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THEORY OF EXTENDED OBJECT TRACKING

In this paper, the theory and problem statement of extended object tracing, classification of normalization's algorithms and main principles of normalizer construction are presented. We also introduce a short summary of experiments with constructed normalizers (compensation of image geometric transformations)

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Tracing (pursuit, centering, automatic centering, supervision) is a process of overlapping of some center on an extended object with the beginning of coordinate system, which is rigidly connected with grid sensor.

Extended objects are fixed with a grid sensor in the form of flat layouts which are characterized with a function of intensity distribution in time $\mathbf{B(x,y,t)}$. At such statement of a problem tracing can be described with normalization operator:

$$\mathbf{F(B)=B(x+\Phi_1(B),\ y+\Phi_2(B),\ t),} \tag{1}$$

where $\mathbf{B(x,y,t) = B_0(x-l,\ y-m,\ t),\ l,m}$ are real-valued parameters, describing the image (object) shift relative to the beginning of coordinates during time station $\mathbf{t}$. The physical meaning of normalizer (1) lies in the fact of compensation of image shift parameters. So, normalization is a procedure of compensation of transformations, which connect samples and input images.

Normalization can be technical and algorithmic. At technical normalization the compensation of various transformations occurs due to change of parameters of computer vision system: movement of the television camera, rotation, change of focal length. Such changes of system parameters occur until the object appears the middle of a viewing field, and if it is rectangular, then its lines won't become parallel to the raster lines. Another way of normalization is algorithmic normalization, when the parameters of computer vision system do not change, and it is the image in digital form that is being transformed. The image is transformed until it corresponds with a real object if technical normalization has been performed.

While solving the problems of supervision and tracing, we often use the normalization method of not of input image, but of a tracing frame normalization that can undergo changes. An input image is a number of points (pixels) $\mathbf{B(x,y)}$ during time station t, that form some kind of a stage (viewing field) and contain samples $\mathbf{B_0}$. Area boundary $\mathbf{D}$, containing pattern icon (master image) $\mathbf{B_0}$, we call tracing frame. Tracing frame normalization can be presented as a choice of much more convenient coordinate system (fig. 1). Tracing frame normalization are often practiced for a group of shifts, scaling and rotation.

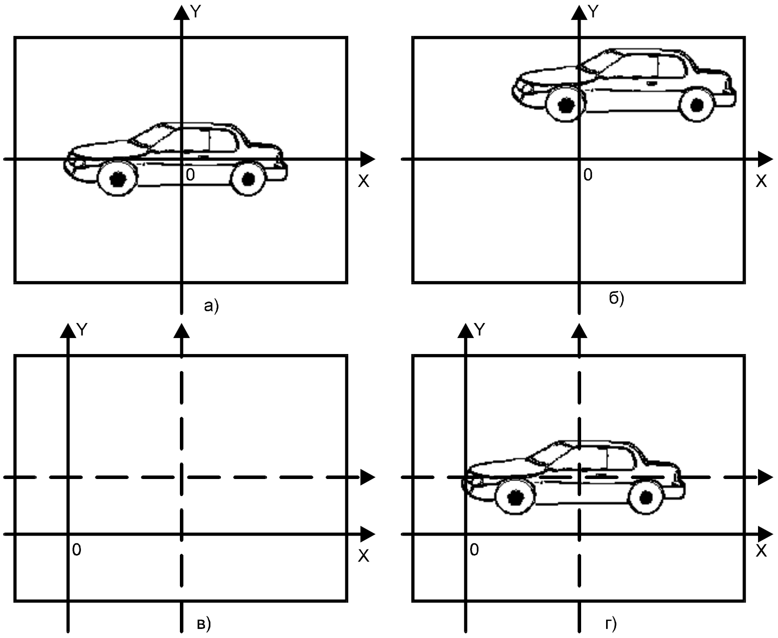

Fig. 1. - Normalization of a tracing frame
a – initial condition; b – image shift; c – normalization of the frame; d – image and frame after normalization; dashed line – new coordinate system

The construction of the tracing frame normalizer comes to a simpe normalizer rendering.

The operator of normalization can be divided into two categories based on the principle of realization: normalizers of parametric and tracing type. The normalization of multiparameter transformations can occur according to a parallel or sequential procedure.

Normalizer realization (1) can be carried out in two ways. The first way is to find the parameters $\mathbf{l}$ and $\mathbf{m}$ by calculation of the functionals $\mathbf{\Phi_1(B),\ \Phi_2(B),}$ and then to apply the transformation (1) according to the calculating values. Then the input image is centered, i.e. the inverse transformation is performed, which converts the image into sample. In case of normalizer application on the base of tracing frame, the process of centering is replaced by application of a frame on the input image, i.e. a template transformation is carried out. Such operators, where we first define the parameters of the unknown normalizing transformation, are called normalizers of parametric type.

Another way of normalizer realization (1) is to perform multiple transformations of shifting with some interval according to the parameters **l** and **m**. At the same time the functionals $\Phi_1(B)$, $\Phi_2(B)$ must be calculated after each interval. The transformations are performed till the functionals $\Phi_1(B)$, $\Phi_2(B)$ reach several representative values. At the same time the coordinates **l** and **m** are on the last interval as the result of addition of all increments Δ**l и** Δ**m**. In this case, as well as in the previous one, the input image or a pattern icon (master image) can be transformed. Such normalization transformations are called normalization operator of tracing type.

To successfully solve the assigned task we should construct normalizers complying with the following requirements: simple mathematical notation, applicability of superpositions, noise immunity, the possibility of technical realization, steady operation at quite wide distortion spectrum.

According to these requirements, we are looking for the normalization functionals in the category of general linear functionals:

$$\Phi_i = \iint\limits_D B(x,y)K_i(x,y)\,dxdy, \tag{2}$$

where **D** is a viewing field; **$K_i(x,y)$ –** functionals' kernel. It is often necessary to increase (broaden) the category of functionals (2), and then we consider nonlinear functional such as:

$$\Phi_i(B) = h_i\left(\frac{f_i\left(\iint\limits_D B(x,y)K_i(x,y)\,dxdy\right)}{g_i\left(\iint\limits_D B(x,y)W_i(x,y)\,dxdy\right)}\right), \tag{3}$$

where **h_i, f_i, g_i** are the functions of an actual argument; **$K_i(x,y)$, $W_i(x,y)$** - kernel. The choice of the functionals of integral type is caused by their good noise immunity and relative simplicity of realization.

As an example we cite the description of the construction of rotation normalizer in rectangular coordinate system. Template **B_0** and input image **B** are connected in the rectangular coordinate system with the following dependence:

$$B(x,y)=B_0(x\cos\theta + y\sin\theta, -x\sin\theta + y\cos\theta), \tag{4}$$

Therefore the normalizing operator will look as follows

$$F(B)=B(x\cos\Phi(B) + y\sin\Phi(B), -x\sin\Phi(B) + y\cos\Phi(B)), \tag{5}$$

and the functional $\Phi(B)$ must fulfill the condition:

$$\Phi(B(x\cos\theta + y\sin\theta, -x\sin\theta + y\cos\theta))= \Phi(B(x,y))+\theta+2\pi K, \tag{6}$$

$k=0, \pm 1, \pm 2$

Functional that satisfies the condition (6) is a functional

$$\Phi(B) = \frac{\iint\limits_D B(x,y)K(x,y)\,dxdy}{\iint\limits_D B(x,y)\,dxdy}, \tag{7}$$

где **K(x,y)=arctg** $\frac{y}{x}$ или **K(x,y)=** $\arcsin\frac{y}{\sqrt{x^2+y^2}}$.

Using an invariant function **x^2+y^2** , we can indicate one of the most universal functionals

$$\Phi(B)=\frac{1}{2}arctg\frac{2\iint\limits_D \varphi(B(x,y))xy\varphi(x^2+y^2)dxdy}{\iint\limits_D \varphi(B(x,y))(x^2-y^2)\varphi(x^2+y^2)dxdy}, \tag{8}$$

Below there is a special case of that normalizer, that was practically implemented in the system of image normalization [2].

$$\Phi(B)=\frac{1}{2}arctg\frac{2\iint\limits_D B(x,y)xydxdy}{\iint\limits_D B(x,y)x^2dxdy-\iint\limits_D B(x,y)y^2dxdy}, \tag{9}$$

The normalization of shifting occurs with the help of normalizers

$$x_c=\frac{1}{2}W\frac{\iint\limits_D B(x,y)xdxdy}{\iint\limits_D B(x,y)dxdy}, \quad y_c=\frac{1}{2}H\frac{\iint\limits_D B(x,y)ydxdy}{\iint\limits_D B(x,y)dxdy},$$

where **W** is the width of viewing field, **H** is the height of viewing field; D is an area corresponding with the input image.

Values **x_c** and **y_c** indicate the value of the shift along the axes x and y in the viewing field in order to make it centered.

By calculating a scale factor we use the following functionals

$$\Phi_x(B)=\frac{\iint\limits_D B(x,y)x^2dxdy}{\iint\limits_D B(x,y)dxdy}, \quad \Phi_y(B)=\frac{\iint\limits_D B(x,y)y^2dxdy}{\iint\limits_D B(x,y)dxdy}.$$

It should be noted that these normalizers are used in parallel as well as in sequential algorithms of normalization with marginal changes.

The system of normalization with the use of described normalizers helps to compensate (balance) the distortion of shifting, rotation and the scale of input image. The rotation compensation occurs successfully under condition that the rotation angle of an image lies within **$(-\pi/2,\pi/2)$,** at the same time miscalculation does not exceed 5%. Error rates of scale factors and parameters lies within the same limits [2].

Список литературы

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