7	85
Mean squared deviations intensity method	11	8	11	11	9	11	11	11	8	11	11	11	11	7	10	6	8	11	8	11	196
Finite difference method	9	10	8	10	8	10	9	9	10	10	9	9	9	10	11	10	11	10	11	10	193
Median point filter	7	7	5	3	7	8	6	6	4	7	7	4	6	4	7	5	3	6	7	5	114
Linear Winer filter	5	6	3	4	3	3	5	3	7	5	4	2	2	6	4	3	6	3	4	4	82

Table 4 – The pivot table of edges detection merit figures after different image preprocessing methods application

Image processing methods:	Summary ranks	
	N	F
Kuwahara filter	93	28
Sectional average filter	68	71
Counter-harmonic filter	47	74
Linear Winer filter	87	82
Indistinct masking method	131	85
Median point filter	33	114
Contrast-limited adaptive histogram equalization	184	119
Lucy-Richardson method	151	178
Input image	158	180
Finite difference method	167	193
Mean squared deviations method of local neighborhoods pixels intensity	202	196

Thus, methods which raise N parameter value in case of simultaneous F parameter value lowering have special image processing importance. Apparently from table 4, the single method which raises N parameter value in case of simultaneous F parameter value lowering is contrast-limited adaptive histogram equalization method.

This method is recommended applied to satellite images before edges detected by Canny detector or other shadow-mask algorithms means.

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