1. Introduction

Edge points are series of pixel locations having drastic change in intensities in digital images. Edge can be detected using spatial domain sharpening filters, given in. Several methods have also been reported. An ideal line edge should comprise one pixel thickness with high intensity value and is to be surrounded by two lower intensity lines. An edge with more than one pixels thickness gives rise to lot of problems regarding the exact locations of the object boundary and also gives rise to handling of more bits of high intensity. Thus edges with more than one pixel need be thinned. There have been a number of studies regarding edge thinning operation e.g. described some fundamental iterative process which was carried out in parallel and serial modes. This survey gives the idea about the deletion or addition of pixels in a local neighbourhood of a particular pixel. In the sequential based thinning algorithm pixels are deleted each iteration of some sequence of pixels as described in. A horizontal and vertical searching technique is used for edge thinning as given in. A novel concept of parallel and serial thinning algorithm is described in. Parallel thinning is carried out based on some predefined criteria for possible thinned patterns.

2. Proposed Method for Edge Detection

The proposed algorithm of the filter approaches the image by flipping the latter and detects edges along horizontal, vertical and diagonal directions. The one and two dimensional filtering mask (kernels) have been operated along both directions such as from left to right side, from top to bottom, from top left to right bottom and from top right to left bottom sides. The same procedures have also been followed along the reverse directions for each of the above operations. Normally, the edges are produced with more than one pixel thickness and thus requiring thinning. The double pixel thick edges are first required to be searched and the present algorithm has been prepared with that aim. Subsequently a pointer method has been
followed to find the location of the edge, after thinning along the direction having higher congregation of high intensity pixels. Two types of spatial convolution filters used in the present study as shown in Figure 1. Let \( f(x,y) \) be an image of dimension \( M \) (number of border pixels in horizontal direction) and \( N \) (number of border pixels in vertical direction). Edge profiles in different angles are mathematically derived as:

For 0° angle, \[ g_0(s,t) = f(x,y) \ast w_1 \]

For 45° angle, \[ g_{45}(s,t) = f(x,y) \ast w_3 \]

For 90° angle, \[ g_9(s,t) = f(x,y) \ast w_2 \]

For 135° angle, \[ g_{135}(s,t) = f(-x+M,y) \ast w_3 \]

For 180° angle, \[ g_{180}(s,t) = f(-x+M,y) \ast w_1 \]

For 225° angle, \[ g_{225}(s,t) = f(-x+M,-y+N) \ast w_3 \]

For 270° angle, \[ g_{270}(s,t) = f(-x,-y+N) \ast w_2 \]

For 315° angle, \[ g_{315}(s,t) = f(-x,-y+N) \ast w_3 \]

Where “\( \ast \)” symbol denotes spatial convolution and \( g(s,t) \) stands for convolution response. The edge detection output using proposed method is shown in Figure 2. Present technique is applied on Lena image (in Matlab), some natural images and a document image taken from courtesy of Google images. In all the cases, very precise edge profile is found.

### 2.1 Proposed Method for Edge Thinning

Proposed algorithm can be divided into two parts namely horizontal searching and vertical searching. After horizontal searching the vertical searching has to be done and the descriptions are given in following sections.

### 2.2 Horizontal Searching

Horizontal searching is carried out by taking 1x2 elements and checks the immediate preceding and next pixel. If the searching in this fashion fails, the method points to 3x2 elements and checks immediate top and bottom elements. Again if this condition does not satisfy then it is pointed to 4x3 elements. In horizontal searching choice starts from two adjacent pixels \( f(i+1, j+1) \) and \( f(i+1, j+2) \), for the initial values of \( i \) and \( j \) are 1.

**Algorithm:** \( M \) and \( N \) be the total number of rows and columns.

1. **Step 1:** for \( i = 1: M-1 \)
   
   for \( j = 1: N-1 \)

2. **Step 2:** Increment \( i \) and \( j \) by 1

3. **Step 3:** Select two elements as \( f(i,j) \) and \( f(i,j+1) \);
   
   if \( f(i,j) == 1 \) and \( f(i,j+1) == 1 \)
   
   goto step 3;

   else goto step 2;

**Figure 1.** One and two dimensional kernels, (a) \( w_1 \) kernel for vertical edge detection, (b) \( w_2 \) kernel for horizontal edge detection, and (c) \( w_3 \) kernel for diagonal edge detection.

**Figure 2.** Edge detected using proposed algorithm. Upper row shows original images and the lower row shows the edge detected images.
Step 3: Check \( f(i, j-1) \) and \( f(i, j+2) \)
   if \( f(i, j-1) == 1 \) or \( f(i, j+2) == 1 \)
   go to step 2;
   else go to step 4;
Step 4: Point to \( 3 \times 2 \) element as \( f(i-1: i+1, j:j+1) \)
   if \( f(i-1, j) == 1 \) and \( f(i+1, j) == 1 \) and \( f(i-1, j+1) == 1 \) or \( f(i+1, j+1) == 1 \)
   set \( f(i, j+1) \) to zero;
   else if \( f(i-1, j) == 1 \) or \( f(i+1, j) == 1 \) and \( f(i-1, j+1) == 1 \) and \( f(i+1, j+1) == 1 \)
   set \( f(i, j) \) is set to zero;
   go to step 2;
   else go to step 5;
Step 5: Point to \( 3 \times 4 \) element as \( f(i-1:i+1, j-1:j+2) \) and check the diagonal elements;
   if \( f(i-1, j-1) == 1 \) and \( f(i+1, j-1) == 1 \) and \( f(i-1, j+2) == 1 \) or \( f(i+1, j+2) == 1 \)
   set \( f(i, j+1) \) to zero;

2.3 Vertical Searching
Vertical searching is similar to that of horizontal searching; it can be viewed as a dual of horizontal searching. In vertical searching, the proposed algorithm searches two vertical elements on image matrix and the choice starts from \( f(i+1, j+1) \) and \( f(i+2, j+1) \), initial value of \( i \) and \( j \) is 1 and then dual of horizontal searching operation is performed.

3. Results and Discussion:
The study has been carried out in MATLAB (R2013a). The edges are detected on a gray level scanned
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document image (taken from Tripura Times, an Indian Daily) having dimension of 506x376 pixels as shown in Figure 3. The performance of the present method is measured by the metrics is also shown in 1. Pratt’s Figure Of Merit (PFOM), and 2. Edge Detection Error Rate (EDER) results are given in Table 1 for the Figure 3.

Table 1. Performance Metrics (Pratt’s figure of merit) of various edge detectors

| PSNR (dB) | Metrics | Edge detection type | Sobel | LoG | Canny | Proposed Method |
|----------|---------|---------------------|-------|-----|-------|-----------------|
| 44       | PFOM    | 0.9973              | 0.9933| 0.9879| 0.9986 |
|          | EDER    | 0.0196              | 0.0151| 0.0144| 0.0138 |
| 36       | PFOM    | 0.9854              | 0.9842| 0.9760| 0.9868 |
|          | EDER    | 0.0458              | 0.0364| 0.0330| 0.0331 |
| 30       | PFOM    | 0.9725              | 0.9523| 0.9470| 0.9777 |
|          | EDER    | 0.0882              | 0.0723| 0.0647| 0.0625 |
| 26       | PFOM    | 0.9299              | 0.9075| 0.9001| 0.9323 |
|          | EDER    | 0.1387              | 0.1149| 0.1089| 0.1043 |
| 24       | PFOM    | 0.9007              | 0.8836| 0.8705| 0.8895 |
|          | EDER    | 0.1710              | 0.1476| 0.1287| 0.1343 |

From Table 1, it can be concluded that PFOM is decreased and EDER is increased with the increase in noise power, but at any amount of added noise power. The value of PFOM should be high and EDER value should be low. Present method holds almost highest value for PFOM and almost least value for EDER at different levels of added noise power. A car image comprises document as number plate is shown in Figure 4, used for edge detection using proposed method and compared with some other novel methods. The precise edge detection of document section is highlighted. The novelty of the proposed study depends on the fact, that for spatial convolution operation in digital image processing, the spatial filter is flapped and dragged over the image from the left top corner pixel and completed to the right lowest corner pixel. In the proposed study, the spatial filter of various dimensions like one dimension horizontal, one dimensional vertical and two dimensional spatial filter are serially used and the effects have been studied. The use of one dimensional convolution masks and flipping of images are rarely seen, possibly has not been used so far. Although from the Table 1, it has been seen that the increase PFOM and EDER values are marginal in nature still the proposed method has greater flexibility of operation in a so called non-conventional way.

4. Conclusion

The proposed method has been found to yield better figure of merit in terms of Pratt’s figure of merit and edge detection error rate compared to those obtained by the Roberts, Prewitt, Sobel, Canny, and LoG operators. The results are expected to provide a basic knowledge of understanding the edge detection and edge thinning in a brisk manner.

Figure 4. Edge detection of an image of a car including number plate. a) Original image, (b) using Sobel, (c) using LoG, (d) using Canny, (e) using Proposed Method.
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6. References

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