EXTRACTING SURFACES OF REVOLUTION BY PERCEPTUAL GROUPING OF ELLIPSES

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Abstract

Ellipses seen in an image may be the 2D projection of 3D circles from the scene. Given this assumption, ellipses can be grouped into perceptual groups from which inferences about the 3D structure of objects can be made. In this paper methods are proposed for extracting groupings corresponding to surfaces of revolution. A Hough transform approach is used for grouping, after which the confidence in the plausibility of the perceptual group is improved by detecting symmetry groupings.

Introduction

The task of interpreting the 3D world from 2D images is inherently under-constrained. However, the problem can be made more tractable by recognising that certain three dimensional relationships between features in a scene give rise to two dimensional relationships in the image that are relatively viewpoint invariant and have a high probability of being non-accidental. The Gestalt movement proposed that the human visual system applies the principles of perceptual organisation to group image features showing those regularities. These are used to recover three dimensional structure from two dimensional views, providing cues to models for scene interpretation.

Recently we proposed several groupings of ellipses [1]. If ellipses detected in the image are assumed to be generated by circular features in the scene inferences can be made about the 3D structure of the generating circles. Here we examine surfaces of revolution, which are obtained by rotating a plane curve around a straight axis. Surfaces of revolution are particularly useful as they are a popular representation for modelling objects. The bottom-up extraction of surfaces of revolution can provide cues for model invocation.

Ellipse Detection and Parametrisation

Edges in images are approximated by straight lines and elliptical arcs [2]. Ellipses are parametrised by centre location (x_c,y_c), length of the minor and major axes (a,b), and orientation of the major axis (θ) in the image. Assuming the ellipse is produced by a circle, the tilt angle $\tau = \pm\cos^{-1}(^a/b)$. There are two possible values as no knowledge is available of the pose of the object. As the tilt tends to zero the ellipses become circular and the orientation becomes degenerate. The position of the centre detected by the ellipse finding algorithm is the correct centre for orthographic projection (assumed here). The accuracy of ellipse fit and hence tilt angle measurement depends on image noise, edge detection accuracy, and the actual tilt angle [3,4]

Perceptual Grouping of Ellipses

Previously we proposed a number of perceptual groupings of ellipses and described the 3D inferences that follow from each grouping [1]. This paper concentrates on the surface of revolution grouping which occurs when ellipses with the same major axis angle and tilt angle have centres lying on a straight line perpendicular to their major axes (figure 1). The grouping is invariant over all viewpoints except the few cases when the viewpoint lies in the plane of the circle, or when the circles are viewed straight-on, and the ellipses degenerate to straight lines or circles.

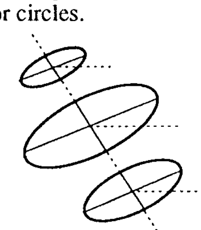

Figure 1. Surface of revolution ellipse grouping.

Method of Grouping

Grouping is determined using formulations of the Hough transform. A two stage process is used. First, parallel planar ellipses are grouped by tilt angle and rotation angle. Then the $\rho\theta$ Hough transform [5] groups those ellipses whose centres lie on a straight line perpendicular to the major axis. Finally the best centre line of the group is determined using linear regression on the centres of the ellipses. Typical bin sizes for the first stage are $\tau = 0.2$ radians and $\theta = 0.5$ radians. For the second stage reasonable results were obtained for a bin size for ρ of 40 pixels. A more general purpose approach to estimating bin size would be to probabilistically quantify the non-accidentalness of the grouping [6].

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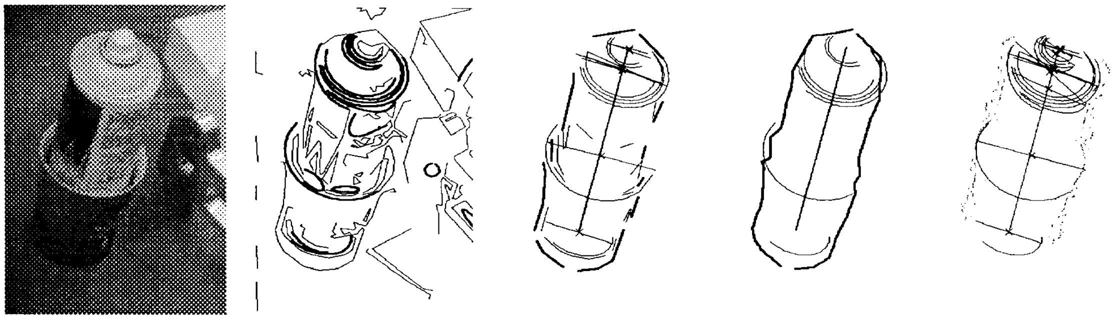

Figure 2a) original image. b) extracted lines and ellipses. c) surface of revolution and symmetric lines. d) reconstructed occluding contour. e) surface of revolution and symmetric pixels.

Methods of Improving Confidence

Once the surface of revolution grouping has been detected the confidence in the hypothesis can be improved by searching for supporting image features. Under orthographic projection the occluding boundary of a surface of revolution is symmetric about the projection of its axis from any point of view [7]. Therefore we look for edges symmetric about the centre line. Symmetry is an important cue for human vision. It is quickly detected in images and used to reduce the search area [8]. Methods proposed to detect this bilateral symmetry are based on searching for line segments and edge pixels that are equidistant from the centre line.

For line segments, only lines within a window around the axis of symmetry are considered. Each line is reflected about the axis to the other side and compared with lines there. Two lines are symmetric if they are similar, defined as similar orientation, significant overlap, and the average distance between them is small. For edge points, pairs of pixels are detected that are equidistant from the centre line. Due to surface markings on the objects several symmetric pairs may be found. The pair of lines or pixels farthest from the axis are chosen as belonging to the occluding contour since there are unlikely to be many symmetric pairs outside the object.

Results

For an image containing a surface of revolution, figure 2a, the straight lines and elliptical arcs (drawn bold) are detected, figure 2b. The ellipses forming the perceptual group, centre line, major axes of the ellipses and lines that possibly form symmetric pairs are shown in figure 2c (outlying pairs shown in bold). Figure 2d shows the hypothesised occluding contour generated by connecting the outlying lines. Figure 2e shows the same perceptual group with detected symmetric pixels. There are false matches in these results due to the surface markings on the object.

Conclusions

This paper has proposed the grouping of ellipses for the detection of surfaces of revolution. This grouping is invariant over changes in viewpoint and will be useful for providing cues for model invocation. Methods are proposed for increasing the confidence in the hypothesised perceptual group by searching for symmetric features in the edge and feature data. Further details are given in [9].

References

[1] Rosin P.L., West G.A.W., "Perceptual Grouping of Circular Arcs under Projection", *Proc. British Machine Vision Conf.*, Oxford, UK, pp. 379-382, 1990.

[2] Rosin P.L., West G.A.W., "Segmenting Curves into Elliptic Arcs and Straight Lines", *Proc. 3rd ICCV*, 1990.

[3] Foster N.J., Sanderson A.C., "Determining Object Orientation using Ellipse Fitting", *Proc. SPIE*, Vol. 521, pp. 34-43, 1984.

[4] Porrill J., "Fitting Ellipses and Predicting Confidence Envelopes using a Bias Corrected Kalman Filter", *IVC*, Vol. 8, pp. 37-41, 1990.

[5] Duda R.O., Hart P.E.,"Use of the Hough Transform to Detect Lines and Curves in Pictures", *Comm. ACM*, Vol. 15, No. 1, pp. 11-15, 1972.

[6] Lowe D., *Perceptual Organization and Visual Recognition*, Kluwer Academic Publisher, 1985.

[7] Nalwa V.S., "Line Drawing Interpretation: Bilateral Symmetry", *IEEE Trans. PAMI*, Vol. 11, pp. 1117-1120, 1989.

[8] Locher P., Nodine C., "The Perceptual Value of Symmetry", *Computers Maths. Applic.*, Vol. 17, No. 4-6, pp. 475-484, 1989.

[9] Rosin P.L., West G.A.W., Technical Report No. 2, School of Computing Science, Curtin University, 1991.