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A NOVEL EDGE DETECTION APPROACH USING MATHEMATICAL MORPHOLOGY

Preeti Adhana , Rajesh Singh
preeti.adhana@gmail.com

ABSTRACT

This paper gives brief about the standard edge detector operators and the rough set theory proposed by Z. Pawlak. And through experimental results compare them with the novel proposed algorithm using the mathematical morphology and conclude the later one to be qualitatively and quantitatively better.

Keywords : Edge detection.

INTRODUCTION

Edge detection's scope is escalating with the advancement of technology and reaching various fields of applications. Edges contain important information in image and edge detection can be considered a low level process in image processing. Edges show relative sudden changes in image and usually contain important information. Various methods are developed for this purpose.

Common traditional edge extraction algorithms such as Canny make use of constant window that can be mixed with some smoothing filters. They need high quality values for their parameters in order to reach extraction efficiency. Although they are simple and have low computational cost, but they are still dependent to lightening conditions, noise etc. Lack of any of these dependencies could result in fail of these traditional methods.[1] addition, using a constant parameter all over the image can result as discontinuity in edges and thus becomes the weakness of these.

STANDARD OPERATORS

Sobel operator[6]

It is a discrete differentiation operator used to compute an approximation of the gradient of image intensity function. At each pixel of an image, it gives either the corresponding gradient vector or normal to the vector. It convolves the input image with the kernel and computes the gradient magnitude and direction. It makes use of following 3x3 two kernels

$$D_i = \begin{bmatrix} -1 & 0 & +1 \\ -2 & 0 & +2 \\ -1 & 0 & +1 \end{bmatrix} \quad \text{And } D_j = \begin{bmatrix} -1 & 0 & +1 \\ -2 & 0 & +2 \\ -1 & 0 & +1 \end{bmatrix}$$

It gives slow computation ability when compared to robert but as it has large kernel thus less sensitive to noise as compared to Robert operator.

Robert operator[6]

A gradient based operator. At first computes the sum of the squares of the difference between diagonally adjacent pixels through discrete differentiation and then calculate approximate gradient of the image. The input image is convolved with the default kernels of operator and gradient magnitude and directions are computed. It follows 2 x2 two kernels

$$D_x = \begin{bmatrix} 1 & 0 \\ 0 & -1 \end{bmatrix} \quad \text{And} \quad D_y = \begin{bmatrix} 0 & 1 \\ -1 & 0 \end{bmatrix}$$

Its simplicity adds a plus point but having small kernel turns it into highly sensitive to noise and not much compatible with today's technology.

Prewitt operator [6][7]

It works similar to sobel operator but with different kernels and performs better.

$$D_i = \begin{bmatrix} -1 & 0 & +1 \\ -1 & 0 & +1 \\ -1 & 0 & +1 \end{bmatrix} \quad \text{And} \quad D_j = \begin{bmatrix} +1 & +1 & +1 \\ 0 & 0 & 0 \\ -1 & -1 & -1 \end{bmatrix}$$

D_i and D_j are the kernels used by prewitt operator.

Canny operator[6][7][8][9][10][11]

The Canny edge detector uses a multi-stage algorithm. It was developed by John F. Canny in 1986 [11]. It gained good edge detection result and has been widely used. But it is vulnerable to various noise disturbances, so its concrete application is limited to a certain degree. It cannot take into account the local feature of the image because of the use of Gauss filter. On one hand, it is a herculean task to eliminate the impact of the local noise, on the other hand, the local edge of the grey value changes slowly will be lost. It is an optimal edge detection technique.

Algorithm of canny

STEP I: Noise reduction by smoothing

Noise contained in image is smoothed by convolving the input image I (i, j) with Gaussian filter G. Mathematically, the smooth resultant image is given by

$$F(i,j)=G*I(i,j)$$

STEP 2: Finding gradients

Detect the edges where the change in gray scale intensity is found to be maximum. Required areas are determined with the help of gradient of images. Sobel operator is used to determine the gradient of smoothened image at each pixel. Sobel operator in i and j directions are given as

$$D_i = \begin{bmatrix} -1 & 0 & +1 \\ -2 & 0 & +2 \\ -1 & 0 & +1 \end{bmatrix} \quad \text{And } D_j = \begin{bmatrix} -1 & 0 & +1 \\ -2 & 0 & +2 \\ -1 & 0 & +1 \end{bmatrix}$$

The sobel masks are convolved with smoothed image and give gradients in i and j directions.

$G_i = D_i * F(i, j)$ and

$G_j = D_j * F(i, j)$.

Therefore edge strength (magnitude of gradient) of a pixel is given by

$$G = \sqrt{Gi^2 + Gj^2}$$

Direction of gradient $\theta = \arctan\left(\frac{G_j}{G_i}\right)$

G_i And G_j are the gradients in the i and j directions.

STEP 3: Non maximum suppressions

(NMS) It is done to preserve all local maxima in the gradient image, and deleting everything else thus results are thin edges. For pixel M (i, j):

• Firstly round the gradient direction θ nearest45 and then compare the gradient magnitude of the pixels in both positive E (i, j) and negative W(i, j) gradient directions.

• If the edge strength of pixel M (i, j) is largest than that of E (i, j) and W (i, j), then preserve the value of gradient and mark M (i, j) as edge pixel, if not then suppress or remove.

STEP 4: Hysteresis thresholding:

The output of NMS still contains the local maxima created by noise. Instead choosing a single threshold, for avoiding the problem of streaking two thresholds t_{high} and t_{low} are used. For a pixel M (i, j) having gradient magnitude G following conditions exists to detect pixel as edge:

- If $G < t_{low}$ than discard the edge.
- If $G > t_{high}$ keep the edge.
- If $t_{low} < G <$ and t_{high} and any of its neighbours in a 3 ×3 region around it have gradient greater than t_{high} than keep the edge.
- If none of pixel (x, y)'s neighbours have high gradient magnitudes but at least one falls between t_{low} and t_{high} search the 5 × 5 region to see if any of these pixels have a magnitude greater than thigh. If so, keep the edge.
- Else, discard the edge.

SECOND ORDER EDGE DETECTOR

Laplacian of Gaussian or Marr Hildrith operator [8]

It was a very popular edge operator before Canny. It is a gradient based operator that uses the Laplacian to take the second derivative of an image. Works on zero crossing method. It uses both Gaussian and laplacian operator. It is based on second order derivative, in particular, the Laplacian ∇^2. A pixel is marked as an edge at a position where second derivative of an image becomes zero. The laplacian operator∇^2 for a 2D image I (i, j) is defined by following formula

$$\nabla^2 = I(i,j) = \frac{\partial^2}{\partial x^2} I(i,j) + \frac{\partial^2}{\partial y^2} I(i,j)$$

And the Gaussian function is defined by the formula

$$G\,(i,j) = \frac{1}{\sqrt{2\Pi\sigma^2}} \exp - \left(\frac{i^2+j^2}{2\sigma^2}\right)$$

Where, E is standard deviation And the LoG operator is computed from

$$\text{LoG} = \frac{\partial^2}{\partial i^2} G(i,j) + \frac{\partial^2}{\partial j^2} G(i,j) = \frac{i^2+j^2-2\sigma^2}{\sigma^4} \exp\left(-\frac{i^2+j^2}{2\sigma^2}\right)$$

Faces two major limitations. False edges and the localization error may be severe at curved edges.

ROUGH SET

[5]Rough set has been widely applied in many fields since it was put forward. The method is effective in artificial intelligence (AI) and knowledge process field. Especially in machine learning, pattern recognition, decision support and data mining.

Lower approximation and upper approximation are two fundamental concepts in rough set theory. Objects are divided into three sets: negative, positive and uncertainty. These three sets are denoted by lower approximation, negative space and boundary.

Basic Concepts of Rough Sets

Rough sets were to serve as approximate description of sets that are not known, incompletely specified, or whose exact specification is complex. Human knowledge about a domain is expressed by classification. This theory [2]-[4] treated knowledge as its ability to classify the perceived objects into different categories. And Objects belonging to same category are considered as indistinguishable.

------Let *U* denote a finite and non-empty set of objects called the universe, and let $R \subseteq U*U$ denote an equivalence relation on *U*. The pair (*U*, *R*) is called an approximation space. The equivalence classes partitioned by *R* are called elementary sets of (*U*, *R*). The equivalence relation and the induced equivalence classes may be regarded as the available information or knowledge about the objects .

Given an arbitrary set $X \subseteq$ U, it may be impossible to describe *X* precisely using the equivalence classes of *R*. That is, the available information is not sufficient to give a precise representation of *X*. In this case, one may characterize *X* by a pair of lower and upper approximations:

$$\underline{RX} = \{x \in U : [x]_R \subseteq X\}$$

$$\overline{RX} = \{x \in U : [x]_R \cap X \neq \Phi\}$$

Where $[x]_R$ is the equivalence class containing *x*. The lower approximation $\underline{RX}$ is the union of all the elementary sets which are subset of *X*. It is the largest composed set contained in *X*. The upper approximation $\overline{RX}$ is the union of

all the elementary sets which have a non-empty intersection with *X* and the smallest composed set containing *X*.

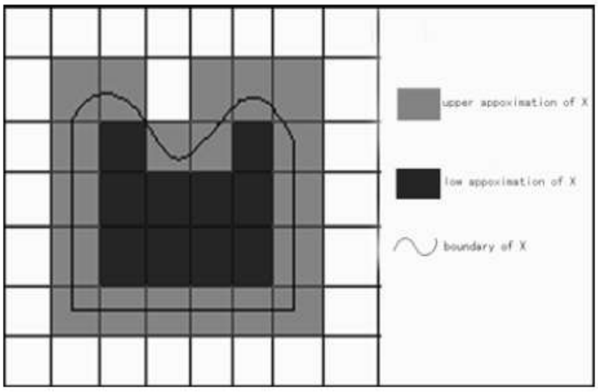

Figure description of rough set

Definition 2: Let *K*=(*U*,*R*) denote approximation sets. The roughness measures $X \subseteq U$ is presented as

$$\gamma_X = \frac{|\underline{RX}|}{|X|}$$

Roughness measures describe the measurement of sets. Roughness measure and accuracy of rough sets are inversely proportional to each other. The mathematical morphological edge detection algorithm based on rough sets is follow.

Step1 construct structure elements B*i* of different directions. In this paper we construct eight SE which have different directions angle. The angles are 00, 22.50, 450, 67.50, 900, 112.50, 1350 and 157.50. These structure elements are shown in, where * denotes the components of SE.

Step 2. Choose the SE according following equation at each pixel.

$$B' = \{B^i \mid r_{B^i} = \max(r_{B_x^1}, r_{B_x^2}, \ldots, r_{B_x^8}), r_{B^i} = \frac{|\underline{RB_x^i}|}{|B_x^i|}\}$$

Step3. Calculate the edge according *E*(*F*)=(*F*⊕*B*)-(*F*Θ*B*) . SE is B' computed by step 2.

PROPOSED ALGORITHM

The proposed method works with the help of simple morphological operations. Following are the steps to be followed:

1. Take original RGB image, I(x, y) as input;
2. Convert the RGB image I(x, y) into gray image I1(x, y);
3. Set threshold = 225;
4. Calculate every pixel;
5. for each pixel of gray image I1 (x, y)

   If pixel value I1 (x, y) < threshold

// Here f(x, y) represents pixel value of gray image I1(x, y).
set C (x, y) = false;
else
set C (x, y) = true;
// C (x, y) represents the binary image.

6. Take transpose of C (x, y)

D (x, y) = C^T ;

7. Apply erosion operation with structuring element having disc shape.

F (x, y) = erosion (C, structure element);

8. Subtract it from the transposed binary image.

H (x, y) = | D (x, y) - F (x, y) |;

9. Follow dilation operation with same structure element.

G (x, y) = dilation (H, structure element);

10. Print the result by the proposed method image.

In this model fixation of threshold has played an important role thus it becomes a matter of deep consideration. The threshold value has been assigned to 225 after checking the outcomes at various thresholds.

EXPERIMENTAL RESULTS

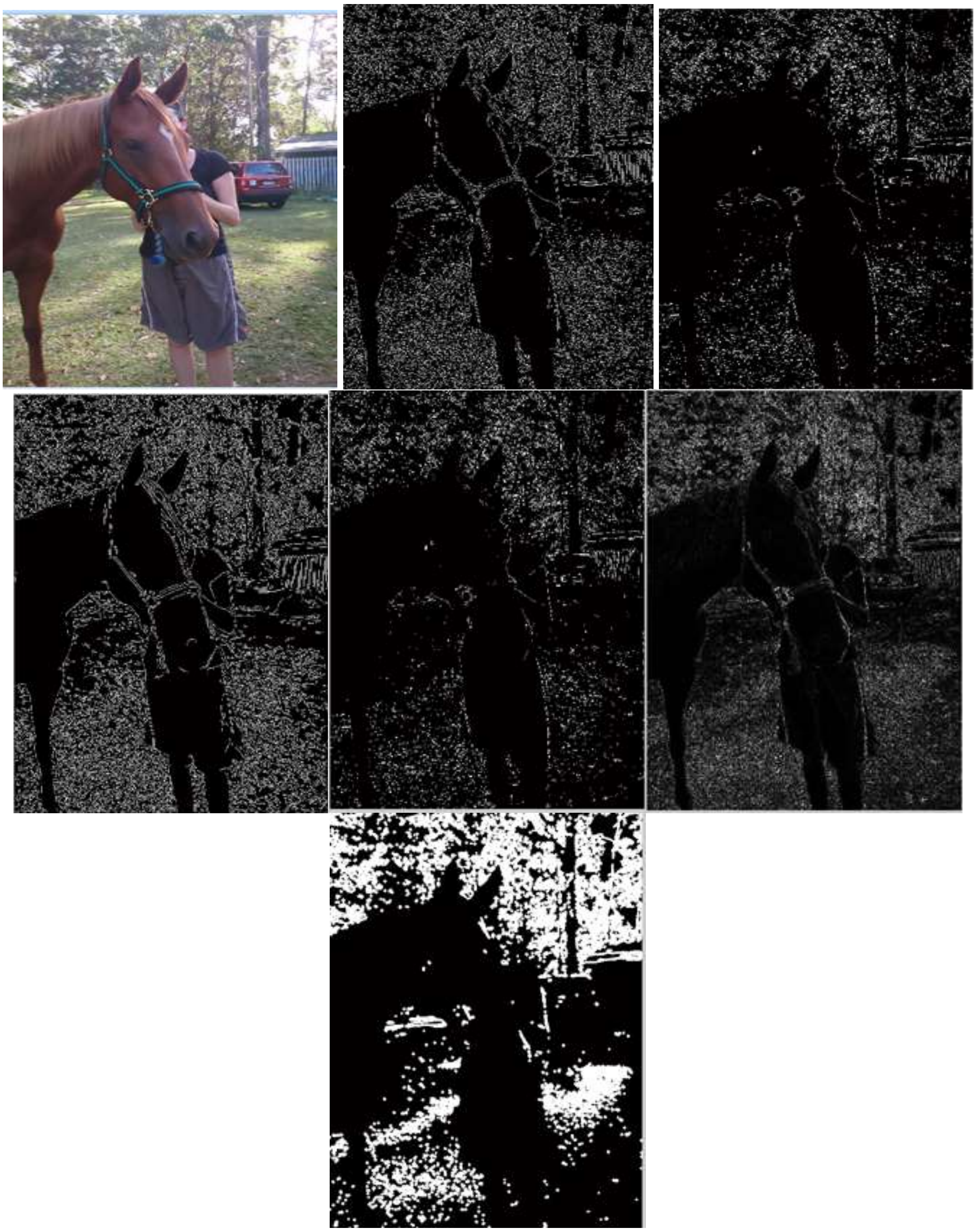

Figure depicting original image, outcomes using the LoG operator, prewitt operator, canny operator, sobel operator, rough set and proposed method.

Mean value

	LoG	Prewitt	Sobel	Canny	Rough set	Proposed method
Image.jpg	0.0949	0.0477	0.1377	0.0476	29.0388	0.2576

Time in seconds

	LoG	Prewitt	Sobel	Canny	Rough set	Proposed method
Image.jpg	1.689549	0.58092	1.348907	0.554352	808.652954	0.953245

CONCLUSION

Through experimental results the proposed method seems to be timely efficient then the rough set theory in visual terms as well as in time constraints and the value of mean value being lesser in the case yielding better output proves that it avoids the knowledge of noisy pixels in the image as compared to rough set theory. The edges are clear and undistorted. Fixed threshold value makes it easy to go around with all kind of images

On the other hand the capability to deal with coloured images adds a positive point the proposed algorithm however in few cases it does not produce timely efficient results but yes they are visually better.

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