**Object Position/Pose Estimation Algorithm by Using Fourier Descriptor**

ELMI BIN ABU BAKAR, "à, L, ŽO, –x

E-mail:{elmi,naito,miyake,horihata}@keisy.tutpse.tut.ac.jp

Tel:+81-532-44-6710 Fax:+81-532-44-6690

---

1. **Introduction**

Recently, in manufacturing industry, Computer Aided Testing (CAT) is the latest important technology. It’s because CAT exists in a final stage in following flow of manufacturing: 1. Design → 2. Production → 3. Quality Control by Testing. This technology had been developed in order to overcome the former method by 3D Measuring Instrument that consume a lot of time for examine one object. If the object position/pose is known in advance before measurement, much time can be reduced. Moreover if the system is constructed by using comparatively inexpensive methods, the complete testing can be conducted in many production lines such as casting, molding and press.

The research on image based measurement of object under multi-perception of view and angle has been proposed. The method is using the shape description since it’s known as robustness, compactness, low computation complexity and perpetual similarity measurement. Therefore, object pose estimation algorithm by Fourier Descriptor had been selected in our research. The aim in our method is to estimate the object pose in 1 degree accuracy.

2. **Method**

a) **Preprocessing Shape Image**

Basically, our research mainly concentrates on pose estimation. Pose estimation in our method is divided into two parts, the first is the projection image as input image is stored to recognize the model database. The second one is designing the 3D geometrical model of object. Here, the CAD data of multi rotation view is stored in database for preprocessing purpose.

b) **Cumulative angular function**

Shape can be represented by boundary angles but due to that tangent angle function \( \theta(l) \) can only assume value \((-\pi, \pi)\) or \((0, 2\pi)\). Therefore, \( \theta(l) \) contains discontinuities of size \( 2\pi \). The Cumulative angle function \( \varphi(l) \) defined by next amount of angular bend between the starting point \( z(0) \) and position \( z(I) \) on the shape boundary. Here, \( L \) is overall perimeter.

\[
\varphi(l) = \theta(l) - 2\pi \frac{l}{L}
\]

We expand \( \varphi(l) \) into a Fourier series;

\[
\varphi(l) = \sum_{k=0}^{\infty} a(n)e^{-jn\theta(l)}
\]

The set of modules of coefficient \( a(n) \) called Fourier Descriptor(FD) of the shape. We normalized them by dividing each of the first value. Finally, the following feature vectors are used as the Fourier Descriptor to index shape.

\[
f = \begin{bmatrix}
a(1) & a(2) & \ldots & a(N/2) \\
a(0) & a(0) & \ldots & a(0)
\end{bmatrix}
\]
c) Create a database

i) 3D geometrical model

Our proposed method based on model of CAD database. The idea is to create a multi rotation view. We consider rotation in pan direction as Fig.3.0 shows.

![Fig.3.0 Geometric Configuration](image)

ii) Projection in Stereo Vision

As for our target image we projected the object by stereo vision. The projection image as input image and its image is stored to recognize the model of CAD database.

3. Similarity Measures

Similarity measures of the query shape and the target shape in database is simply the Euclidean distance between the query and target shape feature vectors.. Suppose the significant shape features are selected and recorded as a one-dimensional vector and expressed as:

Target: \( f_T = [f_{T1}, f_{T2}, f_{T3} \ldots, f_{Nc}] \)

Query: \( f_Q = [f_{Q1}, f_{Q2}, f_{Q3} \ldots, f_{Nc}] \)

The distance measure between two vectors in the feature space can be calculated as similarity measurement

\[
\text{d} = \sqrt{\sum_{i=1}^{Nc} \left| f_{Ti} - f_{Qi} \right|^2}
\]

Where, \( Nc \) is the truncated number of harmonic needed to index the shape.

4. Experimental Result

In this section, we present the simulation result of CAD database pose similarity and projection pose similarity beforehand. The image has a size of 128 x 128. From the simulation of 3D geometrical model of 1 degree rotation in Pan angle direction, we showed the result in Fig.4.0.

![Fig.4.0 Simulation on 1 degree rotation](image)

Above is the result of simulation on CAD for every 1 degree rotation. Similarity (d) value increase when more rotation angle is applied. Here, the estimation of 1 degree rotation toward similarity value as range 0.03~1.50.

In order to calculate the position/pose estimation of the object we choose the 4 poses of CAD database into consideration. Each object pose is rotated in 90 degree changes from the previous pose. We defined the pose of that rotation, as Pose 1, Pose 2, Pose 3 and Pose 4 and we described it in Fig.5.0

![Fig 5.0 Pose for simulation](image)

<table>
<thead>
<tr>
<th>Pose</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.2358</td>
<td>0.4814</td>
<td>0.1796</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>0.2358</td>
<td>0.5576</td>
<td>0.1733</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>0.4814</td>
<td>0.5576</td>
<td>0.5716</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>0.1796</td>
<td>0.1733</td>
<td>0.5716</td>
<td></td>
</tr>
</tbody>
</table>

![Table 1.0 Pose similarity](image)

In Table 1.0 we show the result of pose similarity of above Fig.5.0 pose simulation. From this table we understand that similarity value(d) in pose 2 against the other pose show in high value of similarity. Since for all pose we did a rotation on 90 degree changes. The results of this above pose simulation of 4 are in accuracy range of 0.17 ~0.57. We consider we able to get more sufficient accuracy ±0.1 degree in experimental since the simulation result in Fig 4.0 and Table 1.0 show the sufficient accuracy in our calculation.

5. Conclusion

In this paper, we proposed the novel method for Position/Pose estimation by using Fourier Descriptor. The outline figure of silhouette image is transformed into spectrum graph. Based on feature vectors from that spectrum results we calculate d the similarity by Euclidean distance.

Through the simulation results, we showed that this method performs sufficient accuracy in pose estimation. Therefore, the proposed method is very effective in practical use.

As a future subject, we will make an experiment to confirm the feasibility of this method in practical use. Later, we will apply this system to task of inspecting the parts.

6. References


(2) D. S. Zhang, G. J. Lu, “Shape Retrieval Using Fourier Descriptors”. Int. Conference on Multimedia and Distance Education. Fargo, ND, USA, June 2001.