INTENSITY DISCONTINUITY LOCATION TO SUBPIXEL PRECISION

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Abstract

Lateral inhibition processing of an image yields subpixel precision in the location of intensity discontinuity edges in a digitized image. The method is illustrated using a 512 x 512 x 8 bit image.

Introduction

As has recently been pointed out in the literature (Nevatia & Babu 1978), the effectiveness of many machine vision systems is often limited by the low level processing that constitutes the first stage of the system. Typically, this stage consists of operations such as edge detection, thinning, thresholding, & linking - in other words - line finding.

Given this current state of the art and the inspiration of earlier MIT work (Binford 1970, Herskovitz & Binford 1970), we have implemented an intermediate level vision system that is a marked improvement to this stage of vision systems. An earlier report on this system has been presented elsewhere (MacVicar-Whelan & Binford 81) where further details may be found. We present here improvements in the structure (noise) filter, results for 9 x 9 and 17 x 17 inhibition masks and the hardcopy output was also improved.

Most edge operators use the maximum gradient which requires a thinning operation. Both processes can introduce uncertainties in the resulting edge. The laterally inhibited image, also used in the MIT systems (e.g. Grimson 80 and references therein), is equivalent to a second derivative operation and provides a more precise result due to effective use of more of the information in the grey level image. We have chosen to illustrate our technique with an image that has already been discussed in the literature.

This work waa performed while P.J. Mac Vicar-Whelan was on a l«ave of abwnre from Grand Valley State College*, Michigan. Additional funding was provided by ARPA under contract No. MDA903-80-C-0102.

Lateral Inhibition

Unlike the MIT approach (Difference of Gaussians), we convolve the image with a square mask of side 2n+I to yield the local average intensity (over the 2n+1 x 2n+1 area) and subtract this average from the intensity of the pixel at the centre of the square. The resulting intensity is the laterally inhibited value of the image at the central pixel. Results for n=2,4, and 8 are presented in the figure. It is this value that is used to locate the zero crossings. In the process of calculating the laterally inhibited image, linear intensity functions (including the special case of the constant function) arc mapped into the zero value. An intensity discontinuity is characterised by values that rise/fall to a maximum over *n* pixels, a switch to a maximum of the opposite sign, and a fall/rise to zero again over n pixels.

As is to be expected, when two discontinuities are separated by less than the mask dimension there will be interference which will result in locational errors. While a small mask will minimize this effect, it will be more sensitive to noise and the errors induced by it. Examples of this effect are to be found in the figure where line separation? of only 2 pixels are common.

Discontinuity Point Detection

It is the zero crossing that occurs during the switch from one maxima to the other that is the zero crossing of interest since this zero corresponds to the location of the discontinuity.

For the case of subtracting the value of the single central pixel from the local average, this switch from peak to peak occurs over a 2 pixel interval. It is the location of the zero of this switch that is the zero crossing of interest.

The exact position of the crossing was taken to be the linearly interpolated position between the pixels obtained using the values of intensity on either side of the crossing.

Zero point crossings were calculated in both the horizontal and vertical directions for the processed image.

Discontinuity Point Linking

The zero points or zero crossings of the laterally inhibited image were linked together over a mesh of dimensions equal to a single pixel separation. Decisions on the linking were based upon the intensity values of the corners of a mesh which were four pixel values and a central value equal to the average of the four corner values.

A zero crossing was deemed to occur along the edge of a mesh if one corner of the mesh edge was above zero and the other corner was either equal to or below the zero value. Linear interpolation of these 2 corner values was taken as the subpixel location of the zero crossing. Intramesh points were established using the corner values and the value at the center of the mesh.

Furthermore the central value can be used to disambiguate two trajectories that pass through a single mesh if it is assumed that the calculated value for the center of the mesh is accurate at least in so far as to whether or not it is above or below the zero value. This information can be used to separate two trajectories that pass through a single pixel.

Results

The results of locating intensity discontinuities using our method is illustrated in the Figure for the image of a Lockheed LIOII on a runway - an image that has been used by our group in diverse contexts and reported upon elsewhere in the literature. All results using our method were obtained using a threshold of 2 intensity units. Measured noise was 1.5 units.

The top row of the figure (left to right) illustrates the result of applying the the Nevatia-Babu line finder (ACRONYM'S current linefinder) to the entire image, a 128 x 128 window centred about the plane's nose, and the result of applying 9 x 9 lateral inhibition operator to the digitized image.

The second row illustrates similar results found using a 5 x 5 mask. In addition a second window (18 x 18) about the nose presents details of the high precision obtaainable. Individual pixel structure is represented by the square grid.

An identical sequence of illustrations is presented in the next two rows for 9 x 9 and 17 x 17 masks respectively.

In addition to greater precision our new discontinuity locator, as demonstrated in the figure, does not need to be followed by the customary thinning stage. It is also very accurate since different models of the LIOII can be distinguished on the the basis of the ratio of wing to tail span.

Increasing the size of the inhibition mask provides a cleaner (less small structure) but is accompanied by the undersirable result of broadening fine structure (eg the 2 pixel wide lines in the 128 x 128 windows).

Brooks (1981) presents further results using the Nevatia-Babu technique in the context of ACRONYM. Arnold (1978) presents the edges obtained using a Heuckel operator on this image.

As these results show, our processing produces rather improved results over those that are currently obtainable using other techniques.

We are currently extending this work to provide improved 'real picture' data for some of the other image processing projects being studied in our laboratory.

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