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Noise effect analysis on edge detection in detecting digits with bilateral filter

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Abstract. Recognizing characters such as digits in natural images is a challenge in image processing. Edge detection is the first approach in image recognition. Edge detection using Bilateral Filter can improve image quality. However, in image processing, noise often occurs in the image which causes objects in the image to be more difficult to detect. In this paper, we conducted experiments to detect edges by using Bilateral filters on each edge detection operator against digits on SVHN which added noise and analyzes the effect of noise on edge detection. In the proposed method, edge detection of SVHN with Speckle noise does not produce many edges compared to Salt & Pepper noise so digits in SVHN can still be seen. The performance of the edge detection operator with Bilateral Filter can also be seen from the MSE and PSNR values. The lowest MSE value and the highest PSNR value is on Canny when detecting SVHN edges with Speckle noise.

1. Introduction

The Street view house number (SVHN) is an image containing digits obtained from the house number in the Google Street View image. Recognizing multi-digits numbers from image is a difficult unsolved computer vision problem [1]. Edge detection is the main approach in image recognition and analysis can be based on the edge of the image containing useful information. Edge detection is used to extract the essential features in the image. The detected edges can be wide or nonexistent due to the influence of noise [2]. In image processing, noise often occurs in an image [3]. Noise is a disturbance experienced by the image so as to make the image becomes less good. There is a lot of noise that can affect image quality, including salt n pepper, gaussian and speckle noise. The effect of each noise varies on each image.

In previous studies, we have compared edge detection using gaussian filters and edge detection using bilateral filters where the results show edge detection using bilateral filters has increased [4]. Therefore in this research purpose to analyze the effect of noise on edge detection with bilateral filters in reading numbers on street view house number.

2. Noise

Noise is a disturbance that can affect the appearance of the image and produce unwanted effects such as blurred objects, invisible lines, angles, and disturbing the entire object image. The causes of noise in the image are defects in data transmission, imperfect optics, processing techniques, non-functioning sensors and electronic interference [5].
2.1 Gaussian Noise

Gaussian noise is also known as a Gaussian distribution whose Probability Density Function is the same as a statistical disturbance. Gaussian noise generally interferes with gray values in the image of [6]. This noise due to the characteristics of the gray level and the presence of random variables because of the characteristics of the Density Probability Function (PDF). The effect of this gaussian noise on the image is the appearance of colored dots whose numbers are equal to the percentage of noise. This is given as

\[ P(y) = \frac{1}{\sqrt{2\pi\sigma^2}} \exp\left(-\frac{(y-\mu)^2}{2\sigma^2}\right) \]  

(1)

Where \( g \) = gray value, \( \sigma \) = standard deviation and \( \mu \) = mean.

2.2 Salt & Pepper Noise

The image which has salt & pepper noise in the image will show dark pixels in bright areas and bright pixels in dark areas [7]. This noise generally occurs due to sharp and unexpected changes in image signals, noise arises and causes dead pixels, analog-to-digital converter errors, etc. [8]. The pdf of Impulse noise is given by:

\[ p(z) = \begin{cases} 
P_a & \text{for } z = a \\
P_b & \text{for } z = b \\
0 & \text{otherwise} 
\end{cases} \]  

(2)

If \( b>a \), gray level \( b \) will appear as a bright spot on the image. on the contrary, the gray level \( a \) will appear like a dark spot. If there is no probability of zero value, it will form fine grains such as salt (salt & pepper).

2.3 Speckle Noise

The nature of noise is mutiplicative, meaning that the greater the intensity of the image or the brighter the image, the clearer the noise. Speckle Noise is a noise model that gives a black mark on the part in the form of a noise-affected point. This noise appears during imperfect image capture due to weather, image capture devices and so on [6]. The equation is given by:

\[ v(x,y) = u(x, y) * s(x, y) \]  

(3)

where \( v(x,y) \) is corrupted image, \( u(x, y) \) is multiplicative component, and \( s(x, y) \) is intensity from speckle noise.

3. Bilateral Filter

Bilateral filters are widely used for denoising [9] image filters. Bilateral filters can smooth the image while maintaining the edge that has two kernel filters: spatial kernel and range kernel [10]. The weights can be calculated from the Gaussian function [11]. Spatial kernel \( W_{g_2} \) is the realization of spatial proximity measurement is by the equation

\[ W_{g_2} = \exp\left(-\frac{||x-y||^2}{2\sigma_2^2}\right) \]  

(4)
While range kernel \( W_{\gamma} \) means the weighting of pixels in accordance with the size of the difference in intensity of the pixel with the intensity at the pixel which is the center of analysis on the image. Calculation of range kernel in each pixel is shown in the equation.

\[
W_{\gamma} = \exp \left( \frac{-((I(p)-I(q))^2)}{2\sigma^2} \right)
\]  

(5)

Bilateral Filtering \( W^B(p) \) computation as follows:

\[
W^B(p) = \frac{1}{W} \sum_{p \in N(p)} G_{\sigma_x}(\|p-q\|) G_{\sigma_y}(\|p-Iq\|) Iq
\]

(6)

Where \( I \) is a grey level image, \( N(p) \) is a neighborhood of \( p \), \( Ip \) is the intensity value at pixel location \( p \), \( W_p \) is the normalization factor which ensures pixel weights sum to 1

\[
W_p = \sum_{q \in N(p)} G_{\sigma_x}(\|p-q\|) G_{\sigma_y}(\|p-Iq\|)
\]

(7)

4. Edge Detection

Edge detection is used to extract the essential features [12]. Edge is the essential characteristic of an image [13]. The edges of an image contain crucial information from the image. A significant step in image processing is edge detection. Image edges can represent the objects contained in the image, shape, size, and sometimes also information about the texture.

4.1 Roberts Operator

Roberts operator is a first-order operator, which performs 2-D spatial gradient measurements to find edges [2]. Roberts operators have fast computing rates and are simple operators. The image to be detected by the edge is combined with the mask of the operator and the gradient magnitude to be calculated directly. The Roberts operator uses the following 2x2 convolution kernels:

\[
G_x = \begin{bmatrix} 1 & 0 \\ 0 & -1 \end{bmatrix}, \quad G_y = \begin{bmatrix} 0 & 1 \\ -1 & 0 \end{bmatrix}
\]

4.2. Canny Operator

Canny is one of the modern edge detection algorithms. This algorithm is focuses to separate the background noise from complex image and to find the effective edges for optimized solutions. In 1986 John Canny proposed three criteria to be the basis of filter mining to optimize edge detection in noise-sensitive images. The first step in implementing Canny is to smooth the image [2]. Then find the image gradient in both vertical and horizontal directions [12]. Canny uses a Gaussian filter before applying the mask. Gaussian filters can reduce the noise as much as possible [3]. Canny edge detectors are not sensitive to noise causing Canny can detect weak edges [2].

4.3. Frei Chen Operator

Frei Chen mask contains the base vector. This is implemented in the 3x3 image area represented by the number of nine Frei Chen masks [14].

\[
G_1 = \frac{1}{2\sqrt{2}} \begin{bmatrix} 1 & \sqrt{2} \\ 0 & 0 \\ -1 & -\sqrt{2} \end{bmatrix}, \quad G_2 = \frac{1}{2\sqrt{2}} \begin{bmatrix} 1 & 0 & -1 \\ \sqrt{2} & 0 & -\sqrt{2} \\ 1 & 0 & -1 \end{bmatrix}, \quad G_3 = \frac{1}{2\sqrt{2}} \begin{bmatrix} 0 & -1 & \sqrt{2} \\ 1 & 0 & -1 \\ -\sqrt{2} & 1 & 0 \end{bmatrix}
\]
5. Results and Discussion

The dataset used in this research are Street View House Number (SVHN) from Google Street View image. In this research we used svhn training for edge detection.

![Sample SVHN dataset images](image_url)

**Figure 1.** Sample SVHN dataset images

**Table 1.** Edge detection results on SVHN with bilateral filter

| SVHN  | Robert          | Canny           | Frei Chen       |
|-------|-----------------|-----------------|-----------------|
| ![Image](image_url) | ![Image](image_url) | ![Image](image_url) | ![Image](image_url) |
| MSE: 21780.2  | MSE: 21250.2    | MSE: 21771.5    |
| PSNR: 4.75018 | PSNR: 4.85716   | PSNR: 4.75192   |
| ![Image](image_url) | ![Image](image_url) | ![Image](image_url) | ![Image](image_url) |
| MSE: 15283.4  | MSE: 14581.7    | MSE: 15274.6    |
| PSNR: 6.28861 | PSNR: 6.49272   | PSNR: 6.29111   |
| ![Image](image_url) | ![Image](image_url) | ![Image](image_url) | ![Image](image_url) |
| MSE: 9655.43  | MSE: 9278.44    | MSE: 9647.29    |
| PSNR: 8.28309 | PSNR: 8.45605   | PSNR: 8.28675   |
In table we only show 3 images from the 50 datasets that we have used. The experiment was carried out using bilateral filters on each edge detection operator. The result shows that the edge detection of Robert can't produce an edge at all. This also happened with the other edge detection of Robert. Canny produces pretty good edge detection. The digit in the picture can be seen clearly. As for Frei Chen, there were several missing edges which resulted in the digit not being clearly visible.

Table 2. Edge detection results with Bilateral Filter on SVHN by adding Gaussian Noise

| SVHN with GAUSSIAN NOISE | ROBERT | CANNY | FREI CHEN |
|--------------------------|--------|-------|-----------|
|                          | MSE : 21633.5  PSNR : 4.77953 | MSE : 18444.3  PSNR : 5.47219 | MSE : 21620.9  PSNR : 4.78208 |
|                          | MSE : 15781.7  PSNR : 6.14925 | MSE : 12879.5  PSNR : 7.0318 | MSE : 15777.1  PSNR : 6.15053 |
|                          | MSE : 10210.1  PSNR : 8.04052 | MSE : 7972.1  PSNR : 9.11508 | MSE : 10205  PSNR : 8.04268 |

From the results of Robert's edge detection that we have done, the edges of the image do not appear at all, but in some other edge detection results there are some visible edges even though they do not form digits such as the first image above. Canny produces very many edges. The Gaussian noise in SVHN is also detected as an edge so that the digits of the SVHN cannot be seen. The edge of the digit on Frei Chen's edge detection is quite clearly seen in the first image, but in the next image the edge of the digit is not very clearly visible.

Table 3. Edge detection results with Bilateral Filter on SVHN by adding Salt & Pepper Noise

| SVHN with SALT & PEPPER | ROBERT | CANNY | FREI CHEN |
|-------------------------|--------|-------|-----------|
|                         | MSE : 21279.2  PSNR : 4.85126 | MSE : 18714.3  PSNR : 5.40906 | MSE : 21251.5  PSNR : 4.85692 |
On the edge detection of Robert and Frei Chen shows Salt & Pepper noise is also considered an edge. The digits in SVHN appear vague in the first image, while in the next image the digits are no longer visible. Whereas Canny shows digits that is dimly covered with the edge of the Salt & Pepper noise on the SVHN.

Table 4. Edge detection results with Bilateral Filter on SVHN by adding Speckle Noise

| SVHN with SPECKLE NOISE | ROBERT | CANNY | FREI CHEN |
|-------------------------|--------|-------|-----------|
| ![239](image1) | ![image2] | ![image3] | ![image4] |
| MSE : 15623.3 | MSE : 13501.6 | MSE : 15623.2 |
| PSNR : 6.19309 | PSNR : 6.82695 | PSNR : 6.1931 |
| ![image5] | ![image6] | ![image7] |
| MSE : 9940.13 | MSE : 8384.41 | MSE : 9931.06 |
| PSNR : 8.15688 | PSNR : 8.89608 | PSNR : 8.16085 |

In the first picture, digits are still visible even though the Canny edge detection is not very clear. In the second picture, the digits on the Canny and Frei Chen edge detection can still be seen, but the digits on Robert's edge detection looks vague. And in the third picture, the digits on edge detection can no longer be seen at all. Only Speckle noise is detected by Canny. On Frei Chen's edge detection, the digits can still be detected even if it looks vague.

Figure 2 shows the performance comparison of the edge detection operators for detecting edges in the original SVHN and SVHN which has been given noise where MSE in Robert and Frei Chen is not much different. While the lowest MSE is owned by Canny in detecting SVHN edges with Speckle noise.
Figure 2. Comparative performance of all operators in detecting edges on SVHN based on MSE

Figure 3. Comparative performance of all operators in detecting edges on SVHN based on PSNR

The highest PSNR is owned by Canny in detecting SVHN with Speckle Noise, while Robert and Frei Chen operators have the highest PSNR when detecting the original SVHN edge.

6. Conclusion and Future Work

In this research, adding Gaussian noise to SVHN causes the digits to be difficult to detect by the edge detection operators. Only a few SVHNs can be detected by the operator Frei Chen. Salt & Pepper noise in the SVHN produces many edges so that the digits appear vague and invisible. Compared to Salt & Pepper noise, Speckle noise doesn't produce too much edge. The digits in SVHN are also still visible when edge detection is performed. The performance of the edge detection operator with Bilateral Filter can also be seen from the MSE and PSNR values, where the lowest MSE value and the highest PSNR is on Canny when detecting SVHN edges with Speckle noise. The performance of the proposed algorithm can be improved by using the filter parameters or by using several other filters. Also this can be modified by adding some other type of noise. The modification of the proposed method will inspire future research.
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