An Introduction To Image Segmentation And Edge Linking

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ABSTRACT:

In the following paper, some fundamental methods and techniques of image segmentation and edge linking have been discussed. It talks about:

- Mask operation
- Image Enhancement - Spatial Domain Method
- Image Segmentation - This deals with
    - Point Detection
    - Line Detection
    - Edge Detection
- Edge Linking and Boundary Detection - Local Analysis

The paper begins with an explanation on the *Neighbour of Pixel, Mask Operation and Spatial Domain Method*. The *Image Segmentation* has been described in detail. The concluding section deals with *Edge Linking and Boundary Detection by Local Analysis.*

INTRODUCTION:

Image Processing is concerned with analysis of image already available through some means. Feature enhancement of frames captured on a video camera, such as those taken during space exploration is a good example of use of image processing. One can perform a number of operations on the available image using various techniques.

Some of the applications are:

- Image analysis for Object Detection
- Pattern Recognition
- Image Restoration

Some of the fields where image processing can be used:

- Robotics
- Military Applications
- Molecular Biology
- Medical
- Aeronautics
- Computer Aided Designs

Here I have considered the important fundamentals of Image Processing, required for advanced processes, which include:

- Mask Operation
- Image Enhancement - Spatial Domain Method
- Image Segmentation
- Edge Linking and Boundary Detection

SOME FUNDAMENTALS:

1 *NEIGHBOURHOOD OF A PIXEL:*

An image will be denoted by $f(x, y)$. When referring to a particular pixel, letters like p and q will be used.

A pixel at p at co-ordinates has four horizontal and vertical neighbours, whose co-ordinates are:

$(x+1,y)$, $(x-1,y)$, $(x,y+1)$, $(x,y-1)$

And will be denoted by $N_4(p)$. Each neighbour is at a distance of one unit from the pixel (x, y).

The four diagonal neighbours of p have co-ordinates

$(x+1,y+1)$, $(x+1,y-1)$, $(x-1,y+1)$, $(x-1,y-1)$

and will be denoted by $N_D(p)$. All these points , combined are called 8-neighbours of p , denoted by $N_8(p)$. Some of the points can be outside the image if (x,y) is on the border of the image .

2 *MASK OPERATION :*

The arithmetic and logical operation are used in processing in basically two ways : on pixel - by - pixel basis , or in the neighbourhood oriented operation . For example , addition of two images is done on a pixel-by-pixel basis . Neighbourhood processing is formulated in the context of the Mask operation .

The idea behind a mask operation is to let the value assigned to a pixel be a function of it and it's neighbours . For example , consider the following sub-image (Fig 1.a) . We wish to replace the value of 'e' by the average value of the pixels in the 3 X 3 region centred at 'e' . This performs an arithmetic operation of the form :

$$p = 1/9\ (a+b+c+d+e+f+g+h+i)$$

and assigning to 'e' the value of 'p' .

FIGURE 1

(a)

$$\begin{matrix} & & \vdots & & \\ & a & b & c & \\ \cdots & d & e & f & \cdots \\ & g & h & i & \\ & & \vdots & & \end{matrix}$$

(b)

$$\begin{matrix} w_1 & w_2 & w_3 \\ w_4 & w_5 & w_6 \\ w_7 & w_8 & w_9 \end{matrix}$$

With reference to the mask shown in Fig 1.b , we may view the above operation in more general terms by centring the mask at 'e' , multiplying each pixel under the mask by the corresponding coefficient and adding the result , that is :

$$p = w_1a + w_2b + w_3c + w_4d + w_5e + w_6f + w_7g + w_8h + w_9i$$

If we let $w_i=1/9$,where $i=1,2,3,4,\ldots,9$, this operation yields the same results.

3 *IMAGE ENHANCEMENT BY SPATIAL DOMAIN METHOD :*

The term spatial domain refers to the aggregate of pixels . Spatial domain methods are procedures that operate directly on these pixels . Image processing functions in the spatial domain may be expressed as :

$$g(x,y) = T [f(x,y)]$$

where f(x,y) is the input image , g(x,y) is the processed image , and T is an operator on *f* , defined over some neighbourhood of (x,y) . Generally , we let the value *f* determine the value of g at the co-ordinates (x,y) . One of the principal approach is the mask method .

For example , consider an image of constant intensity that contain s widely isolated points whose intensities are different from the background . These can be detected using the mask shown in Fig 2 .

<u>FIGURE 2</u>

-1	-1	-1
-1	8	-1
-1	-1	-1

The procedure is as follows :

The centre of the mask (8) is moved around the image . At each pixel position we multiply the pixel by the corresponding mask coefficient , i.e. the pixel at the centre is multiplied by 8 , while others by -1. The results of 9 multiplications is then summed . If all the pixels in the mask have same value , the result will be zero , else if the centre of the mask is located on the isolated point , the sum will be different from zero , or else if the point is at an off centre position , the sum will be different from zero . The weaker responses can be eliminated by comparing the sum against a threshold .

IMAGE SEGMENTATION :

Segmentation is the process that subdivides an image into it’s constituent parts or objects , so as to extract them from an image for subsequent processing , such as description and recognition .Image segmentation algorithms are based on either of the two basic properties gray-level values : discontinuity and similarity . We will take into account only the discontinuity detection .

DETECTION OF DISCONTINUITIES :

Here we discuss various techniques for point , line , edge detection in an image . The method adopted are the Spatial Domain Mask as discussed in the previous section . We will express the expressions in the vector form . Let w_1 ,w_2 ,…,w_9 be the coefficients of the 3 x 3 mask and let x_1 ,x_2 ,…,x_9 be the gray-level of the pixel under the mask . Hence they can be expressed as column matrix :

$$w = \begin{matrix} w_1 \\ w_2 \\ . \\ . \\ w_9 \end{matrix} \qquad x = \begin{matrix} x_1 \\ x_2 \\ . \\ . \\ x_9 \end{matrix}$$

Hence the general equation will be :

$$w'x = w_1x_1 + w_2x_2 + \dots + w_9x_9$$

where the prime (‘) represents vector transposition .

1 *POINT DETECTION*

It is already discussed in spatial-mask processing . The entire process remaining the same , if one is interested only in strong responses , we say that an isolated point , whose intensity is different from the background has been detected if

$$| w'x | > T$$

where T is a non-negative threshold .

2 *LINE DETECTION*

Consider the mask shown in Fig 3 . If the first mask is moved around the image , it would respond more strongly to horizontal lines (1 pixel thick) .

FIGURE 3

-1	-1	-1	-1	-1	2	-1	2	-1	2	-1	-1
2	2	2	-1	2	-1	-1	2	-1	-1	2	-1
-1	-1	-1	2	-1	-1	-1	2	-1	-1	-1	2

Maximum response will be generated if the line passes through the middle row of the mask .Similarly the second mask will detect a line at 45° , the third mask will detect a vertical line and the fourth will detect a line -45°.

3 *EDGE DETECTION*

Edge can be defined as the boundary between two regions with relatively distinct gray-level properties . Most of the edge detection techniques compute a local derivative operator . For example consider the Fig. 4 . It shows an image of a simple light object on a dark background , the gray-level profile along a horizontal scan line of the image , and the first and second derivatives of the profile . Note here that the edge is modelled as a ramp because edges in digital images are usually slightly blurred due to sampling .

FIGURE 4

The first derivative of an edge , here is 0 in all regions of constant gray-level , and has a constant constant value during gray-level transition . The second derivative is 0 in all location except at the onset and termination of a gray-level transition . Hence the magnitude of first derivative is used to detect presence of an edge , while sign of the second can be used to find if an edge pixel lies on the dark (background) or light (object) side of an edge .

- *GRADIENT OPERATOR*

The gradient of an image *f(x,y)* at location (x,y) is defined as a two dimensional vector :

$$G[f(x,y)] = \begin{bmatrix} G_x \\ G_y \end{bmatrix} = \begin{bmatrix} df / dx \\ df / dy \end{bmatrix}$$

The magnitude of this vector , generally called gradient is given by :

$$G[f(x,y)]=[G_x^2 + G_y^2]^{1/2}$$

The direction of the gradient vector is given by :

$$a\ (x,y) = tan^{-1}\ (G_y / G_x)$$

where the angle is measured with respect to x-axis .

Consider the Fig. 5 . We define the component of the gradient in the x-direction as :

$$G_x=(x_7 + 2x_8 + x_9) - (x_1+ 2x_2 + x_3)$$

and the component in the y-direction as :

$$G_y=(x_3 + 2x_6 + x_9) - (x_1+ 2x_4 + x_7)$$

One can also use the mask in Fig 5(b) for x-direction and Fig. 5(b) for y .

FIGURE 5

(a)			(b)			(c)			(d)		
x_1	x_2	x_3	-1	-2	-1	-1	0	1	0	1	0
x_4	x_5	x_6	0	0	0	-2	0	2	1	-4	1
x_7	x_8	x_9	1	2	1	-1	0	1	0	1	0

Convolving these masks the image gives the gradient at all points in the image , the resultant image is called gradient image .

LAPLACIAN OPERATOR :

The Laplacian is a second order derivative operator defined as :

$$L[f(x,y)] = d^2f / d^2x + d^2f / d^2y$$

With reference to Fig. 5(a) and 5(d) , we define the digital Laplacian as :

$$L[f(x,y)]=x_2 + x_4 + x_6 + x_8 - 4x_5$$

The mask given in Fig. 5(d) can be used for the same . The Laplacian is 0 in constant areas and on the ramp section of the edge .

EDGE LINKING AND BOUNDARY DETECTION :

In practice , the set of pixel derived from intensity discontinuity techniques seldom characterise a boundary completely because of noise , breaks in the boundary due to non-uniform illumination and other effects . Thus edge detection algorithms are followed by boundary detection techniques designed to assemble edge pixels into a meaningful set of object boundaries .

LOCAL ANALYSIS :

Here we analyse the characteristics of pixels in small neighbourhood (say 3x3 or 5x5) about every point (x,y) in the image that has undergone edge-detection process . All points found similar are linked , thus forming a boundary . These properties are (1) The strength of the response of the gradient operator , (2) The direction of the gradient . Hence

$$(1) \quad | G[f(x,y)] - G[(x',y')] | <= T$$

$$(2) \quad | a(x,y) - a(x',y') | < A$$

where T and A are respective thresholds .
When a point (x', y') satisfies both the conditions , we say that it is in the predefined neighbourhood of (x,y) .

CONCLUSION :

The above technique provides excellent results in edge detection and boundary detection . Moreover , techniques like mask can also be used for complicated processes like image restoration , noise reduction , image segmentation , etc.

SESSION: SESSION 1
ADVANCED COMMUNICATION
IMAGE PROCESSING

TITLE : AN INTRODUCTION TO IMAGE
SEGMENTATION AND EDGE LINKING

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