Detecting Corners for 3D Objects

Misbah Irshad, University of the Punjab, Pakistan
Irfa Elahi, University of the Punjab, Pakistan
Malik Zawwar Hussain, University of the Punjab, Pakistan

ABSTRACT

In this paper, a corner detection algorithm for 3D objects is presented. This algorithm is an extension of corner detection scheme for planar objects (Chetrikov & Zsabo, 1999). This algorithm finds corners and other high curvature points for 3D objects.

Keywords: 3D Objects, Corner Detection, Corner Detection Algorithm, Curvature, Surfaces

1. INTRODUCTION

Corner points are very important to identify a shape. These points are also referred to as significant points. Detection of these points is not an easy task as exactness of detected corners can only be judged by human eye and no other standard criteria is existed. Then accuracy of any corner detection scheme can only be examined if the original corner positions are known. Correct detection of these points help to reverse engineer the shapes accurately. Generally corner detection can be defined as an approach which extracts the dominating features of an image and consequently helps deducing contents of the image. Corner detection can be used in many fields like motion detection, image registration, image mosaicing, video tracking, panorama stitching, object recognition and 3D modeling. Detecting corners has long been an area of interest to researchers in image processing and other areas of computer vision. There are a lot of schemes found in literature for planar objects (Beus & Tiu, 1987; Chetrikov & Zsabo, 1999; Freeman & Davis, 1977; Jyoti, Ratna, & Sainarayanan, 2011; Mikolajczyk & Schmid, 2004; Rosenfeld & Weszka, 1975; Rosenfeld & Johnston, 1973; Sarfraz, Asim, & Masood, 2006). Each of these algorithms takes a chain coded curve (Averbahi & Pratt, 1991; Hou & Wei, 2002) as an input which is converted into a connected sequence of grid points. A measure of corner strength is assigned to each point and corners are selected on the base of this measure. However, in 3D cases no contribution is seen to the authors’ knowledge.

A corner detection scheme for 3D shapes is discussed in this paper and found to be accurate and simple. It is a generalization of the scheme ((Chetrikov & Zsabo, 1999)). Some advantageous features of the purposed 3D scheme are:
• Each corner is detected once.
• It is computationally efficient.
• It is invariant to transformation changes.
• It is highly insensitive to the noise in the image.
• It is robust to minor changes in size and resolution.
• It is very suitable for natural shapes or objects. Independent tuning of the parameters can further fine tune the results if needed in some extreme case.

This paper discusses detection of high curvature points in surfaces. Planar scheme ((Chetrikov & Zsabo, 1999)) is reviewed in Section 2. Proposed approach is described in Section 3. The scheme is demonstrated with examples in Section 4. The paper is concluded in Section 5.

2. DETECTING CORNER POINTS IN PLANAR OBJECTS

In this section the method presented in Chetrikov & Zsabo (1999) is explained. In this algorithm a corner point is determined as a point where a triangle of specified angle can be inscribed within a specified distance from its neighbor points. The algorithm consists of two passes. First pass scans the sequence of points and picks out the candidate corner points. In the second pass, which is post processing step, superfluous candidates are removed.

2.1. First Pass

In the first pass a variable triangle \( \left(p^{-}, p, p^{+}\right) \) is inscribed on the each point \( p \) of the curve as shown in Figure 1. A point \( p_{i} \) is the candidate corner point if it satisfies the following three conditions:

\[
\begin{align*}
d_{\text{min}}^{2} \leq |p - p^{+}|^{2} & \leq d_{\text{max}}^{2} \\
d_{\text{min}}^{2} \leq |p - p^{-}|^{2} & \leq d_{\text{max}}^{2} \\
\alpha & \leq \alpha_{\text{max}}
\end{align*}
\]

where \( p \) is the point under consideration, \( p^{+} \) is the \( k^{th} \) clockwise neighbor of \( p \) and \( p^{-} \) is the \( k^{th} \) anti-clockwise neighbor of \( p \).

\[|a| = a = |p - p^{+}| \] is the distance between \( p \) and \( p^{+} \), \[|b| = b = |p - p^{-}| \] is the distance between \( p \) and \( p^{-} \). If \[|c| = c = |p^{+} - p^{-}| \] the distance \( p^{+}_{k} \) and \( p^{-}_{k} \).

The opening angle of triangle, \( \alpha \) can be found by using cosine law

\[a^{2} + b^{2} - c^{2} - 2ab \cos \alpha = 0\]

which implies

\[\alpha = \cos^{-1}\left(\frac{a^{2} + b^{2} - c^{2}}{2ab}\right)\]

Now each point \( p \) may have zero, one or more than one alpha values. Minimum value of \( \alpha \) among all \( \alpha \) values is chosen as \( \alpha \) value of the point \( p \).

2.2. Second Pass

In the second pass some extra points are eliminated (Figure 2). A candidate corner point \( p \) from the first pass is discarded if it has a sharper valid neighbor \( p_{v} : \alpha(p) > \alpha(p_{v}) \). A candidate point \( p_{v} \) is a valid neighbor of \( p \) if \(|p - p_{v}|^{2} \leq d_{\text{max}}^{2} \) or if it is adjacent to \( p \).

The values \( d_{\text{min}}, d_{\text{max}} \) and \( \alpha_{\text{max}} \) are parameters of the algorithm. Small values of \( d_{\text{min}} \) guarantees the fine corners and the upper limit \( d_{\text{max}} \) is necessary to avoid false sharp triangles formed by distant points in highly varying curves. This is the angle limit that determines the minimum sharpness accepted as high curvature.

This scheme is demonstrated in Figure 3, Figure 4, Figure 5, Figure 6, and Figure 7 for the circles of radii 1, 5, 10 and 15 respectively and the corresponding number of corner points detected is 0, 4, 9 and 0. It can be seen from the figures that by varying radius the number of corner points detected varies. In Figure 7,
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