Inferring Global Perceptual Contours from Local Features*

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Abstract

We attempt to solve the problem of imperfect data produced by state-of-the-art edge detectors through the implementation of laws of Perceptual Grouping, derived from the psychology field.

We introduce a saliency-enhancing operator capable of highlighting features (edges, junctions etc.) which are considered 'important' psychologically. It also infers features which are not detected by low-level detectors. We show how to extract salient curves and junctions and generate a description ranking these features by the likelihood of them occurring accidentally.

We also treat the problem of illusory contours apparent in end-point formations. The scheme is particularly useful as a gap filler and in the presence of a large amount of noise. It is interesting to note that all operations are parameter-free, non-iterative and are linear with the number of edges in the input image.

1 Introduction

Using global perceptual considerations when attempting to connect fragmented edge images can alleviate many problems encountered by algorithms relying on perfect, noise free edges.

In a previous paper ([1]), we have introduced a general algorithm capable of highlighting features due to co-curvilinearity and proximity. We suggested the Extension Field as a 'voting pattern' representing a large family of smooth curves, all at once. Here we further explore the properties of the Extension Field. We also suggest specialized fields that can be used within the same computational paradigm to reveal perceptual phenomena such as end-point formations and straight lines. Experimental results are presented.

Figure 1 depicts examples of perceptual groupings which are of interest to us, and considered to be the result of a pre-attentive process. For a review of other work in the field see 2

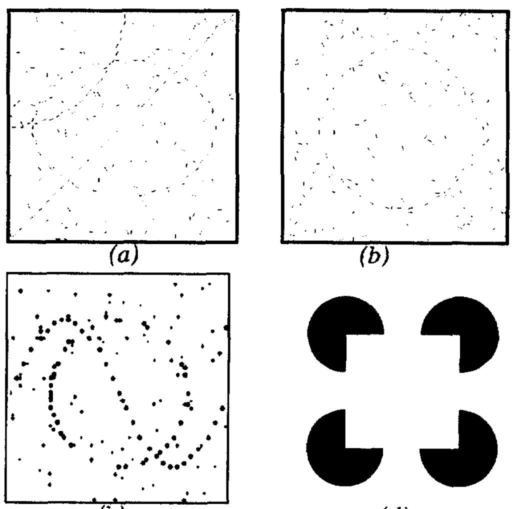
2 Overview of Our Approach

In our method, *each* site (pixel or other cell) collects votes from *every* segment in the image. These votes contain orientation and strength information preferred by the voting segment. A measure of 'agreement' (in terms of orientation) is now computed, and sites which have high agreement values are considered salient. In more technical terms, a vector field is generated by each segment, and a function over the whole space determines points of saliency. A subsequent step links areas of high saliency to produce a description in terms of curves and junctions. A more detailed description can be found in [1] and [2].

Our voting scheme is somewhat related to the Hough transform approach , *but* can detect shapes defined by their *properties* (smoothness etc.) rather than by their *exact shape* (lines, circles, etc.). Our underlying goal is to keep the interpretation as simple as possible in the 'Gestalt' sense. This translates into three major constraints: 1) Co-curvilinearity, 2) Constancy of curvature, and 3) Proximity . With that in mind, we have devised a technique that implicitly imposes the above constrains in the form of an Extension Field emanating from each edge segment, as discussed in the next few sub-sections.

3 The Extension Field

Definition: An ***Extension Field*** is a non-normalized probability directional vector field describing the contribution of a single unit-length edge element to its environment in term of length and direction. The field is of *infinite* extent, although in



(a) (b) (c) (d)

Figure 1 (a) & (b) Two instances of perceptual arrangements. (c) A dot formation. (d) The Kanizsa Square.

* This research was supported by the Advanced Research Projects Agency of the Department of Defense and was monitored by the Air Force Office of Scientific Research under Contract No. F49620-90-C-0078, and by grant from NSF.

practice it disappears at a predefined distance from the edge.

Properties of the extension field

Using a simple example we demonstrate the behavior of the field when extending a straight line. Figure 2 shows a cross-section of a saliency map computed on a series of straight lines with increasing lengths. Clearly, the saliency grows as a function of the length, and the map becomes more directed (thinner ridge). Also, saliency converges to some finite value which is just the infinite integral along the main axis of the Extension Field. This observation can be used to estimate absolute saliency.

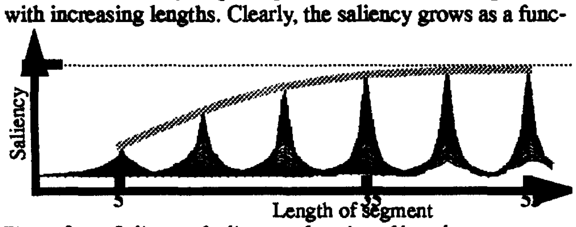


Figure 2 *Saliency of a line as a function of length.*

The Non-maximum Suppression Phenomenon

We have mentioned the superior selectivity of the Enhanced Saliency map. To illustrate this behavior, we look at the eccentricity *only* map of a straight line (Figure 3(a)) Note how low the eccentricity is close to where the real line passes. In Figure 3(b) we see the raw saliency map of the same line. The Enhanced Saliency map is simply the product of the two maps, point by point, and will obviously sharpen the edges of the correct curves, thus creating a Non-maximum suppression affect (Figure 3(c)).

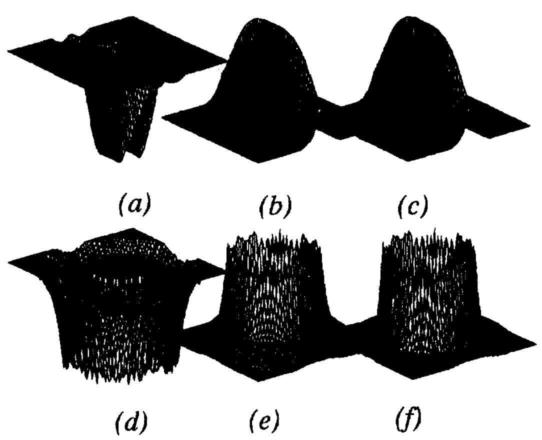


Figure 3 *(a) Eccentricity only map of a saliency map of a straight line. (b) raw saliency map. (c) Product of (a) and (b). (d) -(f) same for a perfect circle.*

4 Special Purpose Fields

Special purpose fields are fields synthesized to enhance a special feature in an image. We present a Straight Field capable of finding straight lines and an End-Point Field to detect illusory contours.We claim that straight angles in T-Junctions are more likely than any other, and convex T-junctions are more common. With the above observations we construct a suitable field.

5 Results

We have tested our approach with the synthetic data shown earlier in Figure 1. The saliency map produced is shown for the various inputs (strength only) as grey-level images).

6 Summary And Conclusion

We have introduced a unified way to extract perceptual features in edge images. The scheme is threshold-free and non-iterative. It is especially suitable for parallel implementation. Also, calculations are simple and stable, as no curvatures or any other derivatives need to be computed on the digital curves.

References

[1] G. Guy and G. Medioni, *Perceptual Grouping using Global Saliency enhancing operators*, Proc. of ICPR92, The Hague, Holland, 1992, pp. 99-104

[2] G. Guy and G. Medioni, *Perceptual Grouping using Global Saliency enhancing operators*, IRIS-USC Technical report.

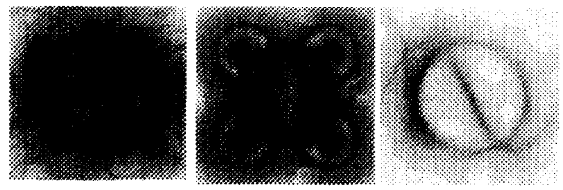


Figure 4 *The Saliency maps of images in figure 1.*

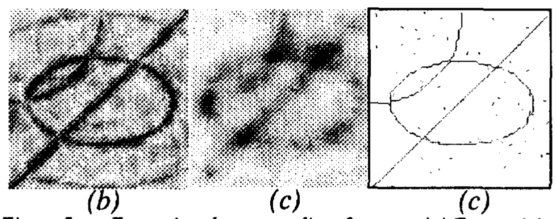


Figure 5 *Extracting the most salient features. (a) Eccentricity enhanced map. (b) Junction saliency map, and (c) linking.*

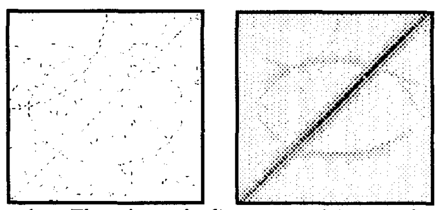


Figure 6 *The enhanced saliency map of the straight field*

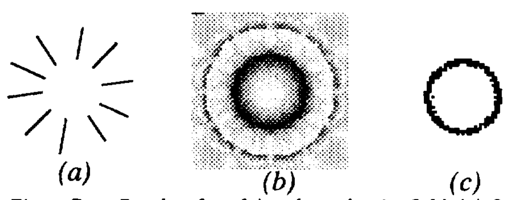


Figure 7 *Results of applying the end-point field. (a) Original image. (b) Saliency map. (c) after ruling-out single votes.*