Appearance-based Object Recognition:
Parametric Eigenspace Representation

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We have developed a new compact representation of object appearance: *parametric eigenspace representation.* A large image set is compressed to obtain a low-dimensional subspace, called the eigenspace, in which the object is represented as a parametric manifold. This appearance representation is a valuable tool for a variety of computer vision applications. I will present several applications in this talk.

(1) Appearance-based Object Recognition [1]

We address the problem of automatically learning object models for recognition and pose estimation. In contrast to the traditional approach, we formulate the recognition problem as appearance matching rather than shape matching. The appearance of an object in a two-dimensional image depends on its shape, reflectance properties, pose in the scene, and the illumination conditions. While shape and reflectance are intrinsic properties of an object and are constant, pose and illumination vary from scene to scene. We introduce a compact representation of object appearance that is parametrized by pose and illumination. For each object of interest, a large set of images is obtained by automatically varying pose and illumination. This large image set is compressed to obtain a eigenspace, in which the object is represented as a manifold. Given an unknown input image, the recognition system projects the image onto the eigenspace. The object is recognized based on the manifold on which it lies. The exact position of the projection on the manifold determines the object's pose in the image. We conducted experiments using several objects with complex appearance characteristics.

(2) Illumination Planning for Object Recognition [2]

I will now address the problem of illumination planning for robust object recognition in structured environments. Given a set of objects, the goal is to determine the illumination at which the objects are most distinguishable in appearance from each other. The set of images of all the objects is represented by the parametric eigenspace. The minimum distance between the manifolds of two objects represents the similarity between the objects in the correlation sense. The optimal illumination is therefore the one that maximizes the shortest distance between object manifolds. Results produced by the illumination planner have been used to enhance the performance of an object recognition system.

(3) Image Segmentation using Eigenspace Representation [3]

The method for segmenting object regions from a complex image by using appearance matching is addressed in this part. We refer to this process as image spotting. For a sample object to be learned, a large set of images obtained by varying pose and size is compactly represented by the parametric eigenspace representation. In the image-spotting stage, a partial region in an input image is projected into the eigenspace, and the location of the projection relative to the manifold determines whether this region belongs to the object. This process is sequentially applied to each location of the input image. This method can extract target objects of arbitrary pose and size.

(4) Robot Tracking of Visual Appearance [4]

Vision-based robot positioning and tracking is addressed. In contrast to previous approaches, inputs to the learning and tracking system are raw brightness images rather than image features, such as edges, corners, lines, and circles. The robot is first moved through several displacements with respect to its desired position, and a large set of object images is acquired. Variations in object images due to robot displacement are represented by the parametric eigenspace. While positioning or tracking, errors in end-effector coordinates are efficiently computed from a single brightness image using the parametric manifold in the subspace.

* This research was done jointly with Shree K. Nayar of Columbia University.

[References]

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