

# VII-INTERNATIONAL EUROPEAN CONFERENCE ON INTERDISCIPLINARY SCIENTIFIC RESEARCH

March 28-30, 2023 / Frankfurt, Germany



## FULL TEXTS BOOK

Editor  
Assist. Prof. Dr. Mehmet Emin KALGI

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# **AN IMPROVED BLOCK BASED HYBRID EDGE DETECTION METHOD TO SUPPORT TEXT RECOGNITION ON NOISY IMAGES**

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## **ABSTRACT**

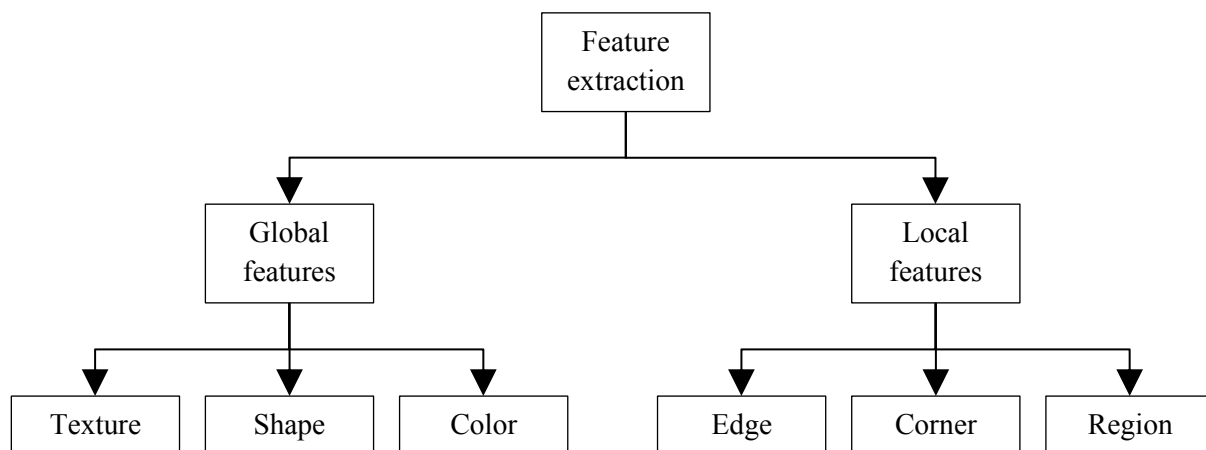
Numerous methods have been proposed for recognizing characters in an image. Some of these use the Canny, Sobel and Prewitt edge detection algorithms. Images captured from the real world in applications such as license plate recognition contain a lot of noise due to physical environmental conditions such as rain and mud. As the amount of noise in the image increases, edge recognition algorithms produce parallel and dashed lines that make text recognition difficult. In this study, a supporting method for edge detection-based text recognition algorithms is proposed. With the proposed work, block-based Shannon Entropy is applied in the low frequency sub-band of the noisy image. In the experimental results, it was observed that the parallel and dashed lines produced by the edge recognition algorithms in the noisy image decreased. The proposed algorithm is not efficient in terms of algorithm complexity for noise-free images, but it can contribute positively to edge recognition in noisy images.

**Keywords:** Edge detection, License plate recognition, Hybrid algorithm.

## **INTRODUCTION**

A digital image is a type of image obtained as a result of the real world image being divided into small pieces called pixels (Turhal et al., 2015). Each pixel has a numerical brightness value. Image processing is a method of computer-analyzing and manipulating digital images using mathematical operators. One of the important purposes of image processing is to efficiently interpret the content of the image and find meaningful and important information from it (Ansari et al., 2017). A property is a numerical value that can be obtained from an image with one or more functions in order to distinguish it from another one or to obtain useful information about the it. The data set in which the desired features of an image are collected is called the feature set. A good feature set should be as small in size (Kumar and Bhatia, 2014) and rich as possible. The purpose of feature extraction is to obtain a processable dataset that is much smaller than the original image and that can classify it. The set of features obtained in feature extraction should contain specific information about the image. Algorithms used in feature extraction systems generally work in three stages. The first stage is the feature extraction stage. At this stage, the image, which is the input data, is converted into a set of features with the feature extraction function. The second stage is the selection stage. At this stage, the number of features required to classify the image is reduced according to the elements of the set of features obtained

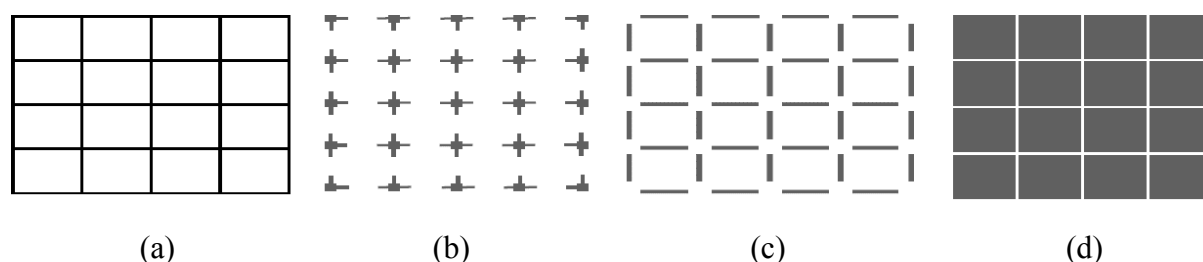
in the previous stage. For this, useless features that will not be used in classification are discarded. In other words, a subset of features is obtained. In the last stage, the image is classified according to the features decided in the selection stage. The success of each stage affects the success of the next stage, and therefore the entire system.



**Figure 1.** Classification of feature extraction methods

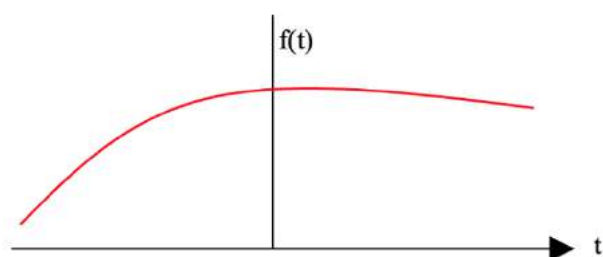
Image features are examined in two categories, local and general features, as shown in Figure 1. Native features are used in many applications such as real-time monitoring, image mining, object tracking, mosaicing. Text recognition methods usually deal with the local features of the image. Initially, the text is detected and distinguished from the whole image using the bounding box technique. This determines the position of the text in the image. This step is followed by segmentation. The text image needs to be improved to remove some background noise and facilitate the text recognition process. The text recognition algorithm gathers useful text information from the optimized region and then outputs the text (Wu et al., 2022).

Edges are points that serve as boundaries between two image regions. Locally, edges have a one-dimensional structure and are points on the same plane (Balan and Sunny, 2018). Although edge pixels occupy only a small portion of the image, they carry most of the image's information. These contours play an important role in describing or describing images (Wu et al., 2022). Corners are properties of the point where two or more edges intersect. Regions are a set of homogeneous points where the density value has similar characteristics (Salahat and Qasaimeh, 2017).



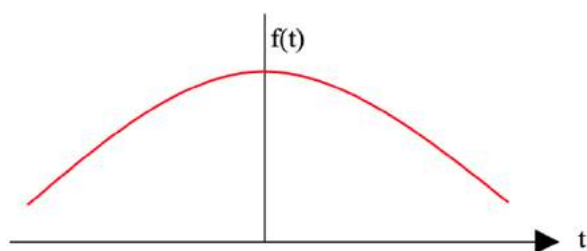
**Figure 2.** Local features of the image (a) input image (b) corners (c) edges (d) regions (Salahat and Qasaimeh, 2017)

In order to find the shape information of an object in the image, the edges of that object must be determined. Edge detection detects sharp and sudden changes in the intensity (brightness or color) of an image, providing information about the formation and locality of edges (Ansari et al., 2017). That is, in order to detect the boundaries of the objects in the image, the edges must be detected (Dharampal, 2015). The most commonly used edge detection algorithms are Prewitt, Sobel, Canny, Roberts and Laplace of Gaussian (Ansari et al., 2017). Edge detection methods are examined in two categories, the first is Laplacian based and the second is gradient based. In the Laplace-based method, the image is used to calculate the zero-pass second-order derivative expression. In general, the edges are found by looking for a zero crossing of a nonlinear differential expression. Typically, a preprocessing step, Gaussian smoothing, is applied for edge detection (Dharampal, 2015). The LoG filter, which is based on applying Laplace and Gaussian filters one after the other, was first proposed by Marr and Hildreth (Marr and Hildreth, 1980). In the gradient-based method, the edges are determined by taking the first-order derivative of the image. The gradient magnitude is used to calculate a measure of edge strength. Let the signal shown in Figure 3 represent an intensity jump in a region of the image.



**Figure 3.** Sample intensity signal of an edge

If the gradient of this signal is taken, the result is shown in figure 4.



**Figure 4.** The gradient of sample edge signal

The derivative indicates a maximum value located in the center of an edge in the original signal. This edge detection method is characteristic of the gradient filter family of edge detection filters. If the value of the gradient exceeds a threshold, the pixel position is reported as an edge position. (Maini and Aggarwal, 2009). The gradient-based approach is also called a digital mask. The first-order derivative of the image is used to find the maximum and minimum values in the gradient-based operator. For a function  $f(x, y)$ , the differential of  $f$  in coordinates  $(x, y)$  as a dimensional column vector is in (1.1).

$$\nabla f = G[f(x, y)] = \begin{bmatrix} Gx \\ Gy \end{bmatrix} = \begin{pmatrix} \frac{df}{dx} \\ \frac{df}{dy} \end{pmatrix} \quad (1.1)$$

Here  $\nabla f$  is the gradient of the vector and the coordinates  $(x, y)$  have the maximum rate of change, which can be observed by vector measurement. The magnitude of the vector  $\nabla f$  denoted as  $M(x, y)$ .

$$M(x, y) = \text{magnitude}(\nabla f) = |G| = \sqrt{Gx^2 + Gy^2} \quad (1.2)$$

$$LoG(x, y) = -\frac{1}{\pi\sigma^4} \left[ 1 - \frac{x^2 + y^2}{2\sigma^2} \right] e^{-\frac{x^2 + y^2}{2\sigma^2}} \quad (1.3)$$

$$M(x, y) = Gx^2 + Gy^2 \quad (1.4)$$

The direction of the gradient is calculated by (1.5).

$$\theta = \tan^{-1}\left(\frac{Gy}{Gx}\right) \quad (1.5)$$

The angle is measured with reference to the x-axis. The direction of the edge is perpendicular to the slope at that point. The gradient of the 2D image is given by (1.6) and (1.7).

$$Gx = f(x + 1, y) - f(x, y) \quad (1.6)$$

$$Gy = f(x, y + 1) - f(x, y) \quad (1.7)$$

In a gradient-based method, pixels with a high gradient are considered as edges. In this study, three gradient-based edge detection methods are used to create the hybrid algorithm which are; Sobel, Prewitt, and Canny.

Irwin Sobel proposed the Sobel edge detection technique in 1970 (Ansari et al., 2017). The result image is obtained by moving the horizontal and vertical 3x3 directional masks (Figure 5) belonging to the Sobel operator on the image.

-1	0	+1	+1	+2	+1
-2	0	+2	0	0	0
-1	0	+1	-1	-2	-1
Gx			Gy		

**Figure 5.** Sobel edge detection operator masks

The Sobel operator mask is hovered over the image starting from the upper left corner. By multiplying the pixel value with the mask coefficient corresponding to each pixel value, all the results are summed to find the operator's response. In the original image, the squares of the responses of the horizontal and vertical masks at the same places are summed and the square root is taken to obtain the true gradient value. When the gradient values are placed in a matrix of the same size as the original image, an image showing the edges of the original image is found (Aybar, 2008).

In 1970, Prewitt proposed the Prewitt edge detection technique, which is a good algorithm for measuring the size and direction of edges (Ansari et al., 2017). The value hold constant  $c$ , which the Sobel operator uses as 2, is taken as 1 in the Prewitt operator (Dharampal, 2015). The Prewitt operator is similar to the Sobel operator and is used to detect vertical and horizontal edges in images. Edge gradient values are calculated by convolution operation using two different masks (figure 6) on the horizontal and vertical pixels on the image (Icer and Turk, 2016).

-1	0	+1	+1	+1	+1
-1	0	+1	0	0	0
-1	0	+1	-1	-1	-1
Gx			Gy		

**Figure 6.** Prewitt edge detection operator masks

The approximation of the partial derivative on the x-axis can be calculated by taking the difference between rows 3 and 1 of the 3\*3 image region. The other mask on the y-axis is applied by taking the difference between the 3<sup>rd</sup> and 1<sup>st</sup> columns to approximate the derivative. Here, the partial derivatives are given as (1.8) and (1.9).

$$Gx = (P_7 + cP_8 + P_9) - (P_1 + cP_2 + P_3) \quad (1.8)$$

$$Gy = (P_3 + cP_6 + P_9) - (P_1 + cP_4 + P_7) \quad (1.9)$$

With value hold constant  $c = 2$ , the partial derivative is calculated by (1.10).

$$Gx = [f(x, y)] = \sqrt{Gx^2 + Gy^2} \quad (1.10)$$

The edge has an orientation angle  $\theta$ , that increases the spatial gradient (1.11).

$$\theta = \arctan (\arctan(Gx/Gy)) \quad (1.11)$$

Canny's proposed method consists of five processes. These are convolution of the image with the first derivative of the Gaussian operator, estimation of noise energy, elimination of non-maximum gradient values by looking at neighboring pixels, binary thresholding, and refinement processes (Canny, 1986). It is a standard, powerful, and commonly used edge detection method. Canny generally gives better results than other methods (Ansari et al., 2017) and has a low error rate. It is considered successful in not missing edges in the image and not detecting non-edge parts as edges. It separates noise from the image before detecting edges using Gaussian Filtering (1.12) (Macit and Koyun, 2023).

$$G_{\sigma} = \frac{1}{2\pi\sigma^2} e^{-\frac{x^2+y^2}{2\sigma^2}} \quad (1.12)$$

Canny uses Sobel filter on images to calculate gradient size and gradient angle (1.13).

$$G[f(x, y)] = \sqrt{Gx^2 + Gy^2} \quad (1.13)$$

The main purpose of doing non-maximum suppression is to sharpen the edge of the image with a blurred gradient size. After non-maximum suppression, some pixel values are no longer true edge pixels due to noise and color variation. The purpose of double thresholding is to eliminate these pixels. Pixels classified as strong after double thresholding are strictly considered edge pixels.

Edge detection algorithms that work with the gradient computation approach work well for step edges. Directional derivatives within the gradient are sensitive to noise due to the nature of the derivative. Sobel, Roberts, and Prewitt operators have problems with angle and direction detection in noisy images and they do not work effectively in corners (Şenel, 2007). Edge detection is difficult in noisy images because the edges contain high frequency content. Attempts to reduce noise cause edges to be blurry and distorted. Therefore, the operators used in noisy images are usually larger (Maini and Aggarwal, 2009). Because the derivative is sensitive to noise, images need to be smoothed before applying derivative-based operators. The amount of smoothing that needs to be applied to the image may vary from image to image, and there is no general formula for this (Şenel, 2007). Edge operators such as Prewitt and Sobel, which are based on the first derivative and have small dimensions, use the step edge model with added Gaussian noise. Although this model is generally convenient in design, it poses two problems in implementation. The first one is that the edges in natural images are not just step edges (Konishi et al., 2003), and the second one is that the complex situation created by objects close to each other does not match the step edge model (Heijden, 1995). If derivative-based operators are applied to images with noise, a result with discrete and virtual edges can be obtained. One of the reasons for this is the low number of samples used during the process, in other words, the number of pixels in the core (Şenel, 2007). Real-world images for text recognition may contain noise due to the effects of the physical world. For example, in the plate image captured for a license plate recognition system, effects such as dirt and mud on the plate may make it difficult to recognize the characters. This research proposes a method to deal with edge detection problems in noisy images which includes a feature extraction step before edge detection. The proposed gradient-based hybrid method has been tested with a muddy plate image and the results are shown in the following sections.

## **METHOD**

One of the most challenging steps in digital image analysis is to properly extract edge information from the image. Edges depend on intensity, lighting, objects, noise, blur (Ansari et al., 2017). The variables that determine the choice of edge detection operator are edge orientation, noise environment and edge structure. The geometry of the operator determines the characteristic direction in which it is most sensitive to edges (Maini and Aggarwal, 2009). In a noisy image, the edge detection algorithm can detect parallel or false edges. The algorithm proposed in this study includes a series of preprocessing for edge recognition in noisy image. In the first step, the low frequency coefficients of the image are taken. These coefficients are divided into color layers, and block coding is performed on each layer. Next, entropy values of

each block are calculated. The output binary matrix is created using a threshold value. In the last step, this matrix is sent to the edge recognition algorithm as an input parameter.

Input image  $I$  is a color image at any resolution. The number of rows is  $r$ , the number of columns is  $c$ , and each pixel is  $x_{i,j}$ .

$$I(c, r) = \{x_{i,j} | 1 \leq i \leq r, 1 \leq j \leq c\} \quad (2.1)$$

Discrete Wavelet Transform (DWT) is performed to get rid of the detail components of the  $I$  and obtain the significant part. A DWT is a wavelet transform that decomposes the host signal into wavelets that are discontinuous (Begum vd., 2022). Two-dimensional wavelet transform is a one-dimensional analysis of a two-dimensional signal (Mistry, 2013). The image signal is passed through the Low Pass Filter (LPF) to obtain its important components.

$$LPF = \sum_i I(i) f[2I - i] \quad (2.2)$$

In the equation,  $i$  indicates the index of the pixel being processed in the one-dimensional signal, and  $f$  is the filter function. The main purpose here is to get rid of the noise a little bit. The number of rows and columns of the  $I_L$  signal obtained after DWT is half of the  $I$  image.

$$I_L(c, r) = \{x_{i,j} | 1 \leq i \leq r/2, 1 \leq j \leq c/2\} \quad (2.3)$$

A license plate image was used to simulate the algorithm. Figure 7 shows this test image and its condition after DWT.



**Figure 7.** (a) Test image (b) Low coefficients

A color image consists of three color planes.  $I_L$  is divided into red, green, and blue color planes. Then, each color plane is scaled to the same size as  $I$ .

$$I_{LR} = \{x_{ij} | 1 \leq i \leq r, 1 \leq j \leq c\} x_{ij} \in \{0,1,2, \dots, 255\} \quad (2.4)$$

$$I_{LG} = \{x_{ij} | 1 \leq i \leq r, 1 \leq j \leq c\} x_{ij} \in \{0,1,2, \dots, 255\} \quad (2.5)$$

$$I_{LB} = \{x_{ij} | 1 \leq i \leq r, 1 \leq j \leq c\} x_{ij} \in \{0,1,2, \dots, 255\} \quad (2.6)$$

A pixel containing an edge can be on any color plane. At this stage, each color plane is divided into  $p \times p$ -sized sub-blocks to approximate the pixels.

$$B_{R(i,j)} = \sum_{i=1}^m \sum_{j=1}^n I_{LR(i,j)} \quad (2.7)$$

$$B_{G(i,j)} = \sum_{i=1}^m \sum_{j=1}^n I_{LG(i,j)} \quad (2.8)$$

$$B_{B(i,j)} = \sum_{i=1}^m \sum_{j=1}^n I_{LB(i,j)} \quad (2.9)$$

The smaller the  $p$ -value is chosen, the sharper the results of the algorithm, but the greater the complexity of the operation. In the next step, entropy measurement is made to estimate whether the blocks are in the edge transition region. The entropy function reaches its maximum value when the probability of the results produced by the system is equal to each other. The total entropy value for color plane vectors with pixel number  $pxp$  is given in (2.10).

$$\sum_{i=1}^p p_i = 1 \{B_{R(i,j)} = x_1, x_2, \dots, x_p\}, \{B_{G(i,j)} = x_1, x_2, \dots, x_p\}, \{B_{B(i,j)} = x_1, x_2, \dots, x_p\} \quad (2.10)$$

The probability for each case is  $p_i \geq 0$ . Assuming the histogram density value  $h(i)$  in a block, the block's entropy  $E(B)$  is calculated as in (2.11).

$$E(B) = \sum_i h_R(i) \log(pxp) h_R(i) \quad (2.11)$$

Blocks with entropy value greater than the mean entropy are marked as edge transition regions. The  $\lambda$  matrix with  $c/p$  columns and  $r/p$  rows is created (2.12) as a noise-free image.

$$\lambda_{(i,j)} = \begin{cases} 0, E(B_{R(i,j)}) < t, E(B_{G(i,j)}) < t, E(B_{B(i,j)}) < t \\ 1, E(B_{R(i,j)}) \geq t, E(B_{G(i,j)}) \geq t, E(B_{B(i,j)}) \geq t \end{cases} \quad (2.12)$$

In the equation, the  $t$  value is the mean of the entropy results of the R, G and B blocks. The  $\lambda$  matrix is a binary matrix and Gaussian smoothing cannot be applied to this matrix. Single pixel noises in the  $I$  image are also present in the  $\lambda$  matrix. To get rid of this noise, bidirectional filtering is applied. First, it is scanned from the first pixel of the  $\lambda$  matrix to the last pixel. At each step, the value of the pixel whose neighbor pixels add up to 0 is set to 0. The same process is repeated from the last pixel to the first pixel, backwards. The proposed algorithm has the ability to repeat this process several times according to the amount of single pixel noise in the image. The  $\lambda$  matrix obtained as a result of these steps is the optimum matrix for edge detection algorithms. Figure 8 shows the  $\lambda$  matrix obtained for the test image after these processes.



**Figure 8.**  $\lambda$  matrix obtained for the test image

Now, one of the Canny, Sobel or Prewitt methods can be applied to the  $\lambda$  matrix to clearly detect edges.

## RESULTS

The biggest problems in edge detection are false edge detection, loss of edges, producing thin or thick lines, etc (Maini and Aggarwal, 2009). Edge detection based text recognition systems can produce erroneous results due to these problems. Text recognition systems are frequently applied in important areas where errors are not desired, such as traffic management, business card recognition, document recognition, license plate recognition, container coding, etc (Wu et

al., 2022). Figure 9 shows the edges detected by the Canny, Sobel and Prewitt edge detection methods on the test image.



**Figure 9.** Edges detected by the (a) Canny, (b) Sobel, and (c) Prewitt edge detection methods on the test image.

In Figure 10, the edges detected by the edge detection methods are shown on the  $\lambda$  matrix created by the proposed method.



**Figure 10.** Edges detected by the proposed (a) hybrid-Canny, (b) hybrid-Sobel, and (c) hybrid-Prewitt edge detection methods on the test image.

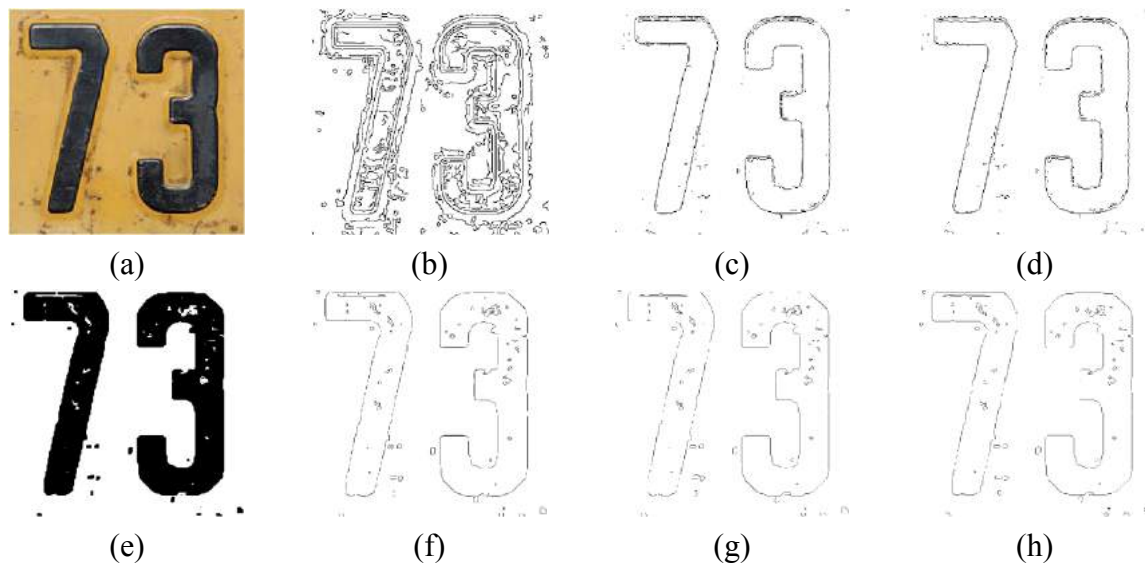
It is obvious that the proposed hybrid method gave better results than the use of edge algorithms alone. False Positive Rate (FPR) was calculated to show the performance of the proposed method mathematically. In statistics, the probability that a value that is actually negative will be falsely classified as positive is called the FPR and it is calculated by (2.13).

$$FPR = \frac{FP}{FP+TN} \quad (2.13)$$

The number of pixels on the lines that are not edges but are defined as edges is considered False Positive (FP), and the number pixels on the lines that are edges and defined as edges is considered True Negative (TN). Visual results for a cross section from the test image are shown in figure 11, and the FPR values are shown in table 1.

**Table 1.** Mathematical results of the proposed method

Method	FPR	Parallel edges	Dashed edges
Canny	0.87	Too much	No
Sobel	0.39	A little	No
Prewitt	0.39	A little	No
Hybrid-Canny	0.31	Slight	No
Hybrid-Sobel	0.11	Slight	Yes
Hybrid-Prewitt	0.13	Slight	Yes



**Figure 11.** Edges detected from a region of the test image (a) by the (b) Canny, (c) Sobel, (d) Prewitt, (e)  $\lambda$  matrix, (f) hbrid-Canny, (g) hybrid-Sobel, and (h) hybrid-Prewitt edge detection methods.

Visual results and FPR results show that the proposed method is successful in noisy license plate image. Although the hybrid-Canny algorithm has a higher FPR value than other proposed hybrid algorithms, it is more suitable for use in text recognition methods because it does not produce dashed lines. The proposed method is successful for images containing text, but has not been tested for other image recognition methods such as face detection, pattern recognition.

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