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Computing features of elementary projective orthogonal transformations of an image

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Abstract: There is considered the problem of normalization of images which arises at processing and analysis of pictures of visual perception of images of the real world. There are investigated features of elementary projective orthogonal transformations of an image for the purpose of possibility of their use in normalization problems. Specificity of computing aspects of application of the elementary projective orthogonal transformations for normalization of images is shown. The conclusion is drawn on necessity of correct use of projective orthogonal transformations for procedures of normalization of images.

Keywords: normalization; image; geometric effect; projective geometry; projective orthogonal transformations.

I. INTRODUCTION

Computer image processing is one of directions of scientific researches in various fields of knowledge from the subsequent realization of the obtained knowledge in practice. It speaks a considerable quantity of applied problems where images or their analysis are used. For today processing and analysis of images are widely used in a robotics, the analysis of space pictures, medicine, remote sensing, technological processes on manufacture and many other fields of life activity of human [1-5].

The finding of the adequate solution for an assigned task is defined in many respects by a choice of corresponding mathematical model. Such model should display most precisely changing processes of perception in the assigned task. Usually, the questions on anatomic structures and the physiological mechanisms realizing corresponding functions of sight aren't considered at modeling of processes of visual perception. As a rule, the basic direction of the prospective research is a construction of some model and in the subsequent studying of its properties on various test images, based on the assigned task.

In spite of possible variety of various problems with use of methods of image processing, it is possible to define a class of subtasks where objects on images can be presented in the form of set of various geometrical figures [6, 7]. In particular convex polygons can be such figures. Then the complex of the different questions, connected with image processing, is turned into consideration of separate problems of transformation and recognition of corresponding figures. At the same time the important question is the account of features of transformation of considered images of figures taking into account their possible geometric effect. As a rule, such effect can arise at a stage of registration of an investigated image in the form of image. It, finally, defines a choice of a direction of research of the given work.

II. Indemnification of Geometric Effect of an Image as a Problem of its Normalization

In the process of perception of images of the object, as a rule, such images differ from each other by presence of geometric effect. Therefore the adequate tool of the description and the analysis of real processes of perception of images of objects are the mathematical model using principles of projective geometry [8].

At the same time normalization procedure can be one of approaches to processing of such representations of perception of images.

The procedure of normalization of the image consists in calculation of unknown parameters of transformations which input images are subjected to, and their subsequent reduction to in advance certain standard.

In the formalized view it can be presented as follows.

Let some group of transformations G and quantity of the images $W(B_0)=\{B_1, B_2, \ldots B_s,\}$ received from the reference picture B_0 by transformations $g \in G$ is specified.

Since all images (B_i , $i=\overline{1,s}$) were received as a result of application of some transformation g, then according to the group theory [9], there is an existence of $g \in G$ where $gB_1 = B_2$. Then images B_1, B_2 are equivalent concerning group of transformations G and concern to one class of equivalence which is presented by the reference picture B_0.

Then such method of normalization consists in definition of parameters of concrete transformation which brings the input picture to the standard:

$$B_0(x,y) = g_i[B_i(x,y)],\ g_i \in G, i=\overline{1,s}.$$

Application of procedure of normalization allows improving perception of the object by the person-operator and system of technical sight.

However, in spite of simplicity of understanding of process of normalization of images, realization of such process is far from a simple problem. Thus the important aspect is a choice of group of transformation where the image is exposed in the course of its perception.

III. Orthogonal Projective Transformations of the Image

The projective group of transformations of the image is the most general mathematical model which is used at processing and normalization of images. The group of projective transformations of the image, in particular, includes the group of affine transformations and the group of transformations of prospect. Thus complexity of projective transformation causes interest to studying of some characteristic subgroups, in particular, and groups of orthogonal projective transformations.

Let's assume, that we have two images: reference $B_0(x,y)$ and input $B(x,y)$, obtained from reference by means of influence on it by the transformation which is included in the projective group. Then, the mathematical model of such transformation can be presented as follows [9]:

$$B_0(x,y) = B\left(\frac{b_{11}x + b_{12}y + b_{13}}{b_{31}x + b_{32}y + b_{33}}, \frac{b_{21}x + b_{22}y + b_{23}}{b_{31}x + b_{32}y + b_{33}}\right), \quad (1)$$

where, transformation matrix $\Pi = \begin{pmatrix} b_{11} & b_{12} & b_{13} \\ b_{21} & b_{22} & b_{23} \\ b_{31} & b_{32} & b_{33} \end{pmatrix}$ and $\det(\Pi) \neq 0$.

If the transformation matrix Π meet the condition $\Pi\Pi^T = E$, E – the individual matrix of the third order, then the mathematical model of representation of group of orthogonal projective transformations is formulated. Such model will be used in future.

Let's consider in particular cases of projective orthogonal transformation when three of its nine parameters are distinct from zero. As a result we will derive following transformations for consideration:

$$X = \pm x/y, \ \pm Y = 1/y, \quad (2)$$

$$X = \pm y/x, \ \pm Y = 1/x, \quad (3)$$

$$X = \pm 1/x, \ \pm Y = y/x, \quad (4)$$

$$X = \pm 1/y, \ \pm Y = x/y. \quad (5)$$

The given transformations are nonparametric.

Nevertheless, consideration of features of the given transformations with reference to a geometrical figure representing a convex polygon is interesting. First of all, such interest is caused by that:

1. Real objects of the image can be described by such polygons;
2. Consideration of possible features of the chosen transformations for the purpose of finding of opportunity of their use for image normalization.

IV. Results of Experiments and Their Discussion

For the purpose of carrying out of corresponding experiments we will consider, how a certain geometrical figure ABCDE will be changed under the influence of such transformations in each quarter of a plane of the transformed field of vision.

First of all, we will consider figure ABCDE which apex ordinates don't accept value on the interval $-1 \le y \le 1$.

As transformations are similar among themselves, we will consider a transformation which is presented by expressions (2) in a case, when $X = x/y$, $Y = 1/y$. The obtained results will be similar and for other transformations, except for a sign and properties in different quarters of a plane.

Let the image figure is located in such a manner that the centre of coordinates is in figure ABCDE (fig. 1).

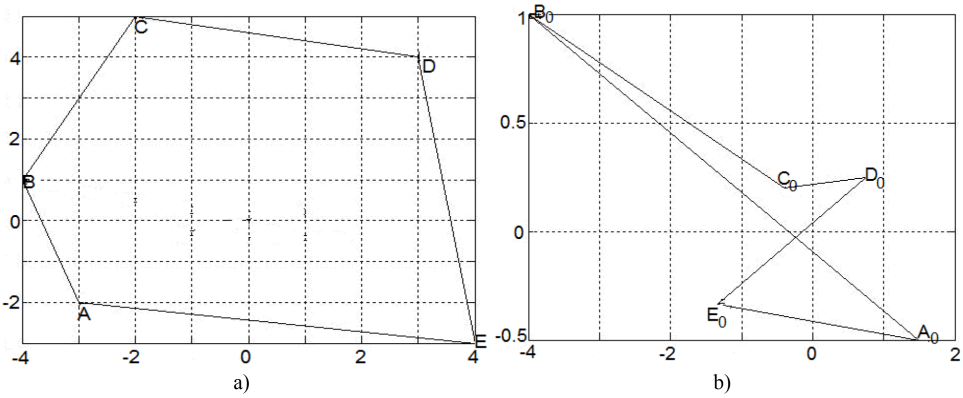
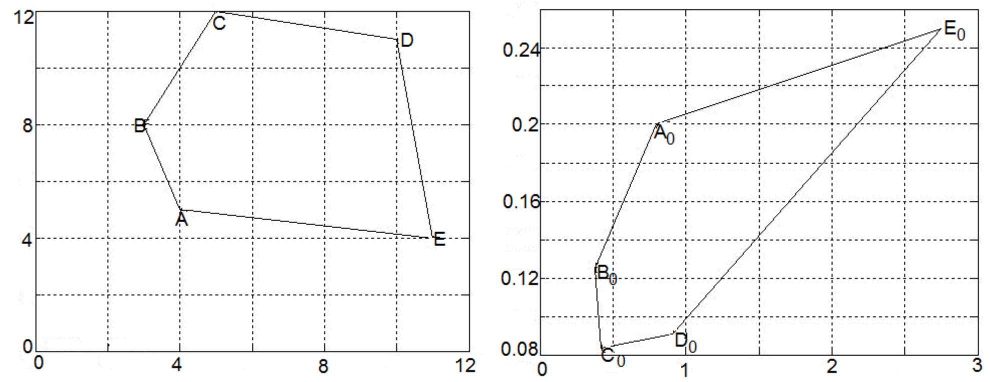


Fig. 1. Initial (a) and deformed (b) image of figure ABCDE which is located in the centre of the beginning of coordinates by transformation $X = x/y$, $Y = 1/y$.

Apparently from fig. 1, in this case convex figure ABCDE is displayed in figure $A_0B_0C_0D_0E_0$ (further on figures it is the deformed figure) with the crossed edges which points were in different quarters. Such transformation deforms the initial image beyond recognition.

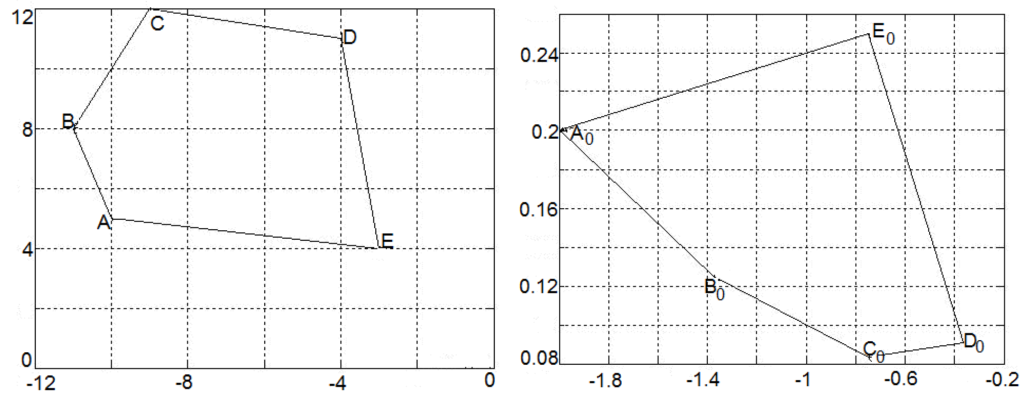
Let figure ABCDE is in I quarter (fig. 2).



a) b)

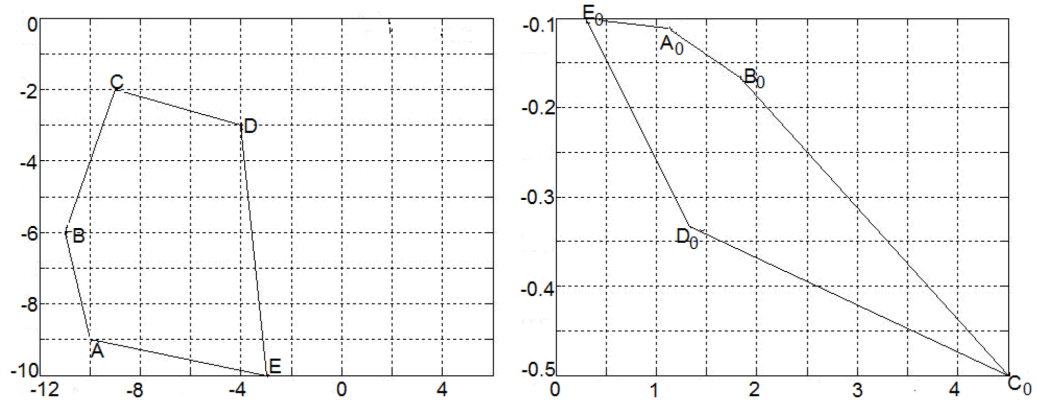
Fig. 2. Initial (a) and deformed (b) image of figure ABCDE which is located in I quarter by transformation $X = x/y$, $Y = 1/y$.

At display the figure has passed in a figure with inverse detour of a contour and settled down on the interval $0 < y \le 1$. Thus the square of the deformed figure is close to zero. Therefore it is necessary to consider, that the figure can be displayed in a point at discrete display. Let's consider figure ABCDE in II, III and IV quarters (fig. 3, fig. 4, fig. 5 accordingly).



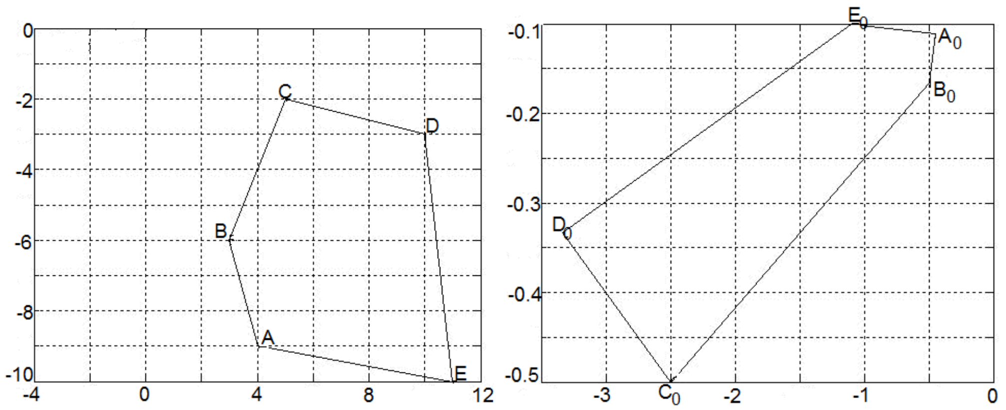
a) b)

Fig. 3. Initial (a) and deformed (b) image of figure ABCDE which is located in II quarter by transformation $X = x/y$, $Y = 1/y$.



a) b)

Fig. 4. Initial (a) and deformed (b) image of figure ABCDE which is located in III quarter by transformation $X = x/y$, $Y = 1/y$.



a) b)

Fig. 5. Initial (a) and deformed (b) image of figure ABCDE which is located in IV quarter by transformation $X = x/y$, $Y = 1/y$.

As we can see from fig. 3, fig. 4 and fig. 5, at display the figures are in the same quarters and aspire to the beginning of coordinates and the more value y, the less image of the figure, in which connection the figure contour has changed the direction in I and III quarters to an opposite direction. Thus it is necessary to consider, that the figure can be displayed in a point at discrete display.

Now let values of ordinate of figure ABCDE are on the interval: $-1 \le y \le 1$. In this case the figure change will be quite the contrary. So on fig. 6 the figure, laying in I quarter, aspires in infinity.

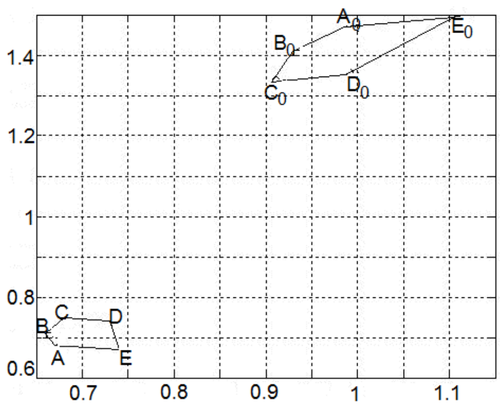
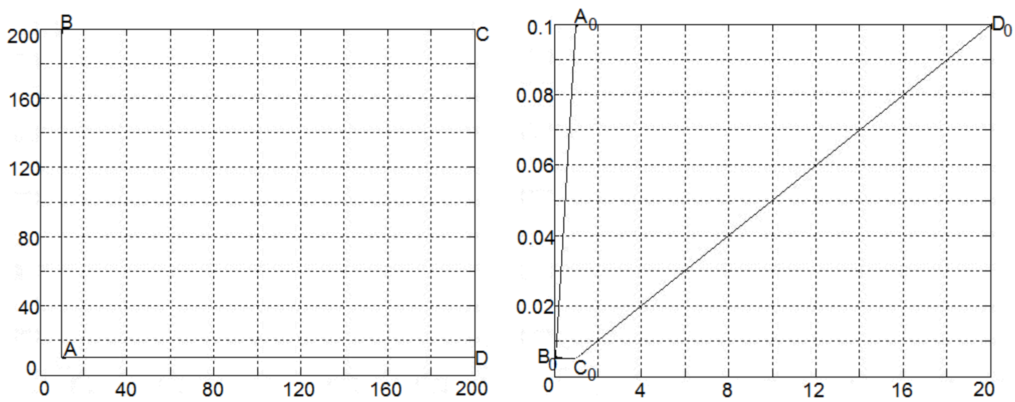


Fig. 6. The initial and deformed image of figure ABCDE which is located in I quarter on the interval, $-1 \le y \le 1$ by transformation $X = x/y$, $Y = 1/y$.

Let's consider who square ABCD with coordinates A(10,10), B(10, 200), C(200, 200), D(200,10) (see fig. 7) will be displayed.



a) b)

Fig. 7. Initial (a) and deformed (b) image of figure ABCD by transformation $X = x/y$, $Y = 1/y$.

As we can see from fig. 7, the square of the figure ABCD aspires to zero at display, and sides AB and CD aspire to crossing.

Now let's consider transformation $X = \frac{1}{x}$, $Y = \frac{y}{x}$.

After similar experiments, we will obtain the same character of behavior except that the figure passes from II quarter in IV, and from III in I. Therefore we will result only transformation of square ABCD with coordinates A(10,10), B(10, 200), C(200, 200), D(200,10) (fig. 8).

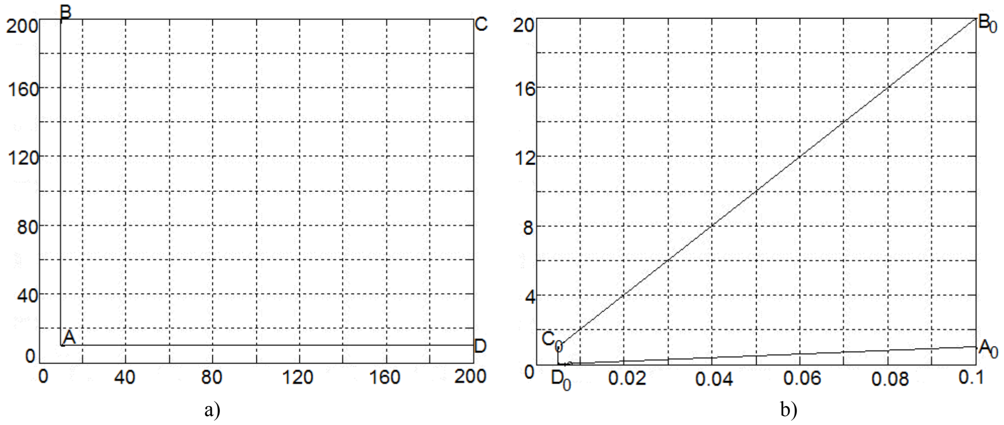


Fig. 8. Initial (a) and deformed (b) image of figure ABCD by transformation $X = \frac{1}{x}$, $Y = \frac{y}{x}$.

The obtained results allow to assert, that independent action of the transformations presented by expressions (2) – (5) leads to following characteristic changes of the initial image:

- Transformations don't exist in the centre of coordinates;
- If image coordinates aren't in the interval, $-1 \le x \le 1$, $-1 \le y \le 1$ then at display the image square aspires to zero, and, the more the image, the less its image.

Let's notice, that every transformation (2) – (5) has an inverse transformation. For example, for the transformation view (3) transformation view (5) is the inverse transformation. However distortions at transformation are so considerable, that the obtained image becomes unrecognizable.

Hence, since transformations (2) – (5) bring distortions which are inadmissible in a real life into the image, and corresponding transformations of parabolic and hyperbolic homologies, as special cases of group of projective transformations, are connected among themselves by compression transformation, it is expedient for consideration of properties of projective geometry (applicable for image normalization) to consider only one of last transformations.

V. Conclusion

Thus, the work considers computing features of the elementary projective orthogonal transformations of the image. Such features are shown on the example of the image of the figure of the polygon and its corresponding transformations. The choice of such figures is proved by that images of real objects can be presented in the form of set of separate polygons.

As a result of the carried out research the conclusion is drawn on necessity of correct use of projective orthogonal transformations of the image for procedures of image normalization.

The obtained results can be useful at a choice of arrangement of a demanded field of vision for the purpose of further use of procedures of normalization in processing of the visions which are presented by their image.

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