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Corner detection in aerospace image by using an expandable mask

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ABSTRACT

An algorithm for searching the breaks in contours based on an expandable mask in the image is proposed. The essence of the algorithm is to eliminate straight contour lines using a form factor. Sequential application of a 3×3 pixel binary mask for each pixel of the contour, except the endpoints, and joining the unit elements to the mask (growing) in the vicinity of the pixel, for which it is impossible to determine whether the fracture using a mask 3×3 pixel. The analysis of the proposed algorithm is compared with Harris method when changing registration conditions of images, specially, brightness, contrast, and rotation. Shown, that the proposed algorithm is more stable with increasing contrast and has a shorter running time compared with Harris method on account of loss the stability with decreasing contrast.

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1. INTRODUCTION

Currently, there are different methods and algorithms for image processing that are increasingly used in the medical field to solve various problems: search for anomalies in medical images, classification of X-rays, and assistance in the analysis. Finding the key points is an important issue for solving the tasks in various fields, such as video surveillance, parameterization, identification of objects, and image stitching. Key points should be: i) uniquely identifiable in some neighborhoods and image as a whole; ii) invariant to affine transformations; iii) stable relative to noise; iv) effective for parameterization and identification of objects in the set of analyzed images.

As a key points for images can be: pixel, line, and intersection of lines–corners. There are a number of methods for finding corners in an image: Harris, [1], Shi–Tomasi [2], and FAST [3]. Corner detectors most often work with the brightness component of the pixel value. To the input of such a detector, working with a luminance component, black and white image served, as a result, and the output is formed by a list of possible angles with the degree of similarity.

Points with a degree of similarity greater than the threshold are defined as angles and less than the threshold–discarded. The disadvantage of using such detectors in the above tasks is that: that they detect the area, where the corner point is found, but do not always locate its coordinates, such as the corner point as a result of the work of these algorithms may be outside the line. Therefore, after application of these detectors is necessary to specify the location of each angle, for example using a mask. To eliminate these drawbacks, it is necessary to use angles and lines as key points.

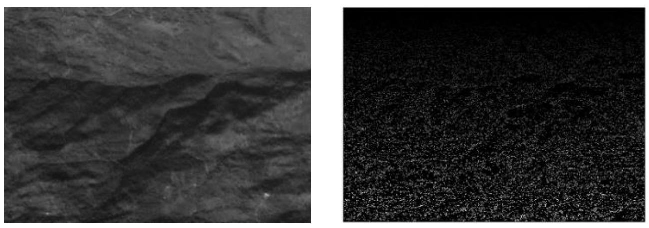
2. METHOD

For tasks such as dividing paths into separate straight lines and stitching images, corners are used as key points. Corner can be classified as shown in: i) L-form (with different angles); ii) Y-form (with different angles) or usually like T-form; iii) X-form (with different angles). As shown in Figure 1 developed an algorithm for corner detection in aerospace image by using an expandable mask. The proposed algorithm is based on the sequential application of a mask at each pixel of a selected contour, not a straight line, and except for endpoints of the contour. In case of an ambiguous solution for a pixel, it is additionally checked by expanding the mask to the size pixels.

Figure 1. Types of corners in the image

The input of the algorithm is an image $I = \|i(y,\ x)\|_{(y\ =\ \overline{0,Y-1},\ x\ =\ \overline{0,X-1})}$, where $i(y,\ x) = 0.255$– the brightness value of a pixel in the image, $Y,\ X$ – the dimensions of the image vertically and horizontally. The algorithm is consisting of the following steps.

- Formation of a matrix of binary images $I_B = \|i_B(y,\ x)\|_{(y\ =\ \overline{0,Y-1},\ x\ =\ \overline{0,X-1})}$, for the input image I using the canny contour filtering algorithm [4], where $i_B(y,\ x) = 1$ for a pixel belonging to the path, $i_B(y,\ x) = 0$ for the background pixel.
- Segmentation of contour lines. Segmentation is carried out by the method (region growing (RG)) [5]–[8]. Each contour pixel $i_B(y,\ x) = 1$ the contour number is assigned, to which it belongs. As a result, a matrix of contours is formed $S = \|s(n)\|_{n=\overline{1,N}}$, and a matrix of the number of endpoints in each contour $K = \|k(n)\|_{n=\overline{0,N}}$, where $s(n)$– coordinates of contour pixels, represented as matrices $X(n) = \|x(n,c)\|_{(c=\overline{0,C-1})}$, $Y(n) = \|y(n,c)\|_{(c=\overline{0,C-1})}$, $k(n)$ is number of the endpoint, N is number of found contours, C is number of pixels in the contour shows in Figures 2 (a) and (b).



(a) (b)

Figure 2. Segmentation of contour lines (a) test image and (b) segmentation (RG) for test image

- Normalization of selected contours by thickness. Contour normalization is carried out using the method of contour line thickness normalization [9]–[11]. In the process of normalization $X(n)$, $Y(n)$ pixels are removed from the contour coordinate matrices, which visually and physically make the line thicker. As a result, $s(n)$, outlines are formed with a thickness of one pixel.
- Contour analysis. The endpoints of the contours are analyzed first $k(n)$. If $k(n) = 2$– the decision is made that the contour $s(n)$ is a line and the form factor is calculated f to check if the contour is curved $s(n)$ [12]–[15]. If $f = [0.8,1.2]$– the decision is made that the contour $s(n)$ is straight lines and therefore has no corners. Therefore, this contour is removed from the matrix S.
- Search corner points. As a result of the execution of the algorithm, angular matrices are formed $X_A = \|x(g,n)\|_{g=\overline{0,G}}$, $Y_A = \|y(g,n)\|_{g=\overline{0,G}}$, where $x(g,n)$, $y(g,n)$– the coordinates of the corner points, g issequence number of the coordinates, G is the number of corner points found, n is contour number to which the corner point belongs [16]–[19].

a. Formatting mask $M_j = \left\| m_j(y,x) \right\|_{(y=\overline{0,2},x=\overline{0,2})}$ in Figure 3, where $j = \overline{1,16}$ is sequence number of the matrix,

$$m_j(0,0) = \begin{cases} 1, & \text{for } j = \{1,2,9\}, \\ 0, & \text{for } j = \{\overline{3..8}, \overline{10..16}\}, \end{cases} \quad m_j(0,1) = \begin{cases} 1, & \text{for } j = \{5,6,13,14\}, \\ 0, & \text{for } j = \{\overline{1..4}, \overline{7..12}, 15,16\}, \end{cases}$$

$$m_j(0,2) = \begin{cases} 1, & \text{for } j = \{1,4,11,16\}, \\ 0, & \text{for } j = \{2,3,\overline{5..10},\overline{12..15},\}, \end{cases} \quad m_j(1,0) = \begin{cases} 1, & \text{for } j = \{6,7,11,12\}, \\ 0, & \text{for } j = \{\overline{1..5}, \overline{8..10}, \overline{13..16}\}, \end{cases}$$

$$m_j(1,1) = 1,$$

$$m_j(1,2) = \begin{cases} 1, & \text{for } j = \{5,\overline{8..10}\}, \\ 0, & \text{for } j = \{\overline{1..4}, 6,7, \overline{11..16}\}, \end{cases} \quad m_j(2,0) = \begin{cases} 1, & \text{for } j = \{2,3,10,14\}, \\ 0, & \text{for } j = \{1,\overline{4..9},\overline{11..13},15,16\}, \end{cases}$$

$$m_j(2,1) = \begin{cases} 1, \text{for } j = \{7,8,15,16\}, \\ 0, \text{for } j = \{\overline{1..6}, \overline{9..14}\}, \end{cases} \quad m_j(2,1) = \begin{cases} 1, & \text{for } j = \{3,4,12,13\}, \\ 0, & \text{for } j = \{1,2,\overline{5..11},\overline{14..16}\}. \end{cases}$$

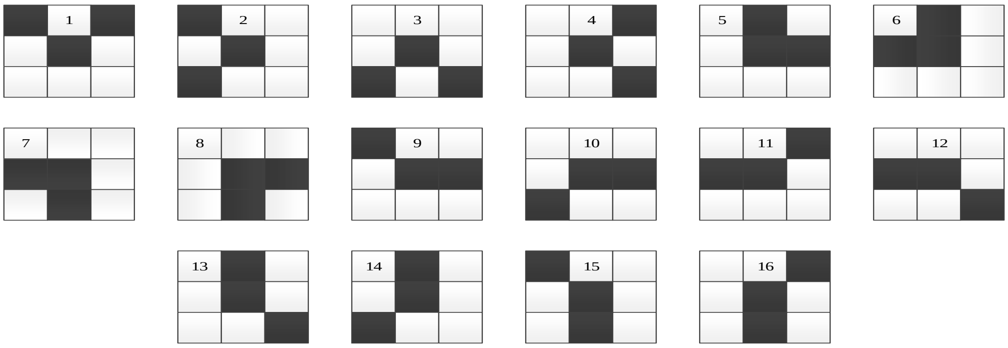


Figure 3. Masks for searching corner points in contours

b. Forming corner matrices Y_A, X_A. The neighborhood of each pixel of the contour $s(n)$ with coordinates $y(n,c), x(n,c)$ matrix $Y(n), X(n)$ is checked for compliance with one of 16 corner masks M_j. If the neighborhood of a pixel with coordinates $y(n,c), x(n,c)$ matches masks $M_1..M_8$ – go to the step d. If the neighborhood of the pixel with coordinates $y(n,c), x(n,c)$ corresponds to the masks $M_9..M_{16}$– go to step c [20]–[23].

c. Clarification. For a contour pixel with coordinates $y(n,c), x(n,c)$, the neighborhood of which corresponds to matrices $M_9..M_{16}$, refinement is performed by expanding the matrix to the size 5×5 pixels as shown in Figure 4. If the neighborhood of the pixel with coordinates $y(n,c), x(n,c)$ corresponds to the expanded matrix (the presence of at least one contour point on each side is checked in the area indicated in gray in Figure 2) go to step d.

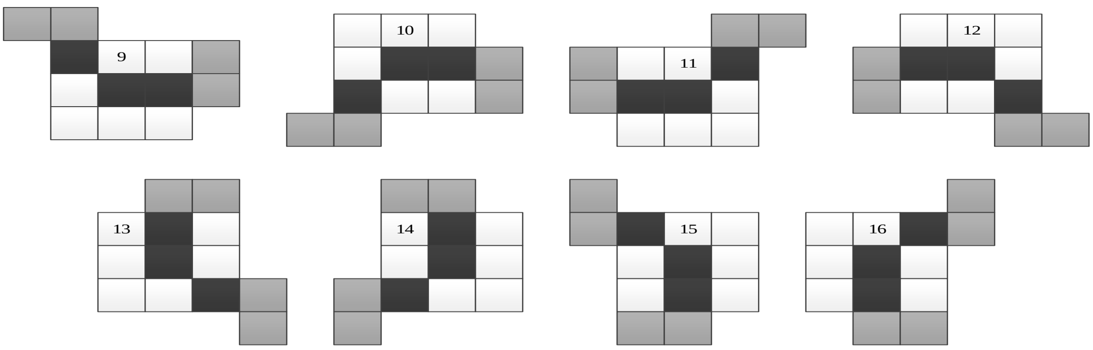


Figure 4. Masks for searching corner points in contours

d. Pixel coordinates $y(n,c), x(n,c)$, defined as a corner point are entered into matrices Y_A, X_A accordingly [24]–[26]. As a result of the algorithm, coordinate matrices are formed Y_A, X_A containing the coordinates of the corner points Figure 5.

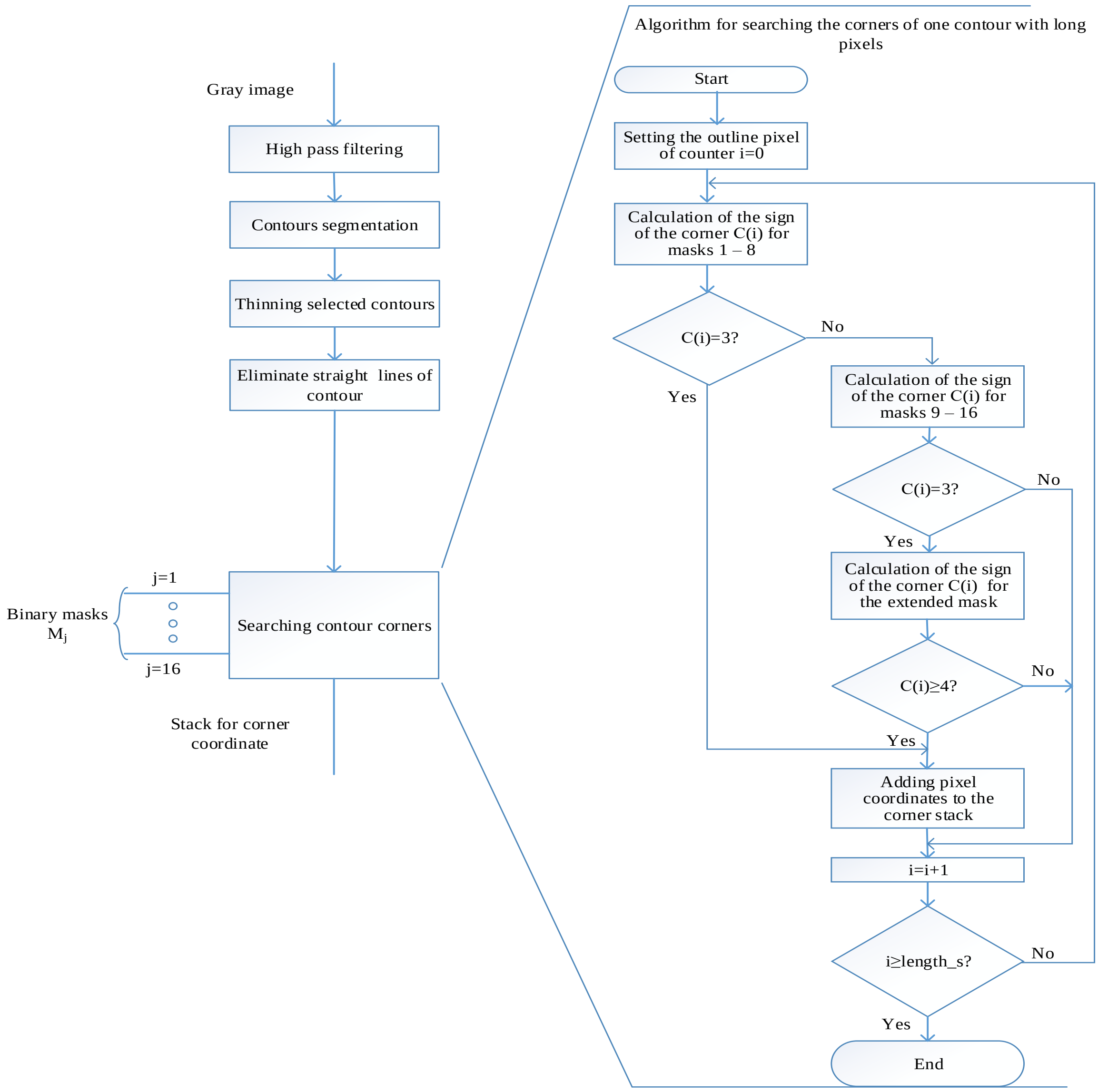
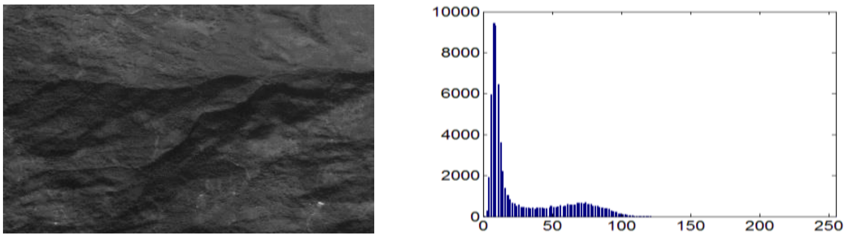


Figure 5. Corner detection in areospace image by using an expandable mask

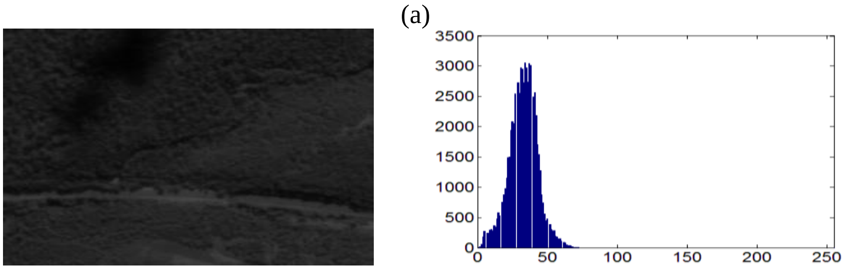
3. RESULTS AND DISCUSSION

The developed algorithm is implemented in the C^{++} programming language using the open computer vision (CV) library. For comparative evaluation algorithm implemented most known methods for angles detection–Harris. The experiment was tested on a computer with the following technical characteristics: processor–intel (R) core (TM) i5-2320 central processing unit (CPU) 3.0 GHz; random acces memory-4 (RAM-4) GB; system type–64-bit operating system, x64 processor; and operating system–windows 7.

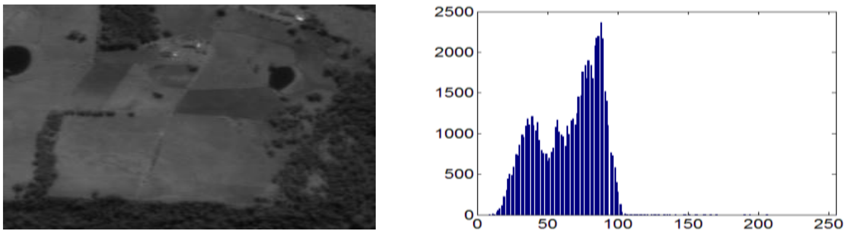
To evaluate the operation of the algorithms, grayscale images were divided into 5 classes according to the type of the brightness of the image histogram. One image from each class was taken for testing. The test image and their histograms are shown in Figures 6(a) to (e).



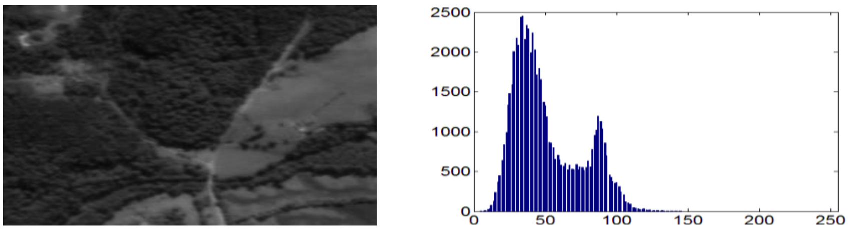
(a)



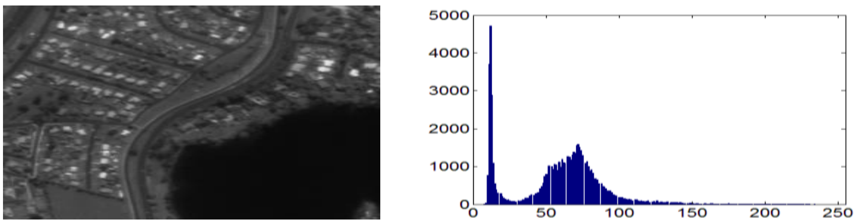
(b)



(c)



(d)



(e)

Figure 6. Test images and their histograms of different classes (a) –1, (b) –2, (c) –3, (d) –4, and (e) –5

For quantitative evaluation of stability $S(\mu)$ the number of detected corners was compared, retained their location after changing in the brightness, contrast, and in the image, rotation as shown in Figures 7(a) to (l), Figures 8(a) to (l), Figures 9(a) to (m), and $\mu = \|b, c, \alpha\|$ with the number of detected corners in the test image. To evaluate the stability of the corner detection, their number $C_i(\mu)$ on the image i, when one of its parameters μ was changed, it was normalized relative to the test image according to:

$$S_i(\mu) = \frac{C_i(\mu)}{C_0} \tag{1}$$

where C_0 is the number of detected corners in the test image. $\mu = \|b, c, \alpha\|$, $b = [-50, 50], \%$, $c = [-50, 50], \%$, $\alpha = [-90, 90], {}^\circ$

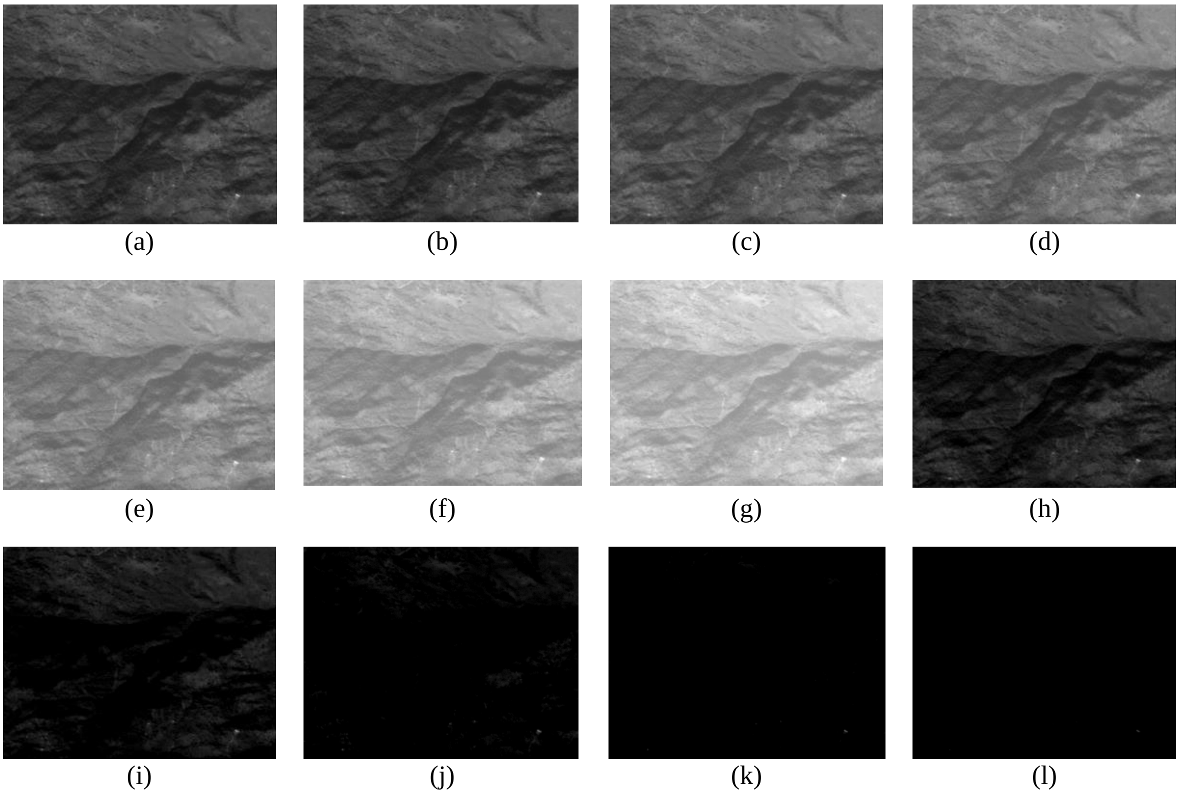


Figure 7. Changing in the brightness (a) test image, (b) 0, (c) 10, (d) 20, (e) 30, (f) 40, (g) 50, (h) -10, (i) -20, (j) -30, (k) -40, and (l) -50

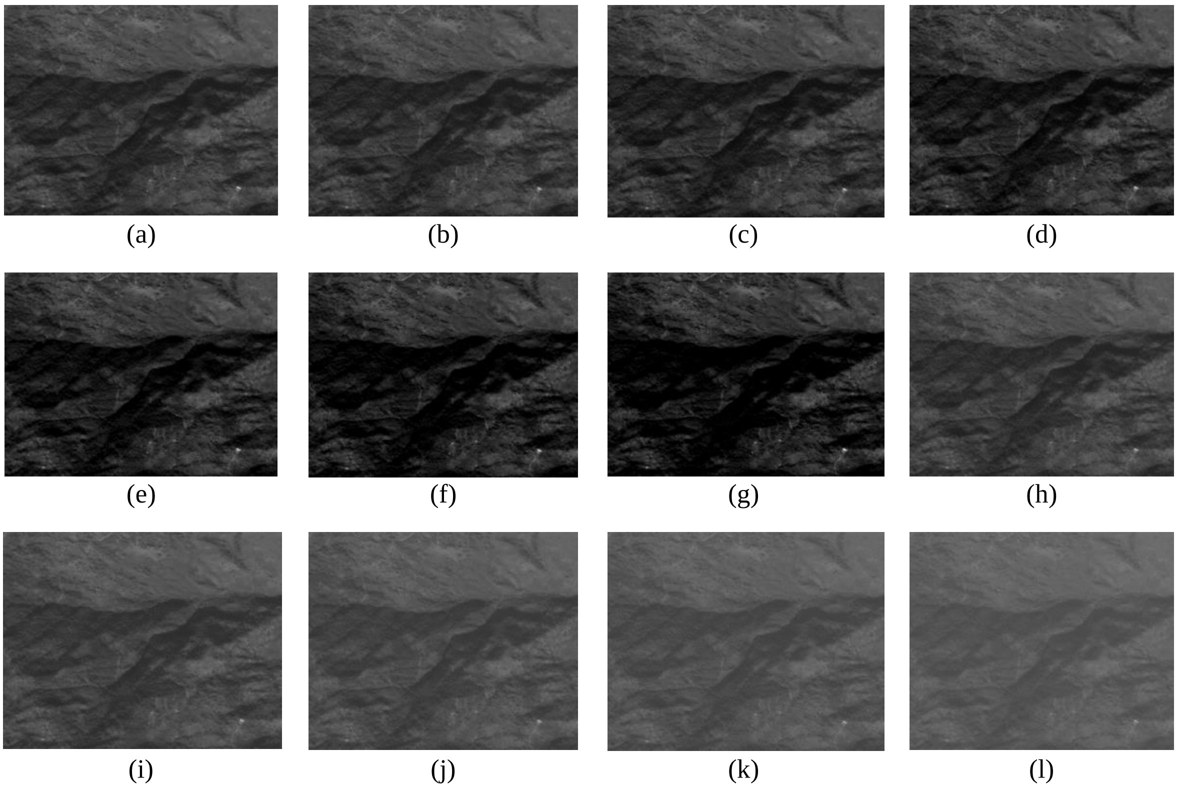


Figure 8. Changing in the contrast (a) test image, (b) 0, (c) 10, (d) 20, (e) 30, (f) 40, (g) 50, (h) -10, (i) -20, (j) -30, (k) -40, and (l) -50

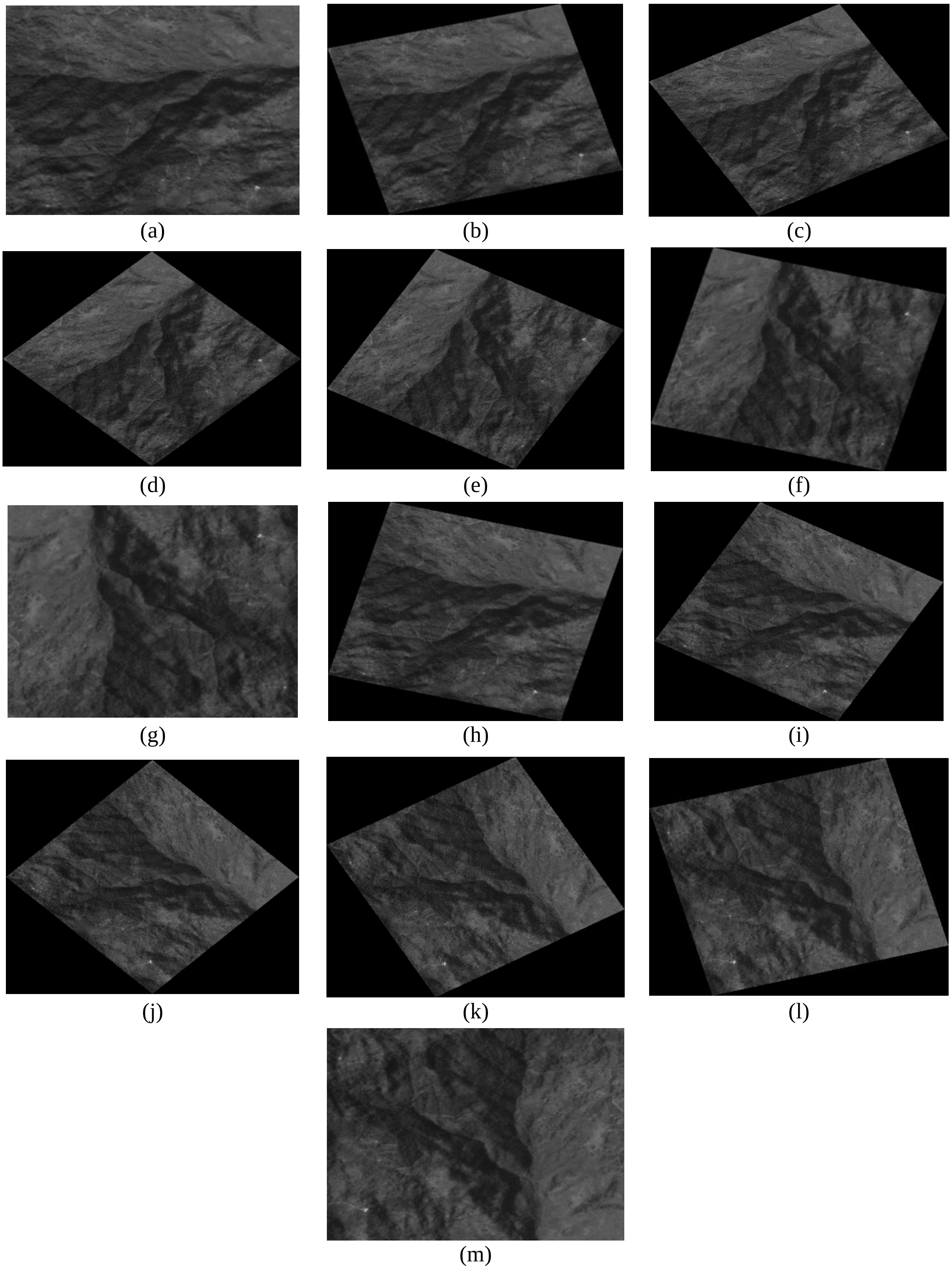
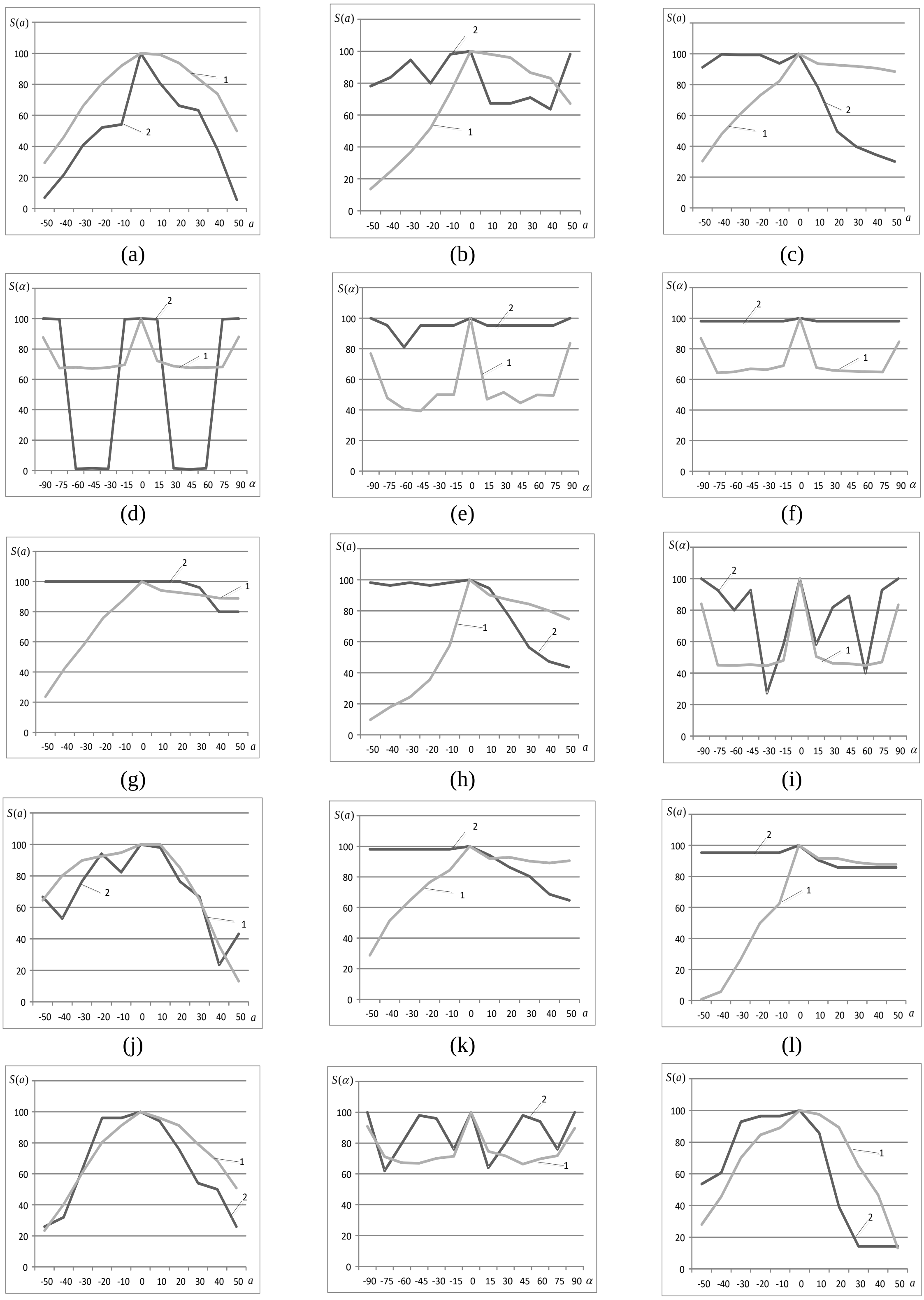


Figure 9. Changing in the rotation, (a) test image, (b) 15, (c) 30, (d) 45, (e) 60, (f) 75, (g) 90, (h) -15, (i) -30, (j) -45, (k) -60, (l) -75, and (m) -90

As shown in Figures 10(a) to (o), the developed algorithm wins up to 44% over the Harris method when changing the brightness from -50 to 50 for the 5 class of the test images Figure 10(a) and the proposed algorithm is slower than Harris method when the brightness changes from -50 to -10 for the 3rd class of images up to 60% Figure 10(b). With a decrease in contrast in the image, the proposed algorithm is slower than Harris method by up to 90%, and with an increase–it wins up to 60% Figure 10(c). When rotating the image, the developed algorithm is more stable for the 5th class of images Figure 10(d) and less stable for 2 and 4 classes of images Figures 10(e), (f).



(a) (b) (c) (d) (e) (f) (g) (h) (i) (j) (k) (l) (m) (n) (o)

Figure 10. Graph for evaluating the stability of corner detection algorithm for different classes and changing parameters of the image (a) class 1, change in the brightness, (b) class 1, change in the contrast, (c) class 1, rotation, (d) class 2, change in the brightness, (e) class 2, change in the contrast, (f) class 2, rotation, (g) class 3, change in the brightness, (h) class 3, change in the contrast, (i) class 3, rotation, (j) class 4, change in the brightness, (k) class 4, change in the contrast, (l) class 4, rotation, (m) class 5, change in the brightness, (n) class 5, change in the contrast, and (o) class 5, rotation

The average running time for each of the test images is shown in Table 1. From the Table 1. It is seen that the average running time of the presented method is 2.5–13.3 times less than the average running time of the Harris method.

Table 1. Average running time of the test algorithms (s)

Algorithms	Image 1	Image 2	Image 3	Image 4	Image 5
Proposed algorithm	1.3	1.2	1.3	0.5	0.6
Harris method	3.3	16	9.8	2.4	2.4

4. CONCLUSION

An algorithm for corner detection in aerospace image based on an expanding mask has been developed. It is shown that the proposed algorithm is up to 60% more stable than the Harris method with increasing contrast. The proposed algorithm is more stable than the Harris method when rotating images of the 5 class, but inferior to Harris method for all other classes of images when rotating at different angles. The disadvantages of the proposed algorithm also include the loss of stability with a decrease in contrast. The above disadvantages of the proposed algorithm are compensated for by the high performance relative to the Harris method. It is shown that the proposed algorithm faster Harris's method by 13.3 times in time.

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