3-D OBJECT RECOGNITION USING APPEARANCE MANIFOLD WITH COVARIANCE MATRIX

Lina*, Tomokazu Takahashi, Ichiro Ide, Hiroshi Murase (Nagoya University)

1. INTRODUCTION

Parametric Eigenspace (PE) method, proposed by Murase and Nayar (see [1]), has shown high recognition capability in recognizing 3-D objects. In PE method, images of each object for each illumination direction are mapped to the eigenspace to obtain a manifold parametrized by the object pose. Next, the shortest Euclidean distance will classify the object to its class. However, this method could not give a satisfying recognition result when it deals with noisy images.

As we deal with objects with various viewpoints and their images are influenced by the presence of noise, it is important to add class-density information, such as covariance matrix, to the system. Our objective is to develop a robust 3-D object recognition system for recognizing noisy images by extending PE method using covariance matrix as a function of viewpoint. Specifically, we propose the Appearance Manifold with Constant Covariance matrix (AMCC) and Appearance Manifold with View-dependent Covariance matrix (AMVC). In AMCC, we use a constant value of covariance matrix obtained from the average value of all covariance matrices for each manifold. In AMVC, the covariance matrix value changes for each viewpoint for each manifold. Experimental results showed that our approach could enhance the recognition performance, as well as perform robust recognition of 3-D objects under varying viewpoints and translation effects.

2. METHODOLOGY

The eigenspace framework provides a good and efficient start to represent object features in a low dimensional space. Transforming images from image space with Karhunen-Loeve method gives us some discrete points in eigenspace. As we train several images related to an object with different viewpoints, their feature points in eigenspace could be assumed to lie on a manifold that continuously relate one point in one view to other points in other views of the same object. However, the problem becomes more complex when some uncontrollable noises appear in the real-world images. To deal with this problem, in our approach we consider using the covariance matrix to perform a more robust classifier. Fig.1 illustrates an appearance manifold with covariance matrix calculation for one object with various viewpoints in the eigenspace.

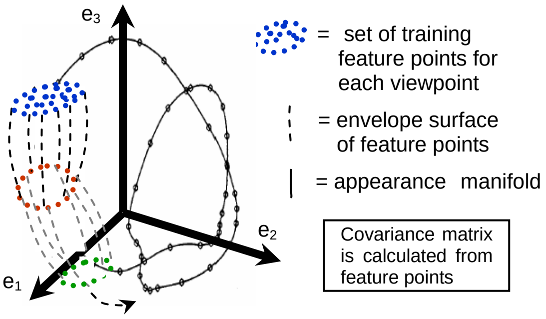

Figure 1. Appearance manifold with covariance matrix

For each θ viewpoint-class in each p manifold, we calculate the average sample vectors ($\mu^{(p)}(\theta)$) and the covariance matrix ($\Sigma^{(p)}(\theta)$). In AMVC, we make a continuous curve which is parameterized by viewpoint rotation (θ) using interpolation method. Thus, we have the manifold of average sample vectors ($\tilde{\mu}^{(p)}(\theta)$) with covariance matrix ($\tilde{\Sigma}^{(p)}(\theta)$). While in AMCC, we simply apply the average value of $\Sigma^{(p)}(\theta)$ to each $\tilde{\Sigma}^{(p)}(\theta)$ and calculate $\tilde{\mu}^{(p)}(\theta)$ in the same way as in AMVC above. Finally, we use the Regularized Mahalanobis distance [2] measurement to classify an object y:

$$d^{(p)}(y) = (y - \tilde{\mu}^{(p)}(\theta))^T [(1-\lambda)(\tilde{\Sigma}^{(p)}(\theta) + \varepsilon I)^{-1} + \lambda I](y - \tilde{\mu}^{(p)}(\theta))$$

3. EXPERIMENTAL RESULTS AND ANALYSIS

To demonstrate our proposed method's performance, we conduct experiments to recognize 10 objects with various 3-D basic shapes with various viewpoints and translation effects. For each object in the training stage, we trained the system with original-captured images and generated images with artificial noises for every 10 degree interval of horizontal positions. While in the testing stage, images of objects were 5 degree shifted from every training image and influenced with various translation effects. In PE, we classified a testing image based on its minimum Euclidean distance to the original-captured images only. However, for AMCC and AMVC, we calculated the minimum Regularized Mahalanobis distance as explained in Section 2 above. Fig. 2 shows the recognition results of the PE, AMCC, and AMVC methods.

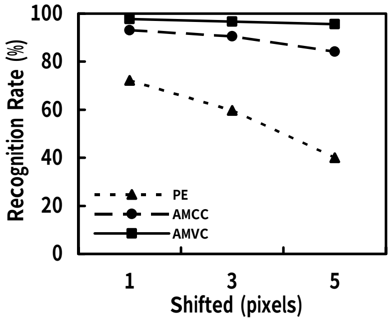

Figure 2. Recognition rates for 3-D objects with translation effects

As can be seen in Fig. 2, our proposed AMVC method gave the best recognition rates compared with AMCC and PE method. Also, AMVC method showed its robustness to the presence and increment of the translation effects in 3-D recognition system.

REFERENCE

[1] H. Murase and S.K.Nayar: IEEE Trans. PAMI, Vol.16, No.12, pp.1219-1227, 1994

[2] J.Mao and A.K.Jain: IEEE Trans. NN, Vol.7, No.1, pp.16-29, 1996