# Selection and Use of Image Features for Segmentation of Boundary Images*

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Abstract

An algorithm is developed to segment arbitrary boundary images into sets of boundaries which represent a single object, and to group together lines which correspond to a single object or object part. The algorithm is based on features which were found to used by humans in the early stages of visual processing, and which have a high correlation with perceptually significant aspects of images. In addition, the data structure used is based on the image representation used in the primate visual cortex.

By using perceptually valid features, the algorithm is able to enhance the perceptually significant edges in an image using simple, local, parallel computations. It demonstrates that selective processing can occur in the parallel stages of early visual processing, without domain specific knowledge, iterative processing, or top-down control of some mechanism to shift attention.

KEYWORDS: image segmentation, boundary images, visual psychophysics

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## 1. Introduction

Images contain too much information for humans or machines to process all of it in detail. The human visual system solves this problem by performing a initial, cursory analysis of the entire image which allows it to pick out automatically what is important in the image (Treisman, 1986), and then to selectively process that information in preference to the rest of the information. That is, a rapid, parallel analysis of the entire image indicates which regions are likely to contain the most useful information. Then the following stages of analysis, which require more focused, serial processing can concentrate primarily on the preselected regions. This can also be a useful approach for a computer vision system, and in fact the parallel computation of intrinsic images can be viewed as an example of the first stage (Barrow and Tenenbaum, 1981). This paper describes another type of processing which enables the early visual processing to indicate which regions of an image are likely to contain the most useful information, and to selectively process such regions in parallel. This is accomplished by selectively processing image features which have a high correlation with perceptually significant aspects of an image. This is not a new approach. For example, edge detection techniques pick out object boundaries and other edges which are more perceptually significant than more uniform image regions (Marr, 1982). However, the research in this paper presents a new set of features which can enable strong inferences about which regions of an image contain the most perceptually relevant information.

Determining which aspects or features of an image contain the most useful information, and should therefore be preferentially processed is difficult because there are nearly an infinite number of potential features. The dimensions of physics cannot necessarily be used to determine which features are relevant, as perceptual features may lie along some other dimensions. For example, the perceived color of a region depends not only on the wavelength and intensity of the light reflected from it, but also on the relative contrast between it and neighboring regions. So how can perceptually relevant features be found?

The question is further complicated as one set of features may be ideal for one task, but useless for another. One basic machine vision task is to segment an image into different regions which correspond to different objects, or object parts. This may be possible based on the color, shading, texture and shape information. But, are the color and shading information necessary for image segmentation? Not always, as humans can readily segment simple line drawings or boundary images which lack that information. So one way to study image segmentation is to study line drawing perception, and as line drawings are much simpler than natural images, this should make the selection of features easier. Once features are found from line drawings, then it is possible to test them in the analysis of natural images.

But even for simple line drawings, it is not obvious which features should be used. As the goal is to find perceptually significant aspects of an image, and then to determine which features correlate with those aspects, it is desirable to determine what aspects of an image have perceptual significance for humans. It is not possible to just introspect about possible features, as the relevant preattentive stages of human visual processing are not available for conscious introspection (Julesz & Schumer, 1981). The approach taken in this paper is to use psychophysical experiments to explore preattentive vision and to discover image features used by humans. Once potential features are found, their usefulness is tested by developing a computational algorithm based on them, and then testing the algorithm. The algorithm developed here can segment arbitrary boundary images containing both straight lines and curves. It is a simple, data-driven, bottom-up approach, which requires no domain specific knowledge, and demonstrates the importance of using perceptually valid features.

## 2. Psychophysical Experiments

The psychophysical experiments are based on the perceived contrast of lines phenomenon (Walters and Weistein, 1982a). The patterns in Fig. 1 can be used to illustrate this phenomenon. When viewed at low contrast the lines in the cube (Fig. 1a) appear to have higher contrast than the lines in Fig. 1b. If these differences in perceived contrast can be correlated with the presence of particular image features, it would suggest that stimuli with those features are processed differently from stimuli lacking the features. In particular, stimuli having features associated with high perceived contrast may be preferentially processed. The aim of the psychophysical experiments was to isolate such features. The experiments have been reported elsewhere (Walters and Weistein, 1982b; Walters, 1984, 1985), so only a brief description is included here.