- Friday, October 24, 1997
  Blurring of Natural Images

1.0 These are the minutes of YORKVIS that took place on 24th Oct 1997. I have decided not to describe the"three short talks related to three-dimensional eye movements" that took place on Oct 17th. In fact we only had time for two (Eliana Klier and Denise Henriques). They were practice talks for the Neurosciences meeting in New Orleans and I leave the titles linked to the abstracts on the web page.

1.1 Next meeting is this Friday (7th) by Hiro Ono (abstract and title see webpage).

2.0 James Elder's talk was entitled "What is the right model for the local blurring of natural images?"

2.1 Blur is an aspect of a retinal image that needs to be centrally represented if the representation is to be complete and accurate. Blur is a useful and significant feature of an image providing a useful cue for depth, three-dimensional form and motion. It is not that blur needs to be stored as such (asking questions about the blur patterns in a remembered picture is not likely to produce coherent answers!) but it needs to be available to systems that are extracting higher-order features such as shape-from-shading.

2.2 Blur can be caused in at least four ways:

2.2.1 Focal (meaning to do with focus). Except when you have pin-hole pupil, objects that are closer or further away than the accommodated distance will be blurred.

2.2.2 Penumbral. The edges of a shadow are blurred because of only partial occlusion of a finite- sized light source.

2.2.3 Shading. Whenever a three-dimensional surface is curved and illuminated from the side.

2.2.4 Motion and diffusion.

2.2.5 At least the first three are ambiguous, that is they all produce an equivalent stimulus on the retina. Can they be described by a single mathematical formula? Elder used penumbral blur in his visual examples.

3.0 What we are trying to do here is develop an image-processing technique that can extract and store blur. Succeeding in this task would mean that an image could be stored as a list of edges along with some cryptic coding concerning the type and extent of blur, along with other pertinent information such as position, brightness, contrast and so on. The image could then be reconstructed from a relatively economical store. Separate processing of different visual attributes is a fundamental principle of how the brain processes visual information and so there may be reciprocal lessons from the dual goals of developing computer imaging techniques and understanding the brain.

3.1 Perhaps the simplest model of the blur associated with an edge is to convolve a step in luminance (representing a perfectly sharp edge) with a Gaussian. This operation produces a smooth curve between the two sides of the step which can be specified by four parameters. This is a convenient function to work with. Differentiating a step convoluted with a Gaussian gives a nice zero crossing (a point where the function goes through zero) which can be taken as the location of the edge (the step part). A second differentiation generates two zero crossings which indicate the width of the Gaussian and corresponds to the spatial extent of the blurring.

3.2 Taking a random image and differentiating it, does indeed provide zero crossings that can be taken as the location of edges. Further differentiation provides the other features. If the simple model is correct, then our task is complete. Because we can now use these zero crossings to reconstruct the image, including blur, any old time we feel like it.

3.3 An immediate and profound problem in using this model is to decide on the SCALE that you want to work at. There is a trade-off between being compact and being complete. Representing all images at all scales represents no economy at all! A clever feature of Elder's model is that it uses multiple scales - different scales for different parts of the image.

4.0 A test of the model is to process an image as follows and see if it looks like the original. (a) identify all edges (this makes some assumption about non-edges which are not relevant here) (b) simulate shading by using a heat-conductivity model in which the identified edges act as radiators (c) apply blur according to the model of 3.1 (of variable scale) to the edges.

4.1 Such a processed image looks quite natural but can be distinguished from the original. The differences can be reduced by convoluting the edges not with a Gaussian but with some other function. To decide which function to use, Elder developed a 'General Exponential Model' (GEM) which allows for convolving the step with a best-fitting function. By identifying which function is chosen, the model actually provides more information about the nature of the blur and allows more convincing image reconstruction.

James Elder
York University