A Study on the Automatic Inspection System using Invariant Moments Algorithm with the Change of Size and Rotation

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크기와 회전 변화에 불변 모멘트 알고리즘을 이용한 자동 검사 시스템에 관한 연구

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Abstract

The purpose of this study is to develop a practical image inspection system that could recognize it correctly, endowing flexibility to the productive field, although the same object for work will be changed in the size and rotated. In this experiment, it selected a fighter, rotating the direction from 30° to 45° simultaneously while changing the size from 1/4 to 1/16, as an object inspection without using another hardware for exclusive image processing. The invariant moments, Hu has suggested, was used as feature vector moment descriptor. As a result of the experiment, the image inspection system developed from this research was operated in real-time regardless of the chance of size and rotation for the object inspection, and it maintained the correspondent rates steadily above from 94% to 96%. Accordingly, it is considered as the flexibility can be considerably endowed to the factory automation when the image inspection system developed from this research is applied to the productive field.

Key Words : Image Inspection System, Invariant Moments, Factory Automation, Productive Field, Moment Descriptor

I. Introduction

Because of the instability of conveyor in the productive field it may recognize the object differently from the same object for working by mistakes. For example, most of the production lines of cold · hot coil in an iron foundry are consisted of automated assembly process. But, the trademark attached work remains as a

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difficult process in the automation technically. The reason this process is difficult in the automation why it differs in the size, weight, and direction of rolling coil. Accordingly, it cannot attach the trademark with the mechanism of rigid body(robot) that can replace the workers. Thus, it needs to cope with the variable situations of size and direction of rolling coil[1].

It is because the inputted rotation data and size data for the object are different from the memorized ones in the automatic inspection system in advance. This problem may be great burden to the process automation using the automatic inspection system. When it can be applied to the field while developing the automatic inspection system that can coincide with the object correctly after overcoming this situation, the process automation can be much smoothly executed. Generally, the speed is very important in the automatic inspection process, so it uses Fourier descriptor and moment descriptor as cognitive feature vector for the object[2]. The Fourier descriptor marks pattern guidelines with the two-dimensional complex function, and compares with the memorized model frequency after changing the complex function into the frequency. It has advantages in the fast speed, but it has, on the other hand, disadvantages very sensitive to the noises because it compares with only external guidelines for the object. The moment descriptor seems to be two-dimensional function like the property of section that it treats the field of inspection object in the mechanics, and it compares with the multi order moment and recognizes it. This method has no disadvantages like the Fourier descriptor. But it has disadvantages to take required time for calculating too long because it calculates the whole field of pixels for the object in order to calculate the multi order moment[3,4]. When examining the applied cases about the automatic inspection system, it is reported that the moment descriptor is superior to the Fourier descriptor[5]. Recently for minimizing the required time about the moment descriptor it is reported a method of calculating the moment optically in real-time, and it developed its exclusive structure and processor[6-8].

In this experiment, it selected a fighter, rotating the rotation from 30° to 45° simultaneously while changing the size from 1/4 to 1/16, as an object inspection without using exclusive hardware. As a algorithm, it used the property of section treated in the mechanics and the invariant moment, Hu has suggested[9].

It proved that it could solved the problems that the algorithm suggested from the result of research did not recognize the same object but the different object wrongly because of the instability of conveyor.

II. Invariant Moment Algorithm

The moment defined physically as a power factor is used as an important feature vector descriptor in the automatic inspection system. When the sectional moment is applied to the image moment in Fig 1, it defines the $p+q$ dimensional moment m_{pq} in the two-dimensional rectangular coordinate system about the object for inspection as below[9].

$$m_{pq} = \int\int_A x^p y^q f(x, y) dA \qquad (1)$$

Here,

$p, q = 0, 1, 2 \ldots$

In the formula (1), $f(x, y)$ is grey level data about

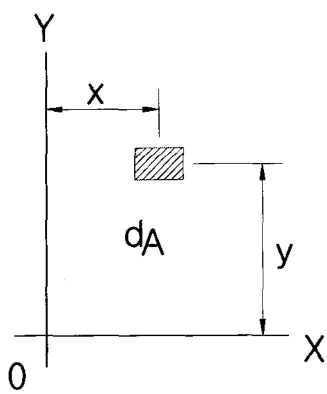

Fig. 1 Statical moment

the coordinate $(x,\ y)$ as two-dimensional function. dA is minute area subdivided into the section, and defines it as a pixel. Also, the dimension in the formula (1) is determined as exponent values in the $x,\ y$ coordinate, and has different characteristics each. In case of binary image, $f(x,\ y)$ becomes 1 in the object for inspection or 0 in the background, or it becomes the opposite each[10]. As for the property of section, sectional primary moment $G_x,\ G_y$ is applied when it calculates the stress for the structure about optional diagram, and examines the degree of stability. If it is applied to the image inspection system, it finds that the image primary moment $m_{10},\ m_{01}$ correspond to the sectional primary moment $G_x,\ G_y$ has a position of central information about the guidelines of object for the inspection like following formula.

$$\left.\begin{aligned} m_{01} &= \int\int_A y dA \\ m_{10} &= \int\int_A x dA \end{aligned}\right\} \quad (2)$$

The image zero-dimensional moment m_{00} is equal to the minute area dA subdivided into the section of the formula (1) that is, the sum of the whole pixels, so it is equal to the area about the object for the inspection. As for the central information about the image for the object for the inspection $\overline{y},\ \overline{x}$, it can be calculated like following formula (4) when it uses the following formula (2) and (3), calculating centroid of diagram $y_0\ .\ x_0$ in the property of section.

$$\left.\begin{aligned} y_0 &= \frac{G_x}{A} \\ x_0 &= \frac{G_y}{A} \end{aligned}\right\} \quad (3)$$

$$\left.\begin{aligned} \overline{y} &= \frac{m_{10}}{m_{00}} \\ \overline{x} &= \frac{m_{01}}{m_{00}} \end{aligned}\right\} \quad (4)$$

In the property of section the sectional secondary moment $I_X,\ I_Y$ add the value, adding square from the axis to the minute area d_A about the whole section, and it uses the sectional rising moment I_{XY} in calculating the secondary moment and the axis of principal section. After applying this concept to the formula (1) the image secondary moment $m_{20},\ m_{11},\ m_{02}$ correspond to the sectional secondary moment $I_X,\ I_Y$ can be calculated as follows.

$$\left.\begin{aligned} m_{02} &= \int\int_A y^2 dA \\ m_{11} &= \int\int_A xy dA \\ m_{20} &= \int\int_A x^2 dA \end{aligned}\right\} \quad (5)$$

As information about the translation of the object for the inspection, the translation invariant movement u_{pq} can be calculated as following formula, using the formula (1) and (4).

$$u_{pq} = \int\int_A (x-\overline{x})^p\ (y-\overline{y})^q f(x,y) dA \quad (6)$$

If the formula (6) is arranged by the degree, it is as follows.

$$\left.\begin{aligned} u_{00} &= m_{00} \\ u_{01} &= u_{10} = 0 \\ u_{02} &= m_{02} - u_{00}\ \overline{y}^2 \\ u_{11} &= m_{11} - u_{00}\,\overline{x}\ \overline{y} \\ u_{20} &= m_{20} - u\ \overline{x}^2 \end{aligned}\right\} \quad (7)$$

In the image inspection system, the inclination of the axis θ is a method calculating the axis inclination in the property of section. If it is applied to the formula (7), it can be calculated as follows.

$$\theta = \frac{1}{2} \tan^{-1}\left(\frac{2u_{11}}{u_{20} - u_{02}}\right) \quad (8)$$

Also, invariant moment in the size transformation n_{pq}

can be defined as following formula, using the formula (7)[9].

$$n_{pq}=\frac{u_{pq}}{u_{00}{}^{r}} \tag{9}$$

Here,

$$r=\frac{(p+q)}{2}+1$$

$$p,\ q\ =\ 2,\ 3,\ 4\ .\ .\ .$$

For calculating the invariant values in the rotatory change with the translation and the change of size Hu induces as following formula, using moment polynomial defined as n_{pq} of the formula (9)[2,9].

$$I_{p-r,r}=\sum_{l=0}^{r}(-i)^{l}\begin{bmatrix}p-2l\\ l\end{bmatrix}\sum_{k=0}^{r}\begin{bmatrix}r\\ k\end{bmatrix}n_{p-2k-l,2k+l} \tag{10}$$

Here,

$$(p-2l)>0,\ \ i=\sqrt{-1}$$

Also, Hu defines 7 invariant moments $\phi_1, \phi_2, \phi_3, \phi_4, \phi_5, \phi_6, \phi_7$ composed of image secondary and third moment in the formula (10) as follows[9].

$$\phi_1=n_{20}+n_{02} \tag{11}$$

$$\phi_2=(n_{20}-n_{02})^2+4\ n_{11}^2 \tag{12}$$

$$\phi_3=(n_{30}-3n_{12})^2+(3\ n_{21}-n_{03}) \tag{13}$$

$$\phi_4=(n_{30}+n_{12})^2+(n_{21}+n_{03})^2 \tag{14}$$

$$\phi_5=(n_{30}+3n_{12})(n_{30}+n_{12})[(n_{30}+n_{12})^2 -3(n_{21}+n_{03})^2]+(3n_{21}-n_{03})(n_{21}+n_{03}) [3(n_{30}+n_{12})^2-(n_{21}+n_{03})^2] \tag{15}$$

$$\phi_6=(n_{20}+n_{02})[\ (n_{30}+n_{12})^2-(n_{21}+n_{03})^2] +4n_{11}(n_{30}+n_{12})\ (n_{21}+n_{03}) \tag{16}$$

$$\phi_7=(3n_{21}-n_{03})(n_{30}+n_{12})[(n_{30}+n_{12})^2 -3(n_{21}+n_{03})^2]+(3n_{12}-n_{30})(n_{21}+n_{03}) [3(n_{30}+n_{12})^2-(n_{21}+n_{03})] \tag{17}$$

As for the normalization of translation of the object, if it is applied to the concept of parallel translation of the coordinate axis in the property of section when the travel is y', x', it can calculate template invariant to the translation like below[2].

$$\left.\begin{aligned} y&=y'-\bar{y}\\ x&=x'-\bar{x}\end{aligned}\right\} \tag{18}$$

The length of half major axis α and half uni-axis β for the object can be calculated like following formula when the formula (7) will be applied to the concept that calculates principal section secondary moment I_1, I_2 in the property of section.

$$\left.\begin{aligned} \alpha&=\frac{(2[(u_{20}+u_{02})+\sqrt{(u_{20}-u_{02})^2+4u_{11}^2}])^{\frac{1}{2}}}{u_{00}}\\ \beta&=\frac{(2[(u_{20}+u_{02})-\sqrt{(u_{20}-u_{02})^2+4u_{11}^2}])^{\frac{1}{2}}}{u_{00}}\end{aligned}\right| \tag{19}$$

The normalization about the rotation can be calculated like following formula when the concept of coordinate axis rotation in the property of section.

$$\left.\begin{aligned} G_{X}'&=G_X\cos\theta-G_Y\sin\theta\\ G_{Y}'&=G_X\sin\theta-G_Y\cos\theta\end{aligned}\right\} \tag{20}$$

Here,

X', Y' : Rotating at the starting point of X, Y axis

III. Simulation and Investigation of Results

In this experiment, it makes the size of original image reduced into 1/4 and 1/16 each like the following Fig, and it simulates on a basis of fighter, rotating 30° and 45°[5].

Automatic inspection simulation flow is the same as

Table 1 below.

As a result of experiment, the moment degree has minuter information as it gets higher degree like n_{12} , n_{21} , n_{30} , n_{03} in the following Table 2 and ϕ_5, ϕ_6, ϕ_7 in the Table 3, 4, and 5. But it finds that the quantitative analysis and the analysis of mathematical meaning are insignificant[5].

This higher moment above the fifth degree is sensitive to the noise signal, so it has disadvantages not to express the result correctly. For improving these problems it introduces a method that selects log to the calculated results, but there is no need to endow the meaning largely because it is just visual effect and it does not change data themselves[6]. If these minute problems are removed, it finds that the rates almost correspond to 94% ~ 96% compared with the reduction to 1/4 and 1/16 and the rotation to 30° and 45° each.

Accordingly, it proved that the image inspection

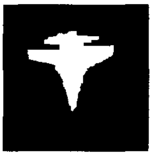

Fig. 2 Original image

Fig. 3 Image reduced to 1/4 of original image

Fig. 4 Image reduced to 1/16 of original image

Fig. 5 Image rotated 30° of original image

Fig. 6 Image reduced to 1/4 and rotated 30° of original image

Fig. 7 Image reduced to 1/16 and rotated 30° of original image

Fig. 8 Image rotated 45° of original image

Fig. 9 Image reduced to 1/4 and rotated 45° of original image

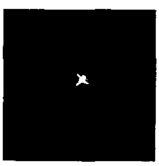

Fig. 10 Image reduced to 1/16 and rotated 45° of original image

Table 1 Simulation algorithm

Experimental Image Input

⇓

Analysis and Arrangement of Physical Data

⇓

Application of Section Moment Algorithm Dealt in Mechanics

⇓

Application of Constant Algorithm in Size, Movement, and Direction

⇓

Quantitative Analysis and Judgement

Table 2. Size invariant moment

	Origin image	Result of Image reduced to 1/4 of original image	Result of Image reduced to 1/16 of original image
n_{20}	0.001120	0.001184	0.001122
n_{11}	0.000129	0.000099	0.000129
n_{02}	0.001191	0.001001	0.001129
n_{21}	0.000000	-0.000001	0.000000
n_{12}	0.000005	0.000002	0.000003
n_{30}	0.000010	0.000009	0.000010
n_{03}	-0.000001	-0.000006	-0.000002

Table 3 Rotation invariant moment

	Origin image	Result of Image rotated 30° of original image	Result of Image rotated 45° of original image
ϕ_1	0.002311304833059	0.002251531979209	0.002239955801053
ϕ_2	0.000000071204441	0.000000076324649	0.000000070433832
ϕ_3	0.000000000013842	0.000000000047468	0.000000000056491
ϕ_4	0.000000000225939	0.000000000201708	0.000000000196195
ϕ_5	-0.000000000000179	-0.000000000035689	-0.000000000019572
ϕ_6	-0.000000000000016	-0.000000000000023	-0.000000000000018
ϕ_7	0.000000000000000	0.000000000000000	0.000000000000000

Table 4 Rotation invariant moment for 1/4 Reduction image

	Result of Image reduced to 1/4 of original image	Result of reduced to 1/4 and rotated 30° of original image	Result of reduced to 1/4 and rotated 45° of original image
ϕ_1	0.002250058032313	0.002185150542248	0.002158942598699
ϕ_2	0.000000066701982	0.000000072488436	0.000000066035087
ϕ_3	0.000000000002783	0.000000000027338	0.000000000025483
ϕ_4	0.000000000173000	0.000000000158271	0.000000000138753
ϕ_5	-0.000000000002867	-0.000000000020393	-0.000000000017474
ϕ_6	-0.000000000000014	-0.000000000000015	-0.000000000000015
ϕ_7	0.000000000000000	0.000000000000000	0.000000000000000

Table 5 Rotation invariant moment for 1/16 Reduction image

	Result of Image reduced to 1/16 of original image	Result of reduced to 1/16 and rotated 30° of original image	Result of reduced to 1/16 and rotated 45° of original image
ϕ_1	0.002257720809112	0.002183578926538	0.002194057950132
ϕ_2	0.000000058421717	0.000000084653935	0.000000054623757
ϕ_3	0.000000000005016	0.000000000012178	0.000000000000368
ϕ_4	0.000000000123153	0.000000000110727	0.000000000075664
ϕ_5	-0.000000000009543	-0.000000000012894	-0.000000000002849
ϕ_6	-0.000000000000016	-0.000000000000017	-0.000000000000011
ϕ_7	0.000000000000000	0.000000000000000	0.000000000000000

system developed from this research recognized it correctly although the same object was in the different size and rotation each. Therefore, when this useful image inspection algorithm is applied to the automation of the trademark attached work by the change of size, weight, and direction of rolling coil, it is considered as it can endow the flexibility to the factory automation considerably[1,10].

IV. Conclusion

For endowing the flexibility to the productive field although the same object changed in its size and rotated in its rotation, the practical image inspection system that could recognize it correctly was developed. The property of section applied in the mechanics is used as a moment descriptor in process of realizing the constant moment detection algorithm of Image inspection system. The coincidence rate is maintained over 94%~96% consistently like Table 2, 3, 4, and 5.

As research subject here after, this study is to investigate the general correlation coefficient matching algorithm with the advantages of fast calculation and the correlation coefficient matching algorithm using the rotation template. And it is to compare the performance with the invariant moment detection algorithm materialized in this research. Also, it is to apply the findings to the real productive field.

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