Foveation from Pulse Images

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ABSTRACT

Humans do not stare at scenes. They foveate. Their eyes dart about the scene at locations of interest during the analysis of the scene. Except for special cases, humans tend to focus on corners and edges of important objects of the scene. This paper will explore the use of pulse image processing as a means of extracting natural segments of an image that can easily be used for the generation of foveation point selection.

1. JUSTIFICATION

Foveation is the process of moving the 'center of attention' to different locations within a scene. While research in human foveation has been progressing over the past three decades (the earlier work of Yarbus [1] is one of the landmarks in foveation research), there is still much to be learned about the process. Research has indicated that human foveation is task dependent, ballistic, and has a general tendency to be more frequent at corners and edges [2]. Models have been proposed to extract foveation points by detecting edges in an input scene [3] [4] [5]. Both of these models have problems with soft edges in the image. In cases where one segment of the image blends smoothly into another it is difficult to define a boundary.

In order to build a more robust foveation system the segmentation process of the mammalian visual cortex will be employed, of which there are many proposed models [6] [7] [8] as well as very similar models from the olfactory, motor, and auditory cortexes [9] [10] [11] [12]. The neurons in these systems have strong similarities [13] in that they resemble reaction-diffusion equations with a non-linearity.

Models of the visual cortex have been employed for several image processing tasks [14] including foveation [15] However, these systems are based on a discrete-time model which has an unfortunate strong dependence upon global illumination, noise and texture. The result of this dependency is that the neurons quickly lose their ability to synchronize their pulse activity across a segment of the image.

This paper presents an analog-time model that maintains segment integrity (apparent by repetitive patterns) as pulse images are produced. The corners and edges of the segments tend to be the corners and edges of the image, which are used to define the foveation points. The advantage of the use of the pulse images is two-fold. Soft boundaries that are difficult to detect can be found using the pulse images, and the corners and edges of the pulse segments are easier to detect than in the original image. The result is a foveation system based upon pulse image generation.

2. THEORY AND APPLICATION

This system has two parts. The first is the pulse image generator and the second is the foveation point selector.

2.1. Pulse Image Generation

The pulse image generator is based upon a culmination of several cortical models[13], which describe a reaction diffusion system with a non-linear operator. Basically, each neuron/pixel has at least two memories that are leaky integrators. When the state of the two memories exceeds a specified condition (usually the neuron potential exceeds a threshold) the neuron will pulse. This positive output will also send information to neighboring neurons and dramatically alter the state of at least one of the memories.

The system used here employs these properties that are common in all cortical models,

$\mathbf{U} = Stimulus$

$Iterate:$

$$\mathbf{U}(t+dt) = e^{-dt/\tau_U}\,\mathbf{U}(t) + \beta\mathbf{U}(t) \otimes \mathbf{K} \quad (1)$$

$$Y_{ij}(t+dt) = \begin{cases} 1 & if\left(\beta\mathbf{U}(t) \otimes \mathbf{K}\right)_{ij} > \Theta_{ij}(t) \\ 0 & Otherwise \end{cases} \quad (2)$$

$$\Theta(t+dt) = e^{-dt/\tau_\Theta}\,\Theta(t) + \gamma\mathbf{Y}(t) \quad (3)$$

This system operates in an analog mode such that dt becomes the time between the current time and the time that the next neuron pulses. The pulse images are **Y** at each dt.

Consider the image in fig. 1. It has some strong edges (underneath the car) and some very soft edges (the boundary between the hood and the side panel, the boundary between the sky and the roof, the boundaries between the fenders and the side panels). Figs. 2 display several of the pulse images generated by this model.

Fig. 1. An input image.

The analog pulse image generator extracts the inherent segments within the image. Furthermore, this system does not experience the desynchronization experienced by discrete-time systems. The iterations displayed in figs. 3 demonstrate the repetitive nature of the generator. An image from the first cycle (figs. 2) was selected and the closest pulse images from the next two cycles are shown below. As can be seen there are significant similarities as the cycle repeats.

2.2. The Detection of Foveation Points

The foveation points are the corners and edges of the pulse image segments. Since these segments have sharp edges and flat solid interiors the detection of corners and edges is simple. Detection of the corners and edges can be performed in several manners. Two methods used here for demonstration are {high-pass filter, peak detection} and {edge detection, small kernel smoothing, peak detection}.

The images in figs. 4 display the location of the 50 highest peaks using these two methods. While it is difficult to compare these results to human foveation points it is seen that the foveation points are on the edges and corners.

As stated earlier the use of the pulse images assists in the definition of soft edges. In these examples there are some points that are different than a more traditional method of the determination of foveation points. The image in fig. 5 displays foveation points derived by the smoothing of the results from a Laplacian operator applied directly to the original image. In this case the pulse images were not used. This latter system did not pick the boundary between the fenders and the body of the car. Furthermore, the latter system selected a glint through behind the vehicle (through the back side window) which the pulse image methods neglected.

The pulse images does have the ability to detect very soft edges that edge enhancement forgoes. Thus, foveation points between soft boundaries can be extracted from the use of pulse images.

3. SUMMARY

Pulse images are images that contain inherent segments and edges of an input image represented by binary elements. These segments tend to have solid interiors and sharp edges. Foveation points can easily be extracted from the edges and corners of these segments. The advantage is that foveation points from soft boundaries can be found, whereas these are difficult to find through the more traditional method.

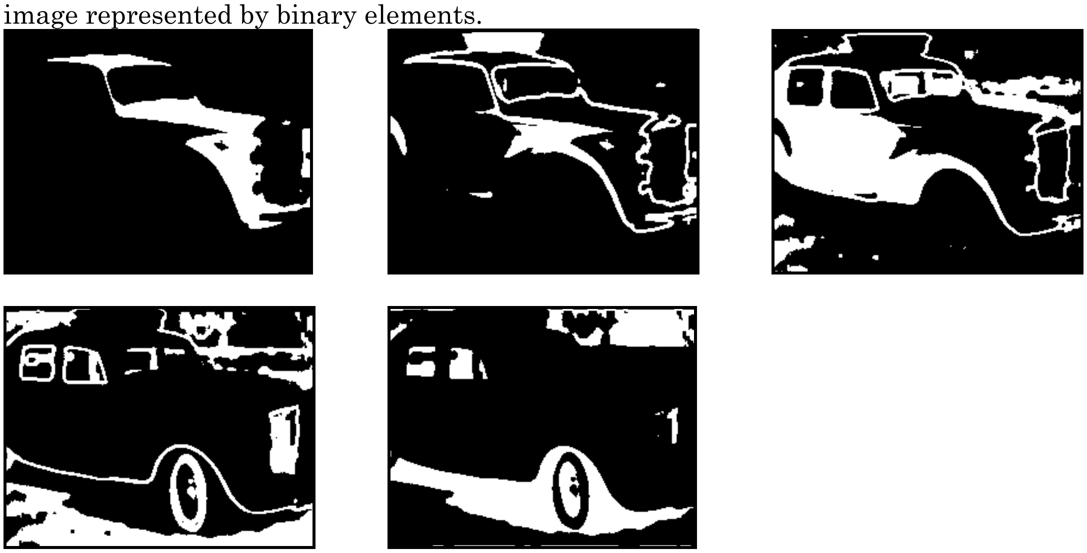
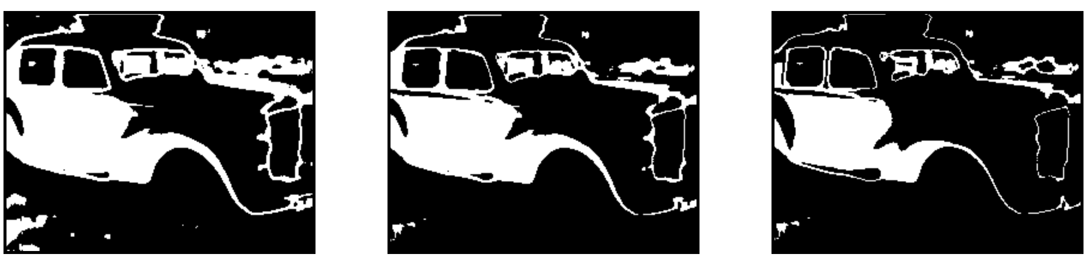


Fig. 2. Consecutive Pulse Images.



Figs. 3. Comparisons of a pulse image over three cycles.

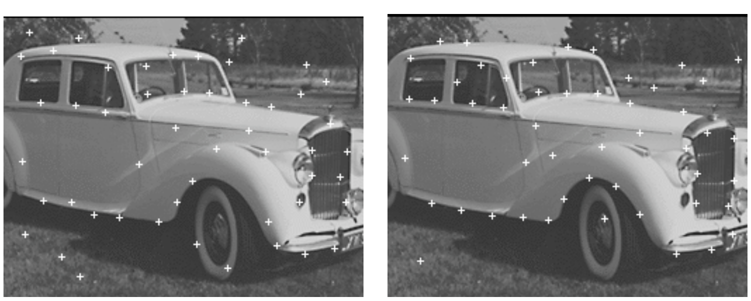


Fig. 4. Results of corner and edge detection. Fig. 4a uses the high-pass filter method and fig. 4b uses the Laplacian-Smoothing method.

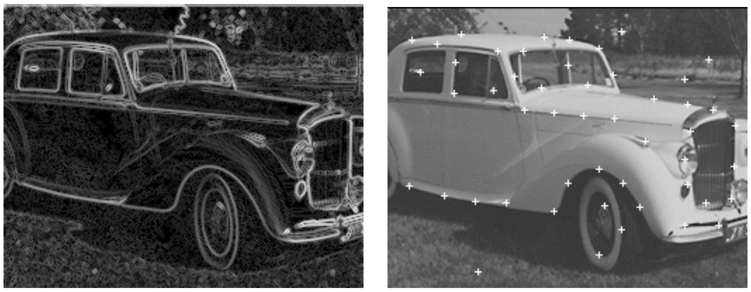


Fig. 5. The edge enhancement of the original image and Foveation points from this image.

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