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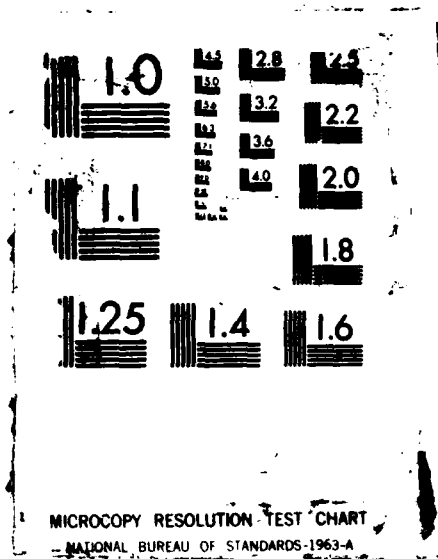
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**Vision Algorithms and Psychophysics
(Annual Technical Report, August 1987)**

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I. Summary

Over the past year, we have made significant progress in understanding shape perception based on curvature extrema. Through psychophysical experiments in conjunction with H.R. Wilson (Univ. of Chicago), we now are able to identify which of several computer algorithms for extracting curvature are biologically the most feasible.

II. Theoretical Studies

Our work has stressed the recovery of 3D shape from 2D image contours, such as a silhouette or cartoon. The description of the 3D shape we desire is topological rather than metrical. Hence our representation for 3D shape has been Gaussian curvature, where the object is described in terms of its "bumps" and "dents", or "ridges" and "furrows". We have shown how such a description can be recovered from the occluding image contour (Richards, Koenderink & Hoffman, 1987). This work continues in two directions: (1) inferring 3D shape in the presence of occlusions (with Koenderink), and (2) viewing shapes in terms of the way they were created—i.e. a process or developmental approach (Leyton, 1987).

In order to make inferences about 3D shape from 2D image contours, it is necessary to have an explicit description of the image contour itself. Over the past few years, we have argued for a curvature-based description, because such image features indicate directly the part boundaries of a 3D object, and also are efficient features for capturing the general topology of any part (Hoffman & Richards, 1986). However, computing curvature from image contours is non-trivial. At least two numerical derivatives must be taken. How should this be done and what space constraints should be used? Recently, we have presented two theoretical schemes for calculating curvature in a biological system (Koenderink & Richards, 1987). Both relate to existing computer vision algorithms (Parent & Zucker, 1986; Richards et al., 1986).

Recent psychophysics (to be described briefly below) suggests both schemes are used by the human visual system, but over different ranges of curvature.

III. Algorithms

At present, most computer implementations for extracting descriptions of 2D shapes from images use serial algorithms. An edge list for a curve is created, and this list is then twice differentiated using some (rather arbitrary) space constant. Often we simply choose a space constant which is a certain percent of the length of the list. However, a more powerful approach is to vary the space constant used for differentiating the curve, and then to compare locations of curvature extrema across scales (Richards et al., 1986). This procedure yields curvature extrema both for the textural aspects of silhouette as well as extrema for the parts of the shape—its bump and dents. Our algorithm is fairly powerful, delivering a description of the curve in terms of a string of "codons". Such strings are quite robust to projective distortions in the shape, or slight changes in view. On complex natural images, results are promising. Changing the viewpoint of the scene, or moving a shape (such as an animal) still results in similar codon descriptions for the object.

We have also used the codon string as a basis for stereopsis. Here enormous distortions between the two image pairs are now possible without failure of proper correspondence. This scheme eliminates the need for an epipolar constraint, and can be applied to heavily aliased pictures or shapes.

IV. Psychophysics (with H.R. Wilson)

As mentioned above, our computer algorithm for extracting curvature for shape descriptors examines a contour at several scales. This is expensive, but required theoretically if one wishes an entirely unambiguous description of a curve. Surprisingly, we have found that the human visual system computes curvature only at the finest scale available. This result is in sharp contrast to the coarse-to-fine strategies used in most vision algorithms, such as stereo and motion (Richards & Wilson, 1987).

Our second psychophysical result is that the human visual system uses two different schemes for computing curvature, one for high curvature, and a separate method for low (Wilson & Richards, 1987). For high curvatures, a "local" method is used which is equivalent to our computer algorithm in the limit as the curve segment approaches zero. For low curvatures, a comparison is needed between two regions along the curve—something like a symmetric axis computation where segments are compared for co-circularity (Parent &



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Zucker, 1986). Both schemes have been analysed theoretically by Koenderink & Richards (1987).

V. Citations

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