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The Recognition Methods Combined Image Processing With 2D or 3D CAD Information (CAD/IP)

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In this paper, we propose the recognition methods by image processing using 2D or 3D CAD. In the case of 2D CAD, an object is recognized by comparing five characters calculated from the center of gravity and contour. In the case of 3D CAD, there are two recognition methods. Firstly 3D CAD figure is transformed into 2D CAD figures. And an object is recognized by comparing 2D CAD figures with inputted images. Secondly the three dimensional coordinates of vertexes on an object are calculated from the images taken from some cameras and compared 3D coordinates with those of 3D CAD figures and recognized the sort of an object.

1. INTRODUCTION

The image processing is widely used to recognize an object by only one image of a camera[1]. In the factory, though 2D CAD is widely used in the design department[2], further 3D CAD has been gradually increased. And data format of 3D CAD figure is standardized such as DXF file [3]. If we can utilize the information of CAD figure for the image processing, the ability of recognition would be advanced remarkably.

In this paper, we propose a recognition method to combine the image processing (IP, for shortly) with the 2D or 3D CAD information to recognize the sort of an object. The characteristics of an object, such as, center of gravity, contour, vertexes, etc. are used to compare CAD figure with the images taken by some cameras.

2. 2 DIMENSIONAL CAD

As 2D CAD figure and IP have 2 dimension, then 2D CAD figure is used to input image for IP without any transformation.

2.1 Characteristics of 2D figure

The inside of 2D CAD figure is painted by black color to make a binary figure. This painted figure (binary figure) can be used as the input of IP[4].

The following characteristics are calculated from the binary figure of 2D CAD.

(1) Center of gravity of binary figure

We define f_{qr} as the binary value at point (q,r) of the binary figure and calculate the center of gravity (X_G,Y_G) by the equation (1).

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$$X_G=\sum_{q=1}^{NX} q\left[\sum_{r=1}^{NY} f_{qr}\right]\Big/N \quad , \quad Y_G=\sum_{r=1}^{NY} r\left[\sum_{q=1}^{NX} f_{qr}\right]\Big/NS \quad , \quad NS=\sum_{q=1}^{NX}\sum_{r=1}^{NY} f_{qr} \qquad (1)$$

$$f_{qr}=\begin{cases}1\text{: Inside of binary image}\\ 2\text{: Otherwise}\end{cases}$$

(2) Contour of binary figure

The contour coordinate (DX_j , DY_j) of the binary figure is obtained by the contour chasing method[5].

(3) Center-contour distance

The distance (CL_j) between the center of gravity and the contour (center-contour distance, for shortly) is calculated by the equation (2).

$$CL_j=\sqrt{(DX_j-X_G)+(DY_j-Y_G)} \quad , \quad (j=1,2,\ldots,N) \qquad (2)$$

(4) Number showing the maximum and minimum values of center-contour distance

The number $(M_r)(r=1,2,\ldots,nt)$ showing the maximum values of the center-contour distance (CL_j) are calculated by the equation (3). The number $(L_r)(r=1,2,\ldots,nt)$ showing the minimum values are calculated from the equation changing the sign > to < in the equation (3).

$$CL_{M_r}=\left\{CL_j \,\middle|\, \begin{matrix}CL_j>CL_{j+1}\\ CL_j>CL_{j-1}\end{matrix} \text{ or } \begin{matrix}CL_1>CL_2\\ CL_1>CL_n\end{matrix} \text{ or } \begin{matrix}CL_n>CL_1\\ CL_n>CL_{n-1}\end{matrix}, \; j=1,2,\cdots,N\right\} \qquad (3)$$

Where, nt shows the number of the maximum or minimum on the center-contour distance.

(5) FFT transformation of center-contour distance

The center-contour distance CL_j is transformed into the power spectral density $F(q)$ by FFT[6]. The frequency ($fmax$) showing the greatest FFT value is calculated by the equation (4).

$$F(f_{max}) = \max_{1\leq q\leq 256} F(q) \qquad (4)$$

2.2 Comparison of characteristics of 2D figure

The camera figure is made by binarization of the image taken by a camera. The camera figure of an object is compared with the binary figure of CAD to determine the sort and direction.

The comparing method has two steps. In the first step, the frequency (f_{max}) showing the greatest FFT value of the camera figure is compared with that of CAD. The sort of an object is estimated roughly as one of CAD figure. In the Second step, the center-contour distance (CL_j) is compared to determine the sort of CAD figure as follows. As an object's size in the input image depends on the distance from the camera to an object, the center-contour distance of the camera figure is expanded to correspond to that of CAD figure. And each one of the maximum values (M_r) of center-contour distance of CAD figure is overlapped to the greatest value of the camera figure (see Fig. 1.), and the coincidence value is calculate from the difference between the corresponded center-contour distances of the camera figure and CAD figure. The similar procedure is applied to calculate the coincidence value between the minimum values (L_r) of CAD figure and the camera figure.

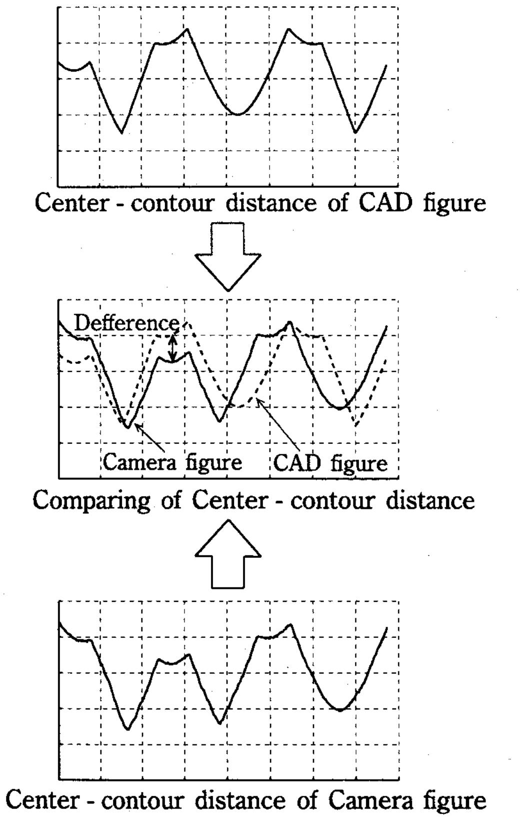

Fig.1 Comparison of the center-contour disatance

2.3 Determination of sort of object

The sort of an object is estimated by using the coincidence values calculated for two cases of the maximum values and the minimum values. Further the direction of an object is estimated from the duration of the comparison of the center-contour distance.

This matching method is useful to determine not only the sort and location, but also the direction of an object.

3. 3 DIMENSIONAL CAD

As the input image by one camera is showed two dimension, the dimension of 3D CAD figure and IP should be adjusted.

Firstly, 3D CAD figure is transformed into 2D CAD figures. They are compared with the 2D images taken by some cameras to determine the sort and the direction of an object.

Secondly, the 3D coordinates of vertexes of an object are calculated by the input images of many cameras. The sort and the direction of an object are determined by comparing the 3D coordinates of vertexes of an object with those of 3D CAD figure.

3.1 Comparing 2D input images with transformed 2D CAD figure

3.1.1 Transforming 3D CAD figure into 2D CAD figure looking at a view point

3D CAD figure is transformed into a 2D CAD figure looked at a given view point in the computer.

(1)Rotation of 3D CAD Figure

The coordinates (X,Y,Z) shows any point in 3D space. R_x R_y and R_z are defined as the rotation angle on X, Y and Z axis.

Firstly, the center of gravity of the figure is moved parallel to the origin (0,0,0). Secondly, all vertexes of the figure are rotated by the equation (5). For Y and Z axis, the similar equations using R_y and R_z are used to rotated the vertexes[7].

$$[\,X\ Y\ Z\ 1\,]=[\,x\ y\ z\ 1\,]\begin{bmatrix}1 & 0 & 0 & 0\\ 0 & \cos R_x & \sin R_x & 0\\ 0 & -\sin R_x & \cos R_x & 0\\ 0 & 0 & 0 & 1\end{bmatrix} \quad (5)$$

(2)Transforming 3D CAD figure into 2D CAD figure

The rotated 3D CAD figure is transformed into 2D CAD figure as follows. The coordinate (AX_1,AY_1,AZ_1) of a vertex of 3D CAD figure is transformed into 2D coordinate (MX_1,MY_1,SC) of 2D CAD figure. The imaginary screen (PS) and the view point(E) are set on Z axis as $(0,0,SC)$ and $(0,0,-DI)$. 2D coordinate on PS is calculated from the equation (6) (see Fig. 2.).

$$MX_1=(DI+SC)AX_1\,/\,(DI+AZ_1)$$
$$MY_1=(DI+SC)AY_1\,/\,(DI+AZ_1) \quad (6)$$

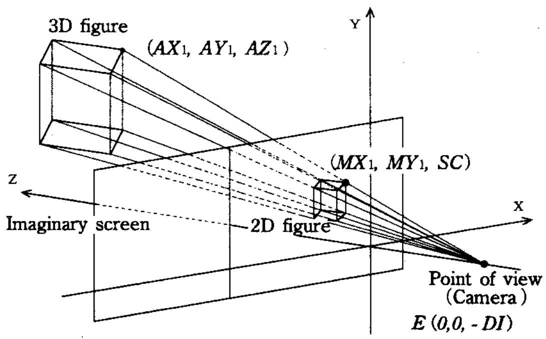

Fig.2 3D CAD figure transformed into 2D figure

3.1.2 Comparing 2D input image with transformed 2D CAD figure

Transformed 2D CAD figures which are looking at any view point on rotating in any direction is made by 3D CAD figure. Since the cameras are located at different positions, the different 2D images of an object are compared with transformed 2D CAD figures. And the sort and direction of an object are determined. The comparing method is applied the 2D comparing method.

This method is very useful to inspect an object and the assembly accuracy. The template of inspection area in 2D figure is made from 3D CAD. An object is inspected by comparing the inspection area in the input image from a camera with the template of transformed 2D CAD.

3.2 Comparing 3D coordinates of vertexes by IP with those of 3D CAD figure

3.2.1 3D coordinates of vertexes from some images

The 3D coordinates of vertexes from some images is calculated by three images of three cameras ($C_1 \sim C_3$) (see Fig. 3.).

(1) Basic surface

We define the basic surface which is parallel to the CCD surface of each camera. The ratios α_{xy} and β_{xy} are calculated by the relation of the points (X,Y,Z_0) on the basic surface and the points (CX,CY) on the CCD surface by the equation (7) .

$$X=\alpha_{xy}\cdot CX \quad , \quad Y=\beta_{xy}\cdot CY \qquad (7)$$

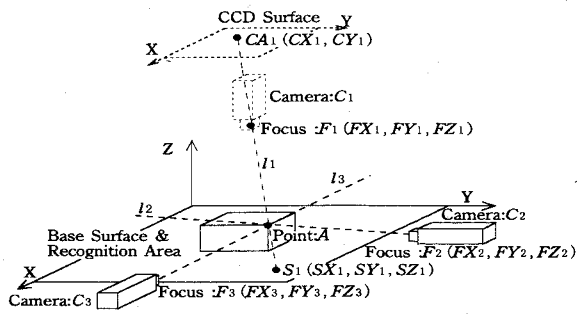

Fig.3 Recognition point and location of camera

(2) Calculation of 3D line l_1

A point (A) on an object is determined in the input image of the camera (C_1). As the coordinate of the point A in the input image is put as $CA_1(CX_1,CY_1)$. The point $S_1(SX_1,SY_1,SZ_1)$ is determined by the coordinate of the point CA_1 by the equation (8).

$$SX_1=\alpha_{xy}\cdot CX_1 \quad , \quad SY_1=\beta_{xy}\cdot CY_1 \quad , \quad SZ_1=Z_0 \qquad (8)$$

The point A exists on the line l_1 in the equation (9) which passes through the focus $F_1(FX_1,FY_1,FZ_1)$ of the camera C_1 and the point S_1.

$$l_1:\ \frac{X-FX_1}{L_1}=\frac{Y-FY_1}{M_1}=\frac{Z-FZ_1}{N_1} \qquad (9)$$

Where,

$$L_1=FX_1-SX_1 \ , \ M_1=FY_1-SY_1 \ , \ N_1=FZ_1-SZ_1$$

(3) Line ll_1 in the input image of camera C_2

We determine the surface (NA) which contains the line l_1 and the focus $F_2(FX_2,FY_2,FZ_2)$ of the camera C_2. And the line ll_1 which is the cross of this surface NA and the CCD surface of the camera C_2 is calculated by the equation (10) (see Fig 4.).

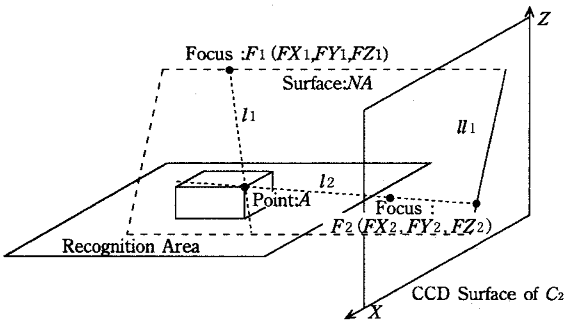

Fig.4 Recognition method of the same point

$$ll_1:\ \left(\frac{M_1(FZ_1-FZ_2)-N_1(FY_1-FY_2)}{L_1(FY_1-FY_2)-M_1(FX_1-FX_2)}\right)X+Z=\left(\frac{M_1(FZ_1-FZ_2)-N_1(FY_1-FY_2)}{L_1(FY_1-FY_2)-M_1(FX_1-FX_2)}\right)FX_1 + \left(\frac{L_1(FZ_1-FZ_2)-N_1(FX_1-FX_2)}{M_1(FX_1-FX_2)-L_1(FY_1-FY_2)}\right)(FY_1-CY_0)+FZ_1 \qquad (10)$$

$$EV_q=\left[\sum_{\substack{a=1\\a\neq b}}^{ms}\sum_{b=1}^{ms}\left\{\min_{\substack{1\le i_1\le nv_q\\1\le i_2\le nv_q, i_1\neq i_2}}\left(\left|D(a,b)-CD_q(i_1,i_2)\right|\right)\right\}\right]$$

Where, (X,CY_0,Z) is a point on the CCD surface of C_2

The line ll_1 is projected the line l_1 on the CCD surface of the camera C_2. Since there is the point A on the line l_1 in the input image of the camera C_2. The point $CA_2(CX_2,CZ_2)$ which is projected the point A on the CCD surface of the camera C_2 is determined by searching on the line l_1.

The line l_2 is determined by the point CA_2. And the line l_3 of the camera C_3 can be determine using the same method.

(4) 3D coordinate of point A

The 3D coordinate of point A is determined by three lines ($l_1 \sim l_3$), as follow (see Fig 3.). The intersection (CP_1) of the line l_1 and l_2 and the intersection (CP_2) of the line l_1 and l_3 are calculated. If the distance of CP_1 and CP_2 is in a given tolerance, then the 3D coordinate of the point A is determined as the middle point of the points CP_1 and CP_2.

3.2.2 Selecting two using cameras

If many cameras are installed around the recognition area, two cameras should be selected to recognize an object. The selecting method of the using cameras are as follows. The lines which through the recognition point and the focus of each cameras are calculated in the input image of the camera C_1. We examine to exist the disturbance on each lines and select the cameras which are able to capture the recognition point (see Fig. 5.). If selected cameras are two or more, the two using cameras are determined as follows.

(1)If selected cameras are two, then they are used to recognize 3D coordinate of vertex.

(2)If selected cameras are three or more, then we find the two cameras which are installed on the nearest p/2 in the selected cameras. They are used to recognize 3D coordinate of vertex.

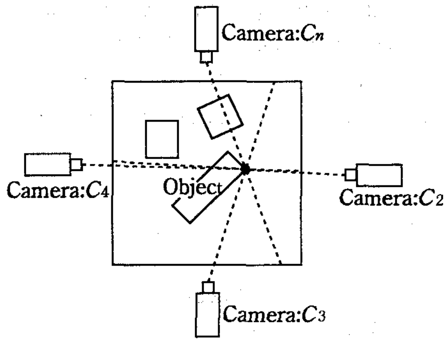

Fig.5 Selecting the using camera

3.2.3 Comparing 3D coordinates of an object with those of 3D CAD figure

3D coordinates of vertexes of an object are compared with those of 3D CAD figure. We calculate three or more vertexes V_p (p=1,2,...,ms) from IP. The recognition method using vertexes are as follow.

(1) Comparing distance among the vertexes

The distance $D(p_1,p_2)$ between the vertex V_{p1} and V_{p2} of an object is calculated. The distance $CD_q(i_1,i_2)$ between the vertexes of 3D CAD figures CK_q is compared with $D(p_1,p_2)$, and calculate the coincidence value (EV_q) by the equation (11). The set S_1 consists CK_q whose coincidence value (EV_q) is less than some given value in the equation (12). The number of figures contained in set S_1 input as CK_{qs}.

$$EV_q=\left[\sum_{a=1}^{ns}\sum_{\substack{b=1\\a\neq b}}^{ns}\left\{\min_{\substack{1\leq i_1\leq nv_q\\1\leq i_2\leq nv_q, i_1\neq i_2}}\left(\left|D(a,b)-CD_q(i_1,i_2)\right|\right)\right\}\right] \quad (11)$$

$$S_1=\left\{CK_q \mid EV_q<\varepsilon \quad (q=1,2,\cdots,ns)\right\} \quad (12)$$

(i)If $S_1=f$, then the following process is not executed and the sort of an object is nothing in the 3D CAD figures.

(ii)If $S_1 \neq f$, then the following process is executed.

The direction of 3D CAD figure contained in the set S_1 using the normal direction which is calculated from three vertexes, and 3D CAD figures rotate to the recognized direction.

(2) Determination of sort and direction.

The sort and direction of an object is determined by the relation of the coordinate of V_p and the height from recognition area.

The coincidence value (HV_q) is calculated by the equation (13), and determined the sort CK_{q0} using the coincidence value (HV_q) by the equation (14).

This recognition method is useful to recognize the many sort of parts.

$$HV_q=H-\min_{\substack{1\leq i\leq nv_p\\1\leq r\leq nr_p}}\left\{ZCV_{q_i}(r)\right\} \quad (13)$$

$$HV_{q_0}=\min\left\{HV_q \mid CK_q\in S_1\right\} \quad (14)$$

Where, $ZCV_{qi}(r)$ is the Z-axis value of the V_p after rotation. H is the Z-axis value of the recognition area.

4. CONCLUSION

We proposed the method to recognize the sort and direction of an object using 2D or 3D CAD information. The characteristics of this method are as follows.

(1)We propose the characteristics which are used to recognize the sort of an object by 2D and 3D CAD information.

(2)The 2D figure is represented by the characteristics, that is, center of gravity, contour, distance between the center of gravity and contour, and FFT.

(3)3D coordinate of vertex is determined by IP using three cameras. And We propose the recognition method of sort and direction of an object using the 3D coordinate of vertexes of IP and 3D CAD figure.

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