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The Introduction of Redundancy for Recognizing Freely Oriented Images based on Parallel Shift Technology

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Abstract

The method of description and recognition of images based on the technology of parallel shift is described. To recognize images, one characteristic feature is used - the area of the image. The main characteristics of the complex image area are described. The method allows specialists to determine the orientation of the image, as well as recognize symmetrical images that have the same functions of area of intersection. To solve the problem, additional elements are introduced on one of the edges of the image, and additional quantitative characteristics of the area are introduced. According to the obtained quantitative characteristics of the function of the area of intersection of the image areas, about the form of the image are decided.

Keywords: image recognition, function of area of intersection, parallel shift technology, image shift

1. Introduction

One of the main tasks of artificial intelligence is the processing and recognition of images in real time. There are many methods of image processing and recognition [1], [2], [3], [4]. Most of them are designed for processing raster images [4, 5]. In modern methods of recognition, the process of recognition and image processing consists of two stages. [6, 7]. The first stage is the formation of characteristic features of the image. From the selected characteristic features of the image, a vector is formed, which in a compressed form describes the image. At the second stage, a standard vector is searched for, which is stored in the memory of the standards of the recognition system. If a template vector is found, the template identifier (image recognition process) determines the input image. If there is no standard image vector for the input image in the recognition system, the generated vector of characteristic features is stored in the memory of characteristic features standard and a new identifier is assigned to it. This process is called the learning process of the recognition system.

All existing methods are based on the selection of the characteristic features of the image by preprocessing it. Images are divided into classes. For each class of images, the developer of the recognition system creates a set of characteristics. The selection of characteristic features is based on special methods that are implemented in software and hardware.

The developer individually determines the set of characteristic features by analyzing the image for each class. A set of characteristic features must be formed so that it can describe the image as a whole. Each characteristic feature is extracted using special methods that should have the best performance. For example, the length of the perimeter of an image displays a portion of information about the form image. This value complements the information about the geometric and topological properties of the image of the figure.

Also, characteristic features are used, which are determined by transforming the analyzed image (Bilan & Yuzhakov, 2018; Bilan, Models, & hardware, 2014; Frank, 2010; Gonzalez & Woods, 2008Minichino & Howse, 2015). These features are not obtained by direct measurements. They are calculated using various mathematical or other models. Such characteristic features are latent characteristic features, which are determined on the basis of studying the properties of the image.

The most widely used are such transformations as Fourier, Hadamard, Hafa, Haar, Hartley transformations (Frank, 2010; Gonzalez & Woods, 2008; Minichino & Howse, 2015) and Radon transformation (Belan & Motornyuk, 2013; Bilan, Models, & hardware, 2014). All these algorithms are very popular; they have shown high accuracy in image processing and recognition systems and are widely used at present. However, despite the difference in the types of functions, it turned out that most of the fast transforming algorithms have a similar structure and differ by no more than the values of the coefficients of the basic operations, and therefore have the same drawbacks in the form of resource-intensive calculations. Therefore, based on the subject of this work and the orientation toward the possibility of hardware implementation, the main criterion for choosing a method for characteristic features extraction is the possibility and simplicity of its implementation.

The formation of quantitative characteristics requires complex measurements or calculations. This situation complicates the methods of preprocessing images and extracting characteristic features. The high-speed methods are hardware-implemented methods. At the same time, program methods are widely used.

One of the ways to improve the performance of image recognition is to reduce the number of characteristic features of the image. This approach reduces the number of preprocessing operations and simplifies the method and the hardware and software tools that implement it. The task is to search for image transformations that enable developer to describe all the properties of an image using the selected characteristic features.

Thus, by analyzing the images, the required minimum set of characteristic features is formed and the methods of the tools for their extraction are determined. One of these characteristic features of the image is the area. The area is determined by simple methods. The image properties can be described by parallel shifting of the image copy and determining the intersection area of the original image with its shifted copy [7], [10], [11]. The area of intersection at each time step of the shift of the image and its copies are calculated and form a set of homogeneous features that describe the shape of the image.

2. Properties of the Area of Images in a Computer System

The area of the image of the figure is considered as a two-dimensional quantitative characteristic. To determine the area, a unit of measurement is used, which is determined by an elementary discrete element of the medium that displays the image of the figure. In modern means of image processing, they can have different shapes (triangle, quadrilateral, and hexagon). However, most often a rectangular form of an elementary discrete image element is used.

The main properties of the area of flat geometric shapes are as follows:

- Positivity. Area is always a nonnegative number.
- Additivity. The area of a complex figure can be represented by the sum of individual figures that make up a complex figure and do not intersect.
- Congruence. The areas of congruent figures are the same.
- Normalization. The area of a square constructed on a unit interval is equal to unity.
- Boundary. The area is characterized only by images bounded by an unbreakable perimeter.

The last property indicates that the area and perimeter of the image are inseparable. In this case, for equal perimeters, there are many images with different areas. To recognize images of plane figures, the main characteristic features, such as the area, length of the perimeter, the angles between the sides and other features are determined. For images represented by a computer, the perimeter (edge) of the images is described by a sequence of straight segments. Adjacent segments form angles. Digital images are polygons, which can be described by the sequence of sides and angles between them, as well as the size of the area. In paper (Belan, Kondratenko, & Al-Zoubi, 2002), studies in this direction were described. In these studies, it was shown that images that have an equal number of vertices, equal sides, but different angles, can have the same area. Examples of such images on Figure 1 are shown. The symbol "H" shows the height of each figure. Each image is divided into elementary forms, the areas of which are calculated and summed to obtain the total area. Graphs of the dependence of the quantity on the height of the polygon were obtained (Figure 2).

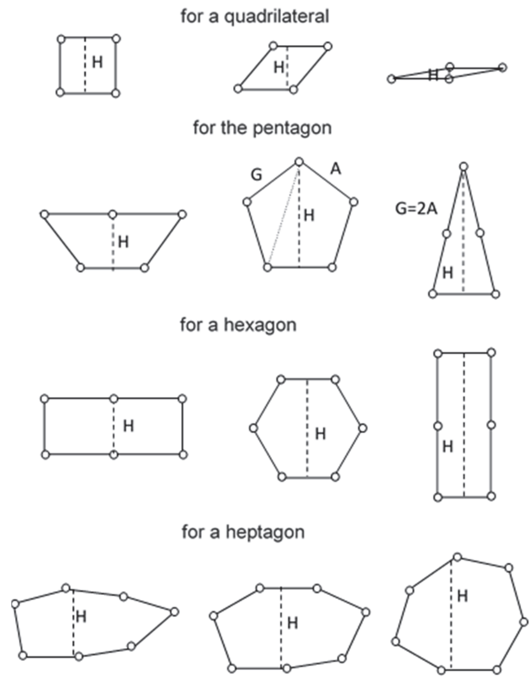

Figure 1. Examples of images that can have equal areas but have only different angles at the vertices

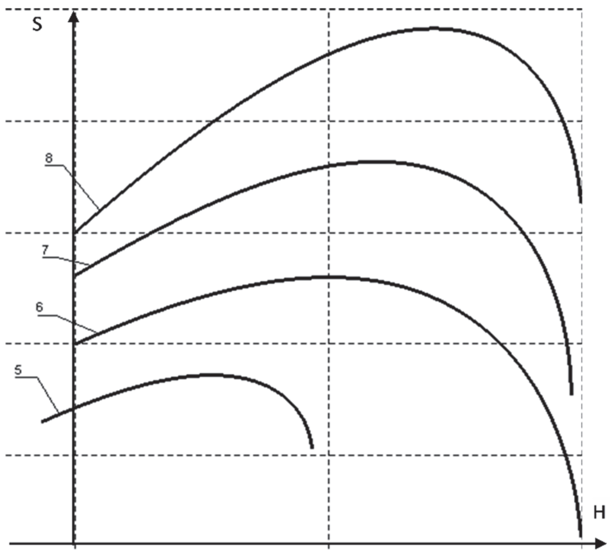

Figure 2. The graph of the change in the area with an equal number of vertices, perimeter values and equal sides.

The shape of the curves shows that the areas can coincide for equal perimeters and polygons, but for different angles at the vertices. This property of images of polygon shapes requires the use of additional characteristic features. Another property of the area appears in the case of using a discrete medium where all the discrete unit elements are equal. This discrete medium is the carrier of the image. In such a medium, the area is always an integer, since the number of discrete elements of the medium represents the area. This property allows you to work with images that consist of different separate graphic elements, in which the contours do not intersect and the elements do not have common points. Such images are complex. The use of well-known mathematical formulas does not give high efficiency, since each element of the image has its own shape and contour.

However, the computation of the complex image area does not carry information about the structure of the image itself. Therefore, a search is being made for new methods for describing complex images using a quantitative area parameter. It was suggested to describe a complex image by the size of the intersection area of the original image with its copy (Frank, 2010; Belan & Yuzhakov, 2013). For this, the parallel shift technology of a copy of the image relative to the original image in different directions was used. Using the parallel shift technology, the images of any complexity can be described. However, there are symmetrical images that are described by parallel shift technology equally. Examples of such images in Figure 3 are shown. In this paper, a method for describing and recognizing symmetrical images based on parallel-shift technology is described.

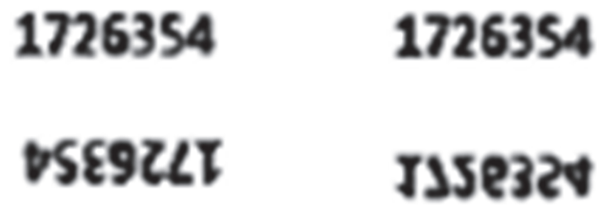

Figure 3. Examples of simple images that are described in the same way using parallel shift technology

3. Image Description Method Based on Parallel Shift Technology

The parallel shift technology (PST) is described in detail in the main characteristic of a PST is the area of the image that onto a discrete homogeneous medium is projected or on a display device of a computer system is formed. Each image is described by a set of uniform quantitative characteristics. Each N-th quantitative characteristic is determined by the area of intersection of the initial image with the image of its copy, shifted to N discrete elements in one of the directions. An example of the formation of a set of quantitative characteristics using PST in Figure 4 is presented.

The set of obtained quantitative characteristics is called the function of area of intersection (FAI). FAI can be conveniently analyzed using a graphical representation. In this case, the curvature of the FAI line is analyzed. The curvature analysis of the FAI allows the user to determine the scale changes in the image.

The main FAI indicators for image recognition are the initial image area S_0, the number of steps of shifting in different directions φ (αi) and the curvature of the line. Directions are selected along straight lines located at different angles α_i. Most often are used corners 0^0, 45^0, 90^0, 135^0 and 180^0 for orthogonal coating. If other coatings are used, the angles change in accordance with the arrangement of the sides of the shape of one discrete direction. For example, six shift directions can be used for hexagonal coverage.

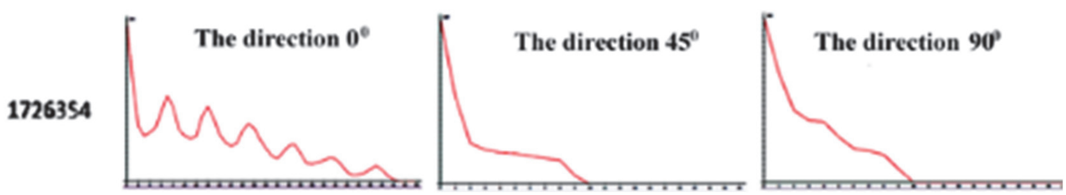

Figure 4. An example of the description of a numeric character images based on parallel shift technology

A shift of a copy of an image in one of the directions occurs before the intersection area becomes 0. FAI describes the form of the image of the object. Therefore, they in image recognition are effectively used. The FAI (α) calculation is carried out as follows.

1. Creating a copy: A copy (an additional array) is created for the array of the input image, which coincides with the initial array.
2. Shift of an additional array: an additional array in one of the directions is shifted, which is determined by the value of the α angle.
3. Creating an array of elements: At each shift step, an FAI(t_i) array of elements is created, which belong to the intersection area. The number of array elements gives the area value at each step of the shift.

In the case of complex images, situations are possible when the curvature of the line coincides with the curvature for other figures at certain steps of the shift. In this case, it is necessary to analyze the entire curve as a whole.

PST is very effective for various types of images. This is especially effective for images that do not have a completely filled form, and consists of different sections belonging to the image. These images include patterns. Each pattern has its own FAI, which differs from the FAI images of other patterns. FAI for many images of patterns are presented in the work (Bilan & Yuzhakov, 2018).

4. The Method of Description of a Free Oriented Images Based on Parallel Shear Technology

In the case of image recognition using PST, the system can not determine a symmetrical images and images that are rotated at a certain angle. Therefore, there is a possibility of false recognition of each image. PST allows to correctly recognize the shape of the image. However, there may be an error that is caused in the opposite orientation image. The method gives the same results in two opposite directions (for example, 00 and 1800).

Let's consider an example of recognition of a simple image using PST for different orientation angles (Figure 5). A binarization threshold of 50% was used. The analysis of this example shows that there are situations when the FAIs of the original and rotated images are equal. For the example presented, such images are the first and last images. This has the property of shifting the image and its area for images that are rotated at opposite angles.

There are many pairs of images that have the same FAIs (Figure 6). Figure 6 shows that the first two images on the left and the last images on the right have equal FAIs. To determine their orientation by one FAIs is impossible. Therefore, it is necessary to introduce additional quantitative characteristic values, which will make it possible to determine their orientation and symmetry.

To solve this problem, it was suggested to add additional elements to the analyzed images, which in a small amount distinguish it from the original image.

After this, the FAI of the original image and FAIadd of the image with the additional elements are determined.

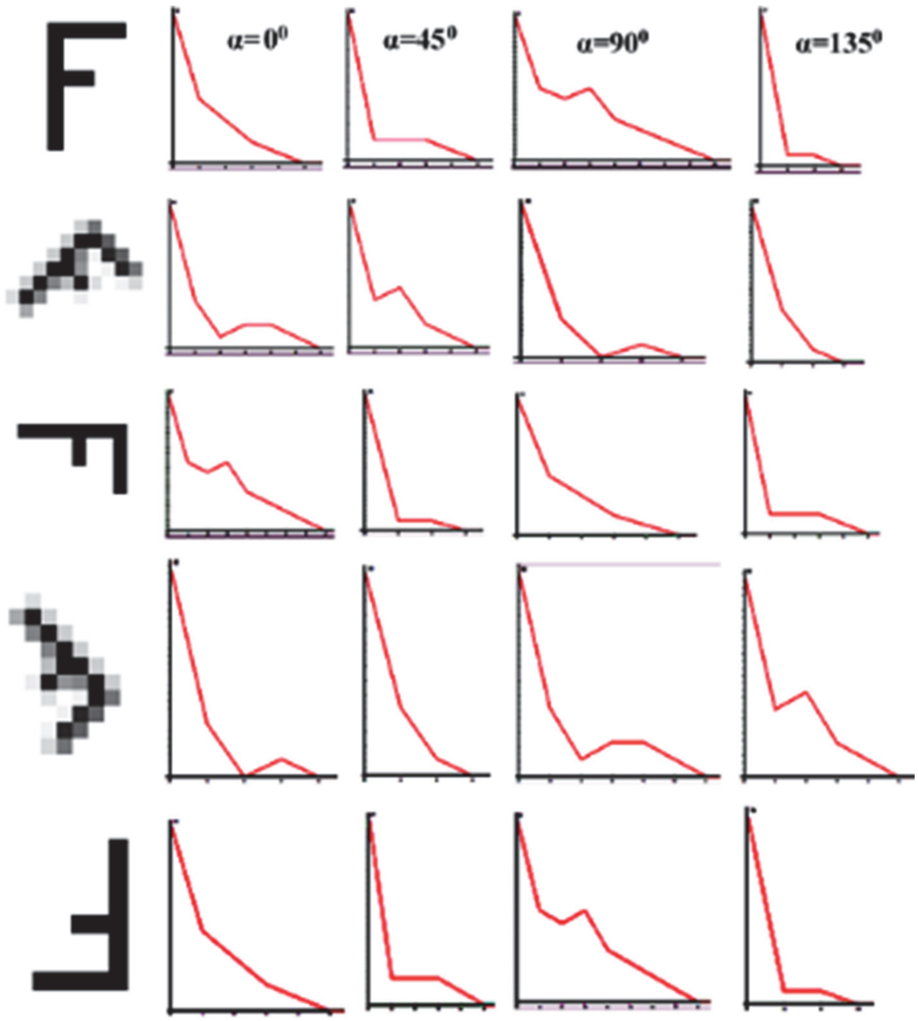

Figure 5. Example of FAI formation for the same image with orientation angles of 0^0, 45^0, 90^0, 135^0 and 180^0 with orthogonal coverage.

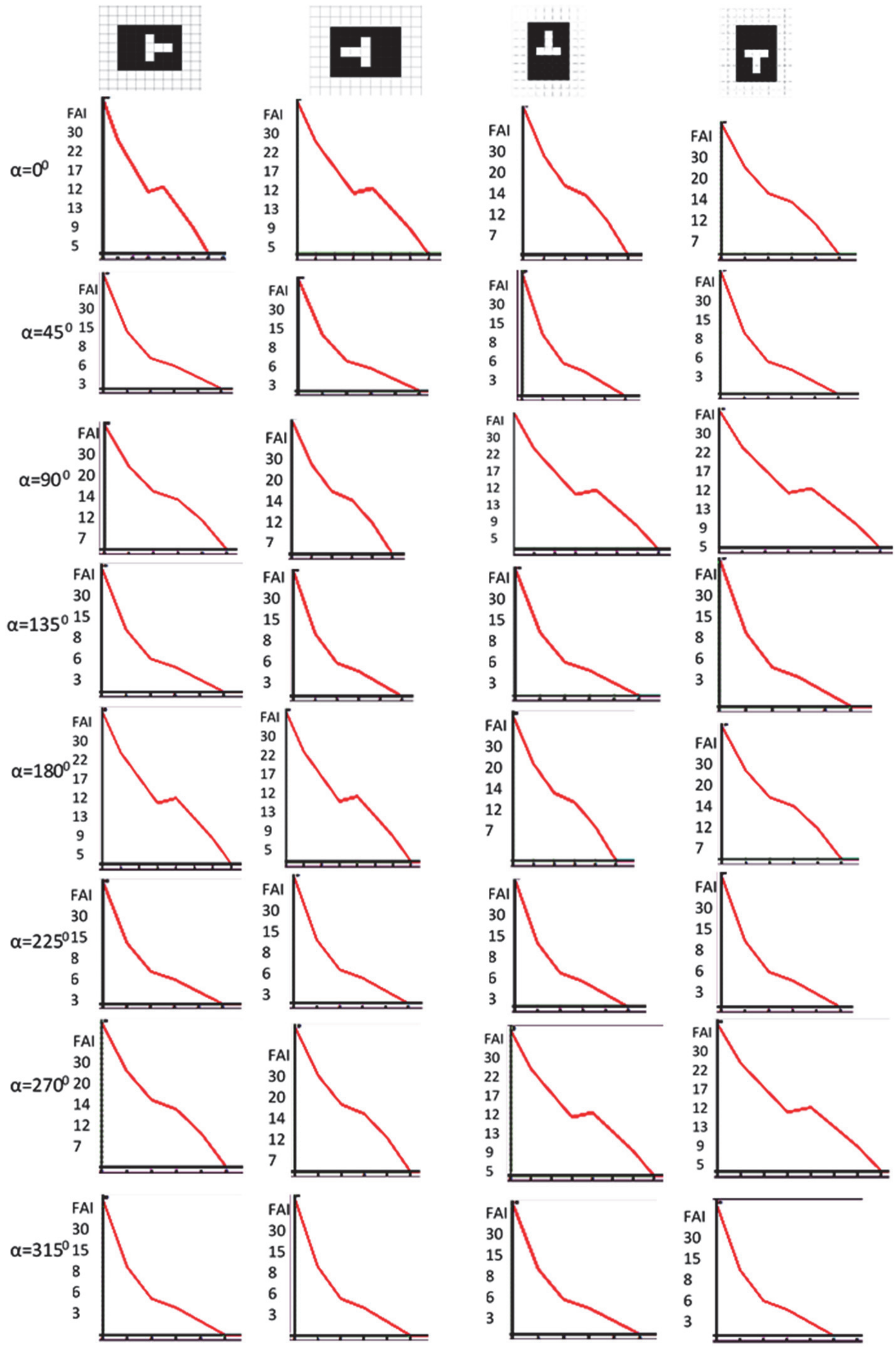

Figure 6. Examples of pairs of images that have the same FAIs.

The shape and quantitative values of FAI_{add} determine the location of the initial figure. Also FAI_{add} is different for symmetrical figures. It's enough to add one single element to get the differences. However, the presence of noise can lead to false recognition of the image. Therefore, it was decided to introduce more additional image elements. The most optimal option is to add a clearly fixed part of the image, which can be selected in any image as a fixed unit (for example, cells of the right (left) column of the image, or the top (bottom) line). An example of obtained FAI_{add} for symmetrical figures in Figure 7 is shown. For this example, to the right edge of the image, elements have been added to the right that form the rightmost column of the image.

Thus, the added additional elements in the image make it different from the original image. However, there are questions with the orientation of the figure. The exact answer to this question can be obtained if you make changes only in one direction (for example, on the right, add elements of the extreme column of the image). All images with embedded additional elements as one right column increase the number of shifts by one in directions 0^0 and 90^0.

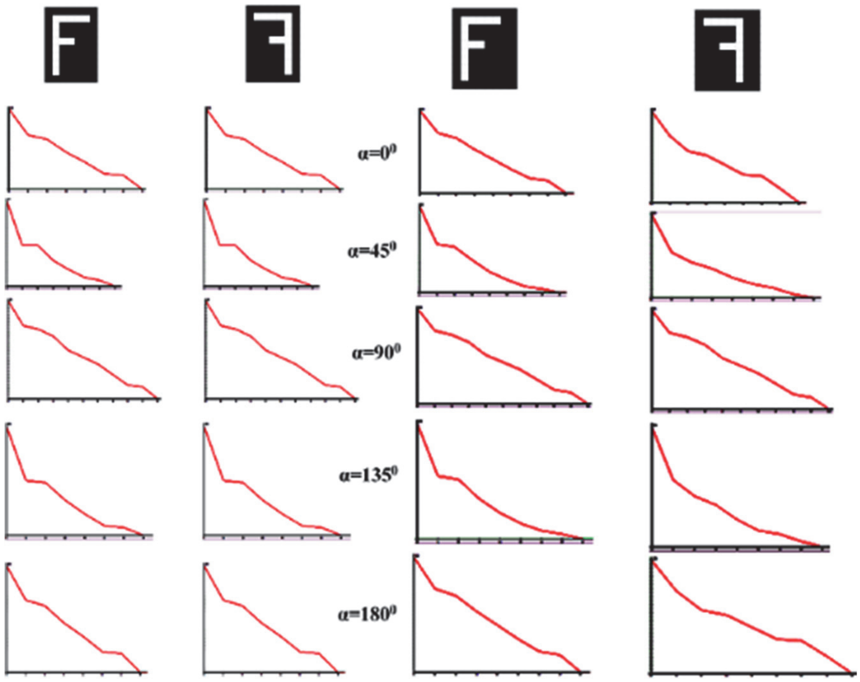

Figure 7. Examples of symmetric image recognition using the FAI_{add}.

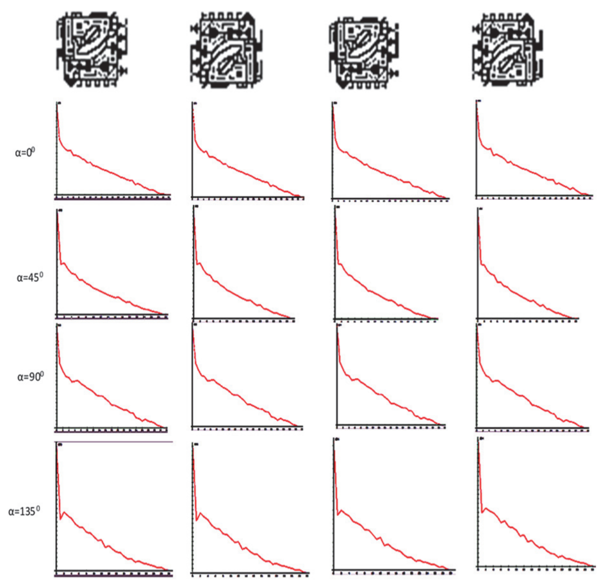

Figure 8. An example of determining differences in complex symmetrical images for directions 0^0, 45^0, 90^0 and 135^0

Thus, the original image is first recognized, and then the modified image is recognized. The modified image can be recognized in parallel with the initial image. On the differences obtained, the orientation and symmetry of the image is determined.

In the example shown in Figure 7 changes are made by adding the rightmost edge elements of the image to the right. For this example, the number of elements in one column of the image increases the initial area. The shape of the FAI curve, which recognize the orientation of the image is changes. An example of determining differences for symmetric images in Figure 8 is shown.

Such directions were chosen in connection with the fact that on these directions there are repetitions of the values for each figure on the remaining considered directions of the shift. FAI(0^0) for each figure are summarized in Table 1. According to the quantitative values, the differences of the modified images from the original images are seen. Differences are also inherent in the other shift directions, copies of the image, which in Table 1 are not shown.

The first difference is that in the modified image the number of shifts is greater by one. Also, at certain shift steps, there are differences that indicate the orientation of the image. In this case, the quantitative characteristics differ for each FAI at each step of the shift. Simplify the recognition algorithm by introducing an equal number of unit cells for all images, which allows to create fixed values for additional values.

Thus, for all the images used, it is enough to enter additional elements in one of the edges of the image or delete the elements on one of the edges of the image and the image will have different content, which makes it possible to accurately recognize it. This method requires the use of additional memory, which is used to store additional arrays of numbers.

Table 1. quantitative values fai (0^0) for every image represented on figure 8

Shift step	**FAI(0^0)** *1st figure*	*2nd figure*	*3rd figure*	*4th figure*
0	675	675	694	694
1	415	415	434	434
2	371	371	376	376
3	347	347	354	357
4	330	330	341	345
5	334	334	343	353
6	296	296	315	298
7	296	296	303	311
8	289	289	300	298
9	272	272	285	288
10	263	263	271	272
11	241	241	250	245
12	244	244	254	256
13	220	220	231	232
14	216	216	222	227
15	208	208	215	215
16	196	196	206	204
17	188	188	193	198
18	182	182	190	193
19	169	169	175	179
20	164	164	170	172
21	155	155	164	166
22	144	144	154	154
23	132	132	141	140
24	128	128	137	138
25	115	115	121	122
26	112	112	123	119
27	110	110	121	122
28	80	80	92	88
29	85	85	90	96
30	77	77	86	84
31	60	60	74	72
32	52	52	56	64
33	42	42	55	49
34	42	42	42	61
35	33	33	52	43
36	18	18	34	30
37	10	10	20	16
38	12	12	17	17
39	0	0	12	12
40	0	0	0	0

5. Conclusion

The problem of image recognition based on the parallel shift technology is solved. The proposed method allows determining the orientation of the image and recognizing images that have different shapes, but are described by equal FAIs. This method is based on a preliminary minor modification of one of the edges of the image (adding or removing elements). To increase the accuracy of recognition and description of images with the same FAIs, additional quantitative characteristics are introduced in the form of an additional function of intersection of areas. Adding image elements additional increases the number of image shifts in the directions of additional elements and in the opposite direction. This increases the number of images that can be recognized using the of parallel shift technology.

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