Efficient Circular Object Pose Determination

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Abstract This paper presents the efficient algorithms for the pose determination of a circular object with and without a priori knowledge of the object radius. The developed algorithms valid for a circular object are the result of the elaboration of Ma's work [2], which determines the pose of a conic object from two perspective views. First, the geometric constraint of a circular object and its projection on the image plane of a camera is described. The number of perspective views required for the object pose determination with and without a priori knowledge of the object radius is also discussed. Second, with a priori knowledge of the object radius, the pose of a circular object is determined from a single perspective view. The object pose information, expressed by two surface normal vectors and one position vector, is given in a closed form and with no ambiguity. Third, without a priori knowledge of the object radius, the pose of a circular object is determined from two perspective views. While the surface normal vectors are obtained from the first view, the position vector is obtained from the two views.

Keywords Pose Determination, Perspective View, Circular Object

1. Introduction

In computer vision and machine vision, the pose determination of an object in a scene has long been studied by many researchers. Most of the previous works used points or straight lines as image features and exploited their correspondence. However, it is very difficult and time consuming to establish the correspondence of these image features mainly due to their local properties. A few attempts were made to use more compact image features, such as curved surfaces, and conics, which have global properties. Since many man-made objects have conics on their surface, the use of a conic as a image feature seems practical.

Geometrically, a conic is the intersection of a cone and a plane, which is an ellipse, a parabola, or a hyperbola. So, the perspective projection of a conic on the image plane of a camera is always a conic. There are two methods for the pose determination of a conic object: direct method and indirect method. The direct method determines the position and the orientation of a conic object directly, whereas the indirect method determines the surface normal of plane on which a conic object lies.

The pose determination of a conic object in a scene can be decomposed into two problems: orientation determination and position determination. Such a decomposition is very important to obtain a closed form solution of the object pose without resorting to numerical methods. Safaee-Rad et al. [1] dealt with the pose determination of a circular object with and without a priori knowledge of the object radius. They defined a cone by the optical center of a camera and the projection of a circular object on the image plane. The object orientation is determined as the surface normal of a plane that intersects the cone and generates a circle. The object position was also determined but specific camera motion is assumed in the case of unknown object radius.

Ma [2] dealt with the pose determination of a conic object from two perspective views. With the wise choice of the world and the camera coordinate systems, he derived a simple form of the geometric constraint of a conic object and its projection on the image plane. Exploiting the correspondence of two conics, he solved the orientation and the position of a conic object using linear algebra. However, in the case of a circular object. his method can be significantly simplified both in formulation and computation.

Quan [3] also dealt with the pose determination of a conic object from two perspective views. Using the projective geometry, he derived the polynomial conditions which should be satisfied for a pair of corresponding conics. From the derived condition, he determined the surface normal of a plane that contains a conic object, which is the orientation of the object. Note that Quan's method is indirect in the object pose determination, while methods by Safaee-Rad et al. and Ma are direct.

In this paper, we present the efficient algorithms for the pose determination of a circular object with and without a priori knowledge of the object radius. The circular object pose determination algorithms are developed by elaborating the direct method by Ma [2]