World Academy of Science, Engineering and Technology
International Journal of Computer and Information Engineering
Vol:3, No:2, 2009

3D CAD models and its feature similarity

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Abstract**—**Knowing the geometrical object pose of products in manufacturing line before robot manipulation is required and less time consuming for overall shape measurement. In order to perform it, the information of shape representation and matching of objects is become required. Objects are compared with its descriptor that conceptually subtracted from each other to form scalar metric. When the metric value is smaller, the object is considered closed to each other. Rotating the object from static pose in some direction introduce the change of value in scalar metric value of boundary information after feature extraction of related object. In this paper, a proposal method for indexing technique for retrieval of 3D geometrical models based on similarity between boundaries shapes in order to measure 3D CAD object pose using object shape feature matching for Computer Aided Testing (CAT) system in production line is proposed. In experimental results shows the effectiveness of proposed method.

Keywords**—**CAD, rendering, feature extraction,feature classification.

I. Introduction

IN digital image processing topics, boundary detection is most fundamental problems. At present, many methods have been introduced in the engineering literature. The object image can be understood from boundary information or region information of related image. In 3D view of object, information of image from projection can be made by rendering the model in some projection platform after converting the information of CAD of the object model. Boundary brings some information of object by representing into outline. If the image information with this boundary by calculating shape with some shape descriptor can be understand beforehand, surely the calculation of the shape of object of any objects shape without pre information is essential. In previous studies, image features such as intensity, texture, color, are viewed as boundary. Thus, a variety of operators using the first derivative of gray scale or texture can be used to detect this discontinuity. To obtain the accuracy of boundary, a refinement of boundary on basis of initial plan is necessary. Statistical methods can also be introduced in boundary detection. These methods have modeled the boundary as a deterministic signal and the noise as random signal with distribution function. Other approaches to boundary detection involve the use of transformation. Here, transformation is include rotation, translation and scale change.

Boundary of the target object can be understood in detail by doing some description on it. In this study,Fourier method had been concentrated in calculation . The reason behind this method it characteristic fulfill some criteria of shape representation. Basically, common criteria such invariance to translation, scale, rotation and symmetric transformations, scalability and efficiency, uniqueness and the most is robustness to distortion and noise. Above criteria should be fulfilled for shape representation for reliable shape retrieval and matching. In this paper, the proposal method to measure 3D object pose from designing stage of CAD data into calculation of object feature matching using MATLAB platform is proposed. In experimental results, the effectiveness of boundary information of the shape proof efficiency object matching (similarity) value during rotation estimation in some models is shown. This paper constituted as follows. Section III A, Generation of object model. In section III B, describe the flow of data transfer algorithm and rendering. Section III C, the feature extraction of the object. Feature classification of boundary based using Fourier Method in section III D. Experimental results are shown in section IV and discussion in section V and the conclusion.

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II. Related work

In Content Based Image Retrieval (CBIR) related literatures , researchers profound many relevant methods for multidimensional indexing, searching and matching have been proposed. For storing and retrieving shape descriptions in multidimensional index,Jagadish[1], introduce the maps shapes into constituent rectangles,where,keeps a few larger rectangles in a multidimensional index and uses area difference between a constituent rectangles of shapes as a similarity measure.Normalization process is done to preserve shape description for invariant under scaling and translation. This approach facing a difficulty when a shape can be normally covered by multiple set of rectangles. As a result, the ambiguity or storing multiple representations of the same shape.Moreover, the matching in the presence of rotation is not possible, for instance, when the two identical shapes may not match if one is rotated by 45 degree.

A study of retrieved partial similarity matches for storing the polygons has been made by Berchtold et al. [2].In his method, he do extract almost all possible boundary segments of polygons, transform each segments into sequence of slope changes, and map resulting sequence into a few Fourier coefficients. Each polygon represented using a set of feature points and the minimum bounding rectangle of these points for each polygon is stored in a multidimensional index. For Shape representation invariant to scaling and translation he also produces normalization process, but the problem facing that the starting point is not invariant. He proposed the solution by handling a storing multiple descriptions of a polygon, each associated to a starting point.

Above mentioned methods are less general than the proposed method in term of notion of similarity is fixed before evaluation of query process. In proposed method, a set of transformation to express the notion of similarity in query. In other words, the query had been evaluated using same index. A comparison of the performance using well known distance measure method as Euclidean and Cosine Angle had been considered .

III. Methods and Approach

A. Generation of object models

In most of image that selected in many literatures is that image taken in WWW browser for any categories of image according to purpose and applications. For CAD data generation require some knowledge of designing for single part or assembly parts. In this study, the generation of the single part of 3D model of simple casting part into consideration. The modeler using SOLID Works since solid works provide an interfacing to the system. So that, tedious programming work , such as reading CAD files and identifying individual surfaces is relieved. Designing the object shape is considered in a few aspects, where the model should having holes, corner curve, concave and convex whether in thin or thick in reasonable size as casting products. The model of CAD generation objects as Fig.1 shown.

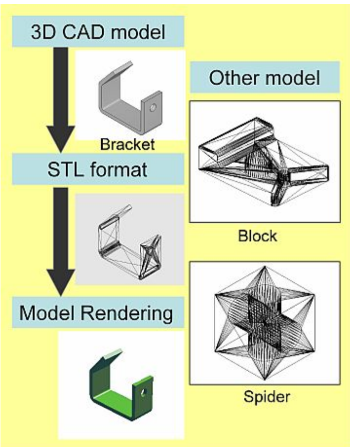

Fig. 1. Generation flow.

B. Data transfer and Rendering

From the generation of CAD data that had been explained in previous section. The proposed model database of each model is in ASCII STL format before conversion. This format has been chosen since it preserves the important information of model beside can easily generate the model back when it considered necessary. The environment using MATLAB platform for model transformation and rendering is applicable by our algorithm. A single camera in our projection unit to project the CAD model in the perspective projection view is used.

C. Feature extraction

1) Preprocessing: The preprocessing of image is done to extract the input image into boundary image or contour image before calculating the shape description of the object. The outline silhouette that had been choosen in our research can be described as single closed curve. The boundary image in our study is the outline of the object shape. In rendering process, some illumination noise in the projection image as for real projection system has been generated. In order to verify the algorithm is noise sensitive, the additional noise such Salted and Pepper noise in some range is applied in projection image in database. Preprocess the image by filtering noise using median filter and adaptive median. The binarization image is according the Histogram Equalization and Edge image extraction using Adaptive threshold method. The preprocessing flow is shown in Fig.2.

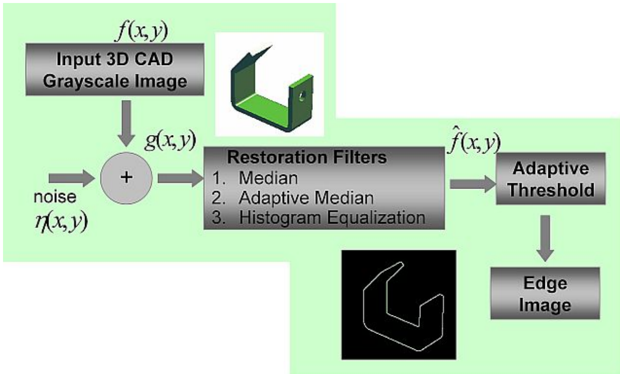

Fig. 2. Preprocessing flow.

2) Parameterization of the boundary: Let consider P points in digital boundary of the shape on xy-plane. Traveling the boundary anti clockwise keeping constant T seconds and Keep the coordinate every second. So, a complete set of coordinates describing the boundary. The complex coordinates of the complete boundary can be written as;

$$s(k) = x_k + iy_k \tag{1}$$

For k=0, 1, 2, P-1.which is periodic with P. The Fig.3 shows the coordinate system where x-axis treated as real axis and the y-axis as imaginary axis of a sequence of complex numbers.

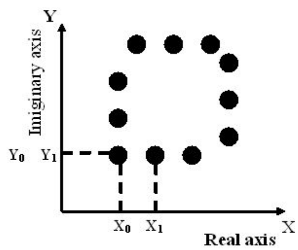

Fig. 3. Coordinate System.

3) Applying Fourier Transform: The discrete Fourier Transform of s(k) gives

$$a(u) = \frac{1}{N}\sum_{k=0}^{N-1} s(k)e^{\frac{-i2uk\pi}{N}} \tag{2}$$

For u=0,1,2,...,N-1. The complex coefficients a(u) are called Fourier descriptors of the boundary. Applying inverse Fourier Transform to a(u) restores s(k);

$$s(k) = \sum_{u=0}^{N-1} a(u) e^{\frac{i2uk\pi}{N}} \tag{3}$$

For k=0, 1, 2, N-1. The restored pixel value are exactly the same as the ones that started with. This coefficients also called Fourier descriptors, describe the shape of the object in frequency domain. The transformation is loss-less since the energy in the frequency domain is the same as the energy in the spatial domain (due to Parseval's theorem) and also the inverse Fourier Transform gives the original boundary function.

D. Feature classification

1) Shape matching using Euclidean distance: To match the boundary image from database, the representation of edge using above equation can be considered as the boundary function

$$s(k) = x_k + iy_k; \tag{4}$$

$$s'(k) = x'_k + iy'_k; \tag{5}$$

(for k=0,...,N-1). A typical measure of similarity between two boundaries in Euclidean distance,which corresponds to mean square error and which is also directly related to the cross correlation[3].

$$Dist(s, s') = \sqrt{\sum_{k=0}^{N-1} |s_k - s'_k|^2} \tag{6}$$

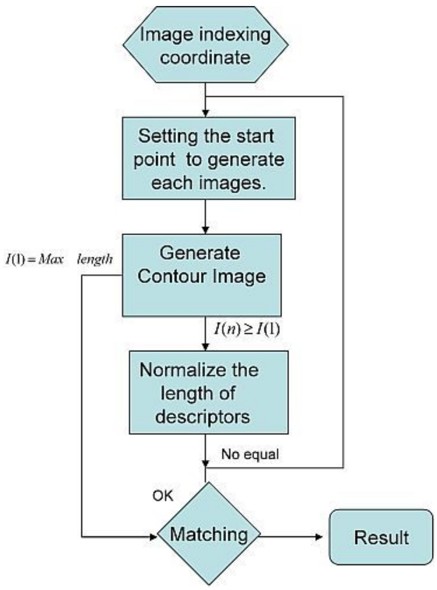

Fig. 4. Indexing flow.

In Fig.4 shows the steps to normalize descriptor length during calculating Fourier descriptor. I(1) is for target image(Pose 0) in our database and I(N) is query in database that length will normalized.

2) Shape matching using Cosine distance: It can be considered the similarity between two boundaries in Cosine Distance using the cosine of the angle between two vectors. Here, equivalent to their inner product after each has been normalized to have unit length higher values for more similar vector.

$$Dist_{cos} = \frac{\sum_{k=1}^{N} s_k * s'_k}{\sqrt{\sum_{k=1}^{N} s_k^2 \sum_{k=1}^{N} {s'_k}^2}} \tag{7}$$

IV. Experimental results and discussion

A. Example database

In this section, describe a set of experiments data of CAD model image in our database for evaluating similarity performance. The candidate's image is in grayscale images (560 X 420 pixels). In Table I,the image taken in range of [0,360] for each 1 degree one pose in rotation of Z axis of geometrical system coordinate. Preprocessing the image as mention in previous section and calculating the image boundary feature vector in feature classification and similarity matching.

TABLE I
Candidates Image

Rotation	Angle Value
Z axis (CW)	[0,1,2,3,...,359,360]

In order to explore the characteristic each model of object while rotation is performed the similarity matching toward clock wise(CW) is considered in calculation as shown in Table II.

TABLE II
Matching sets

Direction	Matching sets
(CW)	[0-0,0-(1),...,0-(360)]

B. Experimental results

In this section the results for model in database is presented. The Bracket object result shown in Fig.5 for Euclidean result and Fig.6 represented Cosine result for shape matching data. From the result of rotation of CW direction of each degree. In both distance method, the graph drastically change when reach pose at rotation degree 36,76,135,171,216,269,304 and return back to origin pose. Details of the pose of rotated shape in Fig.7, here let consider the CW direction into consideration for Fig.5. From Pose changes figure the pose at rotation 36 degree is in convex while the origin pose is in concave is can be understand,the matching sets shows disimilarity value high. Also, the same phenomena happen while rotated at 216 degree. The rest of rotation degree from 76 degree to 171 degree,the similarity value keep below 0.4 and so on for 269 degree to 360 degree. For Euclidean best matching value is closed to 0. In Fig.6.The similarity using Cosine method where the best similarity value closed to value 1. Eventhough, the value of similarity change is in small range from 0.92 to 1.0,

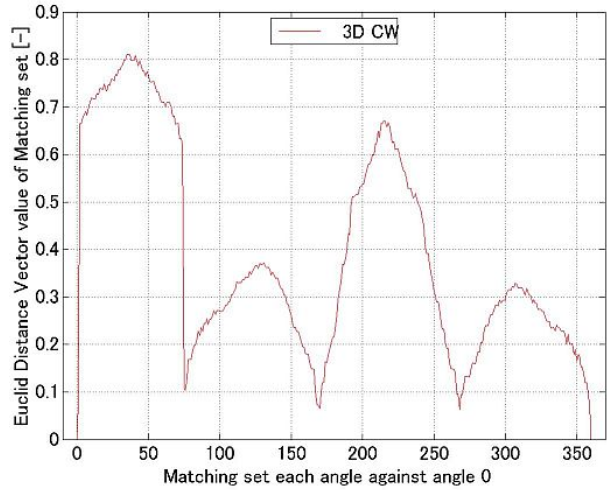

Fig. 5. Euclidean result for Spider object

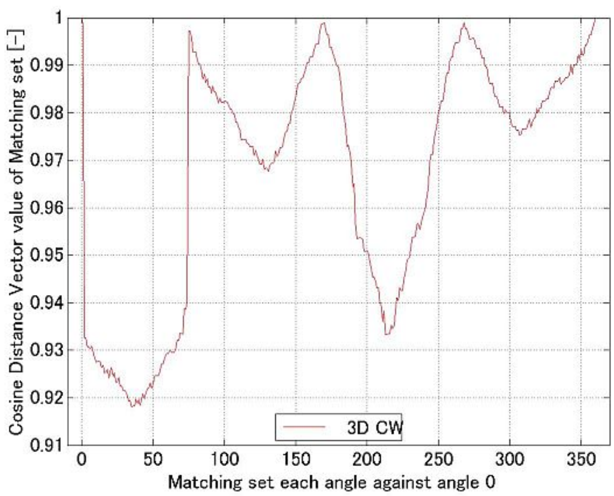

Fig. 6. Cosine result for Spider object

but the tendency of graph change is same as Euclidean distance method was found. n-best matches is can be considered as range of pose changes effected in region 0 to 90,91 to 180, 181 to 269 and 270 to 360 range.

C. Applications

For application purpose ,two different feature object of 3D models into consideration is had been paid.In Fig.8 and Fig.9 represented the similarity of Flat object model(called Block) and Cube object with hole in center(called Spider).In both similarity graph shows that similarity is more higher compare to bracket model, where for Block Model the similarity value keep below 0.4 for almost rotation pose and the spider object show below 0.3 value. The Block object graph also shown 4 region value changes during pose rotation and Spider Object shows more than 4 region changes due to Spider object outline pose change is very small.

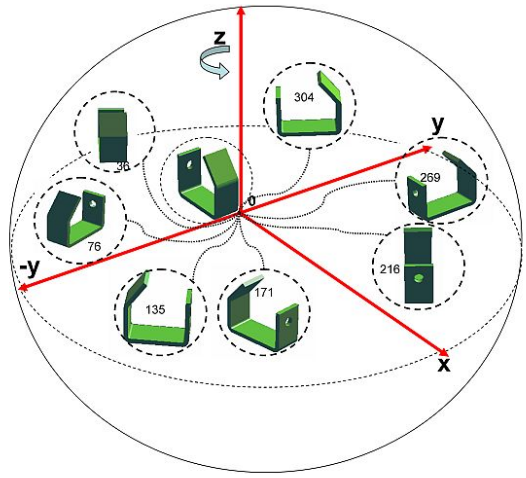

Fig. 7. Pose Changes(Shape of pose rotation at origin)

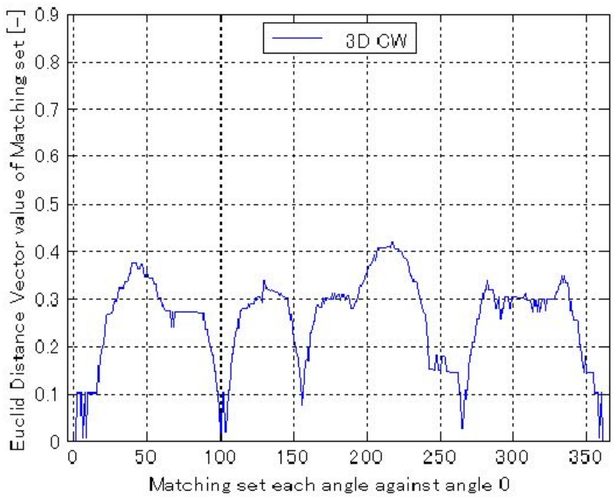

Fig. 8. Euclidean result for Block object

D. Discussion

In calculation of boundary edge using Fourier descriptors for rotation estimation of pose against original pose show some change for bracket object while rotated in CW direction is confirmed. This distance matching of above pose bring independent value changes according to boundary representation as can be understand in Fig.7 shown. Using method of angle

TABLE III
N BEST MATCHES REGION OF 3 MODELS

Items	0-90	91-180	181-270	271-360
Bracket	0.7197	0.2755	0.5078	0.2392
Block	0.2728	0.2805	0.3076	0.2966
Spider	0.1318	0.2037	0.1636	0.0996

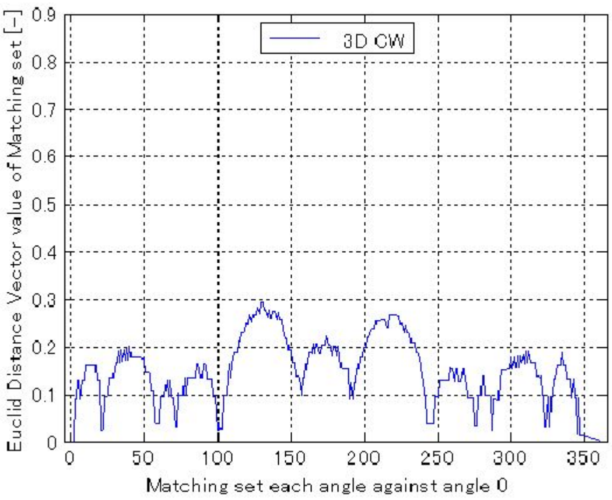

Fig. 9. Eucliden result for Spider object

between two vector bring small value of dissimilarity compare to boundary equation.In table 3, using the Euclidean distance method result as shown in Fig.5, Fig.8 and Fig.9 the n best matches value for 4 related region had been calculated.From the table 3, it clearly understand that Spider object show the high similarity value for all region compare with the Block object preserve the small changes in all region.

V. Conclusion

In this paper, the novel method for object pose estimation using 3D CAD model information into silhouette boundary has been proposed. Descriptors with fixed number of coefficients is calculated for Euclidean distance and Cosine distance. Total 36 matching sets of rotation every 1 degree for 360 poses versus pose 0 was used. Object poses were recovered by interpolating the poses corresponding to n-best matches. The feature of 3D object from it boundary can introduce the changes value of it pose while rotated compare to origin pose.

Acknowledgment

This research was supported in part by Global COE Program ”Frontiers of Intelligent Sensing ”, MEXT, Japan .

References

[1] Jagadish HV. ”A Retrieval technique for similar shapes”. In. Proc ACM SIGMOD International Conference on Management of DATA, Denver, Colo, USA, 1991, pp.208-217.
[2] Berchtold.S,Keim D.A, Kriegal HP. ”Using extended feature objects for partial similarity retrieval”, VLDB J(6), 1997, pp.333-348.
[3] Davood Rafiee and Alberto 0. Mondezon. ”Efficient retrieval of similar shapes”, VLDB J(11), 2002, pp.17-27.
[4] D.S.Zhang and G.J.Lu, ”Shape Retrieval Using Fourier Descriptors.” Int. Conference on Multimedia and Distance Education. Fargo, ND, USA, June 2001.
[5] M.Sonka,V.Hlavac, R.Boyle, *Image Processing, Analysis, and Machine Vision*, Second Edition, Brooks /Cole Publishing Company, 1999, pp.240-248.
[6] J.BOHM,C.BRENNER,Others, ”Automated Extraction of Features from CAD Models for 3D object recognition.” ISPRS, Vol.XXXIII, Asmeterdam, 2000.
[7] The Mathworks, *Image Processing toolbox User’s Guide, Version 5*, The Mathwork, Inc. Natick, MA., 1993-2005.
[8] Zahn C.T.and Roskies R.Z. ”Fourier Descriptors for Plane Closed Curves”. IEEE Transactions on Computers, March 1972, Vol.C21, No,pp.269-281.
[9] Hui .C, Ohnishi.N, and Others. ”Retrieval-Combination Approach to estimate 3D Human Pose from Monocular Image.” ITE, 2007, Vol.61, No.2, pp223-233.
[10] Solid Works(1995) Solid works 2001 plus. USA, Massachusetts: Solid Works corporation.
[11] S.Ekvall,D.Kragic,F.Hoffman,Öbject recognition and pose estimation using color and geometric modeling.” Journal of Image and Vision Computing 23, 2005, pg 943-945.
[12] A.B.Elmi, T.Miyake, Z.Zhang and T.Imamura, ”Shape representation and matching for Computer Aided Testing System,Precision Engineering Japan Fall Conference”, 2006, pg. 717-718.

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