MAINTENANCE OF INVARIANCY OF RECOGNITION OF OBJECTS TO LINEAR CHANGES OF THEIR IMAGES BY THE AUTOMATED MANUFACTURE

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Now, technical sight became real alternative to the person on operations of visual or manual quality assurance of the produced production, allowing the companies to increase productivity and to lower the costs arising at quality assurance of each unit of production separately that occurs at performance of the control by the person.

At recognition of images of objects arise some the difficulties connected with their linear changes (turn of the image around of the centre of gravity and change of a site in a coordinate plane), it arises because products, after manufacture, lay on a conveyor line in the casual image as their strict orientation in space is a complex and expensive problem. It leads to loss of the information on number, a place and absolute value of attributes, random errors of measurements of objects attributes values change etc. These and other destabilizing factors reduce authenticity of recognition of images for elimination of which recognition should be invariant to changes of positions of images [1].

For maintenance of invariance to turn of the image around of the centre of gravity and to changes of a site of the image different methods and means were suggested [2-5]. However, these methods cannot provide the greatest invariance of recognition of images because in the given works the basic emphasis was done for the statistical moments which for maintenance of invariance to linear changes of images of objects were considered as their basic attributes. The analysis of the specified works has shown, that attributes, in this case, too integrated, and consequently reliability - low. Therefore the researches directed on search of the best methods and means of achievement of invariance of recognition of images in systems of technical sight remain actual.

In the given work it is offered to use the statistical moments as reference points of the image, and on the basis of given principle to develop a technique of recognition of images, invariant to their linear transformations.

For reception of the fullest information on object, it is necessary to make the analysis of its images in three mutually perpendicular planes of projection XOY, XOZ and YOZ. The technique of processing of the image is identical to three planes of a projection, therefore we shall consider only one plane of projection XOY.

Let's admit, that the information on object (its image), in the form of file A1 $(X_i; Y_i)$, is stored in memory of a computer, and it can be represented in system of coordinates XOY on the screen of the monitor in the form of a flat figure. If the object makes movement (parallel moving on ΔX, and ΔY, in a direction of coordinate axes OX, OY and turn around of centre of gravity C by angle φ in plane XOY) then its new image in the form of a flat figure on the screen of the monitor is accompanied by change of coordinates of central points in system of coordinates XOY. Therefore, for recognition of object under images it is necessary to solve a problem of achievement of invariance of recognition of images to linear transformations of images. In our case as a compared object the reference object which by means of system AutoCAD was turned by angle $\phi = 75^0$ with a view of check of working capacity of suggested method is taken.

On the basis of available data about objects we shall define, whether and how many the turned object corresponds to reference one. Originally, in all cases we shall do the assumption, that objects are identical, and the compared object has made parallel moving to a direction of coordinate axes OX, OY and turn around of centre of gravity C by angle φ in relation to reference object. Let's find this angle. For the beginning we define coordinates of the centers of weights (point $C_1(X_{C1}; Y_{C1})$ and $C_2(X_{C2}; Y_{C2})$) images, on known coordinates of central points

A1 stored in memory (X_i, Y_i) and A2(X_j, Y_j) of both objects which are calculated as arithmetic-mean values of points of corresponding files [6].

We form rectangular systems of coordinates $X_1C_1Y_1$ and $X_2C_2Y_2$, and calculate new coordinates of points of both images, accordingly in these systems of coordinates:

$$X_i' = X_i - X_{C1} \qquad Y_i' = Y_i - Y_{C1} \tag{1}$$

$$X_j' = X_j - X_{C2} \qquad Y_j' = Y_j - Y_{C2} \tag{2}$$

We receive two new data files A1'(X_i', Y_i') and A2'(X_j', Y_j').

On the basis of obtained results we calculate the axial moments and the equatorial moments of inertia of both images accordingly, relative to systems of coordinates $X_1C_1Y_1$ and $X_2C_2Y_2$:

$$J_{X1} = \sum_{i-1}^{n} (Y_i')^2 \Delta s; \quad J_{Y1} = \sum_{i=1}^{n} (X_i')^2 \Delta s; \quad J_{X1Y1} = \sum_{i=1}^{n} X_i' Y_i' \Delta s \tag{3}$$

$$J_{X2} = \sum_{j-1}^{n} (Y_j')^2 \Delta s; \quad J_{Y2} = \sum_{j=1}^{n} (X_j')^2 \Delta s; \quad J_{X2Y2} = \sum_{j=1}^{n} X_j' Y_j' \Delta s \tag{4}$$

Where: $J_{X1}, J_{Y1}, J_{X2}, J_{Y2}$ - accordingly, the axial moments of the first and second image; J_{X1Y1}, J_{X2Y2} - accordingly, the centrifugal moments of the first and second image.

The axial moments, the centrifugal moments of images and the angle of turn are related by formulas:

$$J_{X2} = J_{X1} \cos^2 \phi + J_{Y1} \sin^2 \phi + J_{X1Y1} \sin 2\phi \tag{5}$$

$$J_{Y2} = J_{X1} \sin^2 \phi + J_{Y1} \cos^2 \phi - J_{X1Y1} \sin 2\phi \tag{6}$$

Solving the equations (8) and (9) we find expression for angle of turn:

$$\phi = \pm \frac{1}{2} \arcsin \frac{J_{Y1} - J_{X1}}{\sqrt{(J_{Y2} - J_{X2})^2 + 4J_{X2Y2}{}^2}} \pm arctg \frac{J_{X2} - J_{Y2}}{2J_{X2Y2}} + \pi \cdot n \tag{7}$$

where: n = 0, 1, 2, …, N.

If $J_{Y1} > J_{X1}$ and $J_{Y1} > J_{Y2}$, then arcsin is to be taken with a sign "+", and arctg with a sign "-".
If $J_{Y1} > J_{X1}$ and $J_{Y1} < J_{Y2}$, then arcsin is to be taken with a sign "+", and arctg with a sign "+".
If $J_{Y1} < J_{X1}$ and $J_{Y1} > J_{Y2}$, then arcsin is to be taken with a sign "-", and arctg with a sign "+".
If $J_{Y1} < J_{X1}$ and $J_{Y1} < J_{Y2}$, then arcsin is to be taken with a sign "-", and arctg with a sign "-".

Due to presence in above specified equation of $\pi \cdot n$, as a result of calculation we shall receive two angle: ϕ and $\phi + \pi$.

Having defined an angle ϕ, we shall make turn of the compared image on this angle. It is made in order that numberings of central points of reference and compared objects have coincided, that will facilitate process of recognition.

By means of known formulas we transfer coordinates of points of files A1'(X_i', Y_i') and A2'(X_j', Y_j') from the Cartesian system of coordinates in polar [6]. We receive two data files A1''(R_i, ψ_i) and A2''(R_j, ψ_j).

Let's transform angle ψ_i and ψ_j so that these angle laid in a limit $0 \le \psi_i, \psi_j < 360$.

We shall subtract from polar coordinates of the second file angle ϕ and $\phi + \pi$.

$$\psi_{j1} = \psi_j - \phi \qquad \psi_{j2} = \psi_j - \phi + \pi \tag{8}$$

We receive two data files $A2_1$''(R_{j1}, ψ_{j1}) and $A2_2$''(R_{j2}, ψ_{j2}).

We find $\psi_i = \min$, $\psi_{j1} = \min$, $\psi_{j2} = \min$, and we make ranging lines of files in which first lines are equal to the obtained minimal values.

We make comparison of reference file A1''(R_i, ψ_i) with each of obtained files $A2_1$''(R_{j1}, ψ_{j1}) and $A2_2$''(R_{j2}, ψ_{j2}) of compared object.

For this purpose we shall find a difference:

$$S_{i1} = R_i - R_{j1}; \qquad S_{i2} = R_i - R_{j2} \tag{9}$$

also we shall make two files $Z1(R_i; S_{i1})$ and $Z2(R_i; S_{i2})$.

If difference S_{i1} and S_{i2} between files will not surpass the certain value these objects are really identical and compared object will turn on a corresponding angle.

The measure of affinity between objects gets out proceeding from applicability of object. We shall put a condition, that the given product is not interfaced, i. e. edges of a product are not included into connection with edges of other products [7].

As a measure of affinity between objects it is possible to take a condition:

$$R_i - \frac{D(R_i)}{2} \le R_j \le R_i + \frac{D(R_i)}{2} \tag{10}$$

where: D (Ri) - the admissions established by standard СТ СЭВ 177 - 75 acting on the given moment in Azerbaijan republic. Value D is established depending on quality (degrees of accuracy) of manufacturing of a product and depends on size R_i.

Table 1

Coordinates of reference object in the Cartesian system of coordinates XOY		Coordinates of the turned object in the Cartesian system of coordinates XOY		Coordinates of reference object in polar system of coordinates concerning the centre of gravity		Coordinates of the turned object in polar system of coordinates concerning the centre of gravity	
X	Y	X	Y	R	ψ	R	ψ
166.9957	148.2002	126.3524	166.7200	80.7023	11.6020	80.6987	86.6025
150.5475	160.7206	110.0016	154.0728	68.8913	24.6663	68.8880	99,6675
161.5130	187.3264	87.1404	171.5507	92.0705	36.9961	92.0675	111,9600
147.4146	205.3245	66.1066	162.5909	94.4343	50.9665	94.4319	125,9682
160.7297	231.9303	43.8536	182.3385	123.6530	53.9393	123.6509	128,9407
130.1832	250.7109	17.8069	157.6935	126.0305	70.4175	126.0292	145,4191
94.9372	250.7109	8.6846	123.6485	118.9467	86.6287	118.9465	161,6304
81.6220	226.4526	28.6700	104.5085	94.6937	93,8270	94.6940	168,8293
20.5289	193.5866	44.6041	36.9908	91.3300	137,5723	91.3327	212.5739
20.5289	170.1109	67.2799	30.9148	77.4551	150,4998	77.4583	225.5012
7.9970	156.8079	76.8861	15.3669	83.7146	162,7310	83.7183	237.7415
7.9970	134.8973	98.0501	9.6959	79.9988	177,9030	80.0026	252.9031
19.7456	121.5944	113.9406	17.6013	68.9815	188.6508	68.9850	263.6504
40.8932	121.5944	119.4140	38.0283	48.1796	192.4363	48.1831	267.4354
50.2922	105.9439	136.9638	43.0563	45.7700	214.6547	45.7730	289,6521
50.2922	84.8157	157.3720	37.5879	60.3412	231.3947	60.3435	306,3918
35.4105	55.0798	182.2431	15.5171	93.1219	235.6590	93.1241	310,6570
54.2084	42.5594	199.2021	30.4340	95.5627	249.3290	95.5640	324,3269
66.7403	21.4312	222.8538	37.0705	112.5538	259.1423	112.5544	334,1404
94.1539	33.9516	217.8552	66.7905	98.2151	273,6260	98.2148	348,6240
114.5183	33.9516	223.1259	86.4610	101.5574	285,1700	101.5564	0.1680
132.5329	49.6021	212.6712	107.9124	93.6632	298,4293	93.6614	13.4273
146.6313	80.1206	186.8416	129.4292	78.3120	318,5406	78.3092	33.5388
163.8627	93.4235	178.4518	149.5165	85.1455	333,0820	85.1422	48.0809

By other words, meeting of a condition is necessary:

$$\left|S_i(R_i)\right| \le \frac{D(R_i)}{2} \qquad (11)$$

If all values R_j satisfy to a condition (11), the made assumption is true.
If even one R_j does not satisfy to a condition (11) the given product is considered as defect.

For check of an offered technique, as an example, data specified in table 1 used. In the table, for easy presentation, numbering of central points of reference and compared objects coincides, that in a reality happens very seldom. In the first pair columns coordinates of central points of reference object in the Cartesian system of coordinates XOY are presented. By means of system AutoCAD of the image of object have been moved to in parallel to coordinate axes OX and OY, and turned around of the centre of gravity by angle φ. In the second pair columns coordinates of central points of the turned object in the Cartesian system of coordinates XOY are presented. In the third and fourth pair columns coordinates of central points of the reference and turned object in polar system of coordinates concerning the centers of weights of objects are presented. By means of the offered technique, after corresponding calculations the values of ϕ and $\phi + \pi$, A1’’(R_i, ψ_i) and A2’’(R_j, ψ_j), $A2_1$’’(R_{j1}, ψ_{j1}) and $A2_2$’’(R_{j2}, ψ_{j2}), Z1 (R_i; S_{i1}) and Z2(R_i; S_{i2}) have been obtained. The greatest value $S_{i1} = 0.0038$, and $S_{i2} = 46.2975$. Value S_{i1} is included into limits of quality №4 for which D = 0.01. Value S_{i2} is not included into limits of any quality and it can be excluded from the analysis of the image. The average degree of accuracy (quality №4 is from the middle of some qualities) is caused by roundings off of calculations made at performance. Increasing accuracy of spent calculations, it is possible to lower number quality (to raise accuracy). Therefore, quality №4 and above turned image corresponds to reference, and quality below №4 the turned image will be considered as defect.

The technique of recognition of images of objects presented by given work, invariant to their linear transformations, allows to define with a high degree of reliability the conformity of the turned image with reference.

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