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A study on Development of Optimal Noise Filter Algorithm for Laser Vision System in GMA Welding

Qian-Qian Wu[a], Jong-Pyo Lee[a], Min-Ho Park[a], Cheol-Kyun Park[a], and Ill-Soo Kim[a]*

[a]*Dept. of Mechanical Engineering, Mokpo National University, Mokpo 534-729, Korea*

Abstract

In recent years, noise filter of image processing have been widely used in automated manufacturing processes in noisy environment, such as removal of noise in arc welding process, because such filters are robust even in the presence of extreme noise. Since arc, soot and splash etc., salt noise which has certain noise amplitude at random location was found in captured image. It is important to employ a noise filter to intensify the laser lines and ultimately remove or reduce the noise. In this study, the welding seam image captured from the CCD camera was processed by noise filters to remove the noise due to the complexity of welding environment. Comparison of three noise filters (Gaussian filter, Median filter and Wiener filter) was made to find out the optimal noise filtering algorithm. The result showed that the Median filter algorithm is the preferred method, as not only this algorithm performance provided lower MSE (Mean Square Error) and RMSE (Root Mean Square Error) values than those of Gaussian filter and Wiener filter, but also the values of the PSNR (Peak Signal-to-Noise Ratio) and SNR (Signal-to-Noise Ratio) were higher. Therefore, the Median filter can be considered to have a better enhancement effect than the other two filters.

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Keywords: Gaussian filter, GMA (Gas Metal Arc) welding process, Image process, Median filter, Wiener filter

1. Introduction

GMA welding is one of the oldest and fastest growing metals joining process and plays an important role in manufacturing industries. In weld seam tracking system, filters play a key role to overcome noises from complex welding environment. In the image process of automatic technologies, the objective is to reduce the noise of the

* Corresponding author. Tel.: +82-61-450-2416;fax: +82-61-452-6376.
E-mail address: ilsookim@mokpo.ac.kr

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seam image. Due to the complexity of welding environment, there are a lot of noises in the seam image which may affect the welding quality [1] and even lead to the weld seam tracking failure. Thus, it is necessary to develop suitable noise filter for image processing. To remove the noise in the images, such as Gaussian, salt and pepper noise, many filters were proposed, and among them the Wiener and Median filters were mainly developed for linear and non-linear noise in the image [2, 3].

In recent years, there have been many attempts to construct digital filters which have the qualities of noise attenuation [4]. Furthermore, nonlinear diffusion equations called an anisotropic diffusion algorithm have been proposed for Gaussian noise removal [5]. Tomasi and Manducci [6] have proposed a bilateral filter to remove Gaussian noise. Also, Tamer Rabie [7] has recommended a robust estimation based filter to remove Gaussian noise with detail preservation. Moreover, Garnett et al. [8] has suggested a trilateral filter to remove different type of noises in an image. Vijaykumar [9] proposed a simple and efficient method to remove low to high density Gaussian noise which performance with less computational time. Peters [10] presented a new morphological image cleaning algorithm for image noise reduction based on morphological size distributions, which is suitable to enhance scanned images and still-video images. For impulsive noise, the Median filter is one of the best [10-12]. Hwang [13] proposed two new algorithms for adaptive Median filters, i.e., Ranked-order based Adaptive Median Filter (RAMF) and impulse Size based Adaptive Median Filter (SAMF). Simulations on standard images confirm that these algorithms are superior to standard Median filters. Gupta [14] improved the algorithm of Median filter for image processing and compared the result to that of Mean and Median filter to verify its performance. Srinivasan [15] proposed a new decision-based algorithm for restoration of images that are highly corrupted by impulse noise. The new algorithm showed significantly better image quality than a Standard Median Filter (SMF), Adaptive Median Filters (AMF), a Threshold Decomposition Filter (TDF), cascade, and recursive nonlinear filters.

In this paper, the Gaussian filter, Wiener filter and Median filter were considered according to the analysis on the noise in the welding process. And the comparison results presented that Median filter was superior to Gaussian filter and Wiener filter since the filtered image showed clearer laser band with less noise. Therefore, Median filter was finally employed.

2. Description of GMA Welding with Automatic Seam Tracking System

To perform GMA robotic welding, the required equipment are current/voltage sensors, LVS controller, carriage controller, feeding device, welding machine and tandem welding carriage, etc., as shown in Fig. 1. Laser vision sensor is used to track the weld seam. The setup of the head is shown in Fig. 2. To track the weld seam, a CCD camera is needed to capture the real-time image of welding process. In this study, the welding was performed on SM490A steel which is mainly used in marine pressure vessel required specification on the manual welding condition.

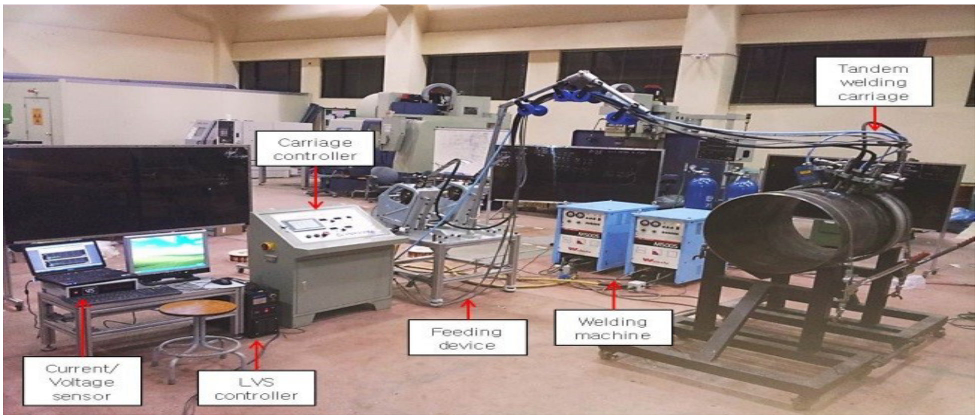


Fig. 1GMA welding equipment

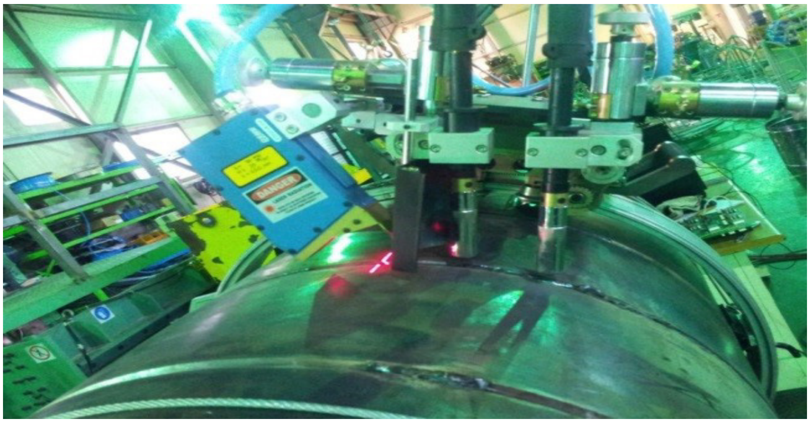


Fig.2Setup of the laser vision sensor

The principle of visual measurement with laser vision system is shown in Fig. 3. A lens shaped plan-convex cylinder is employed to convert a laser beam to a plane and to form a stripe on the welding works. A CCD camera with a light filter is used to capture the stripe. It is a narrow band filter to allow the light in a small range with the center of laser light wave length to pass through. It makes the laser stripe image to be very clear against the dark background. A laser emitter, a plano-convex cylinder lens, and a camera with a light filter constitute a structured light vision sensor, which is mounted on the end-effector of an arc welding robot to form a hand-eye system. The camera outputs a video signal, which is inputted to an image capture card installed in a computer. Then the signal is converted to image [16].

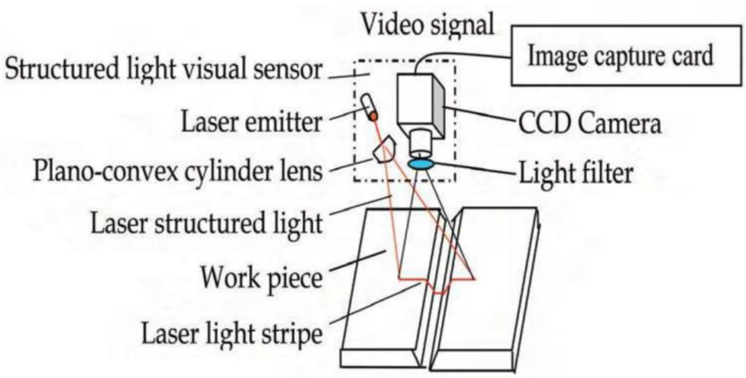


Fig. 3 The principle of structured light vision sensor

In general, the captured image is suffered from arc light, splash and background brightness during welding. Thus, during a normal image processing, the image should firstly be processed to enhance the seam information in the image based on noise filter. It is worth to mention that the original image captured from the CCD camera is in RGB (Red, Green and Blue) model in that it should be converted to gray scale. The converted gray scale values of the image are obtained by forming a weighted sum of the R, G and B components as shown in Eq. 1 [17].

$$L=0.2989R+0.5870G+0.1440B \tag{1}$$

where L is the luminance of the pixel in the gray scaled image.

3. Development of Algorithms for Noise Filters

Gaussian filter is commonly used to blur images and remove Gauss noise, which usually has certain locations but the distribution of the noise amplitude is normal (the average value is 0). In other words, Gaussian removes “high-frequency” components from the image. Thus, Gaussian filter is more effective at smoothing images. The Gaussian filter uses a Gaussian kernel to blur the image, whose function for the two dimensions [18] is as following.

$$G(x,y)=\frac{1}{2\pi\sigma^2}e^{-\frac{x^2+y^2}{2\sigma^2}} \tag{2}$$

where x is the distance from the origin in the horizontal axis, y is the distance from the origin in the vertical axis, and σ is the standard deviation of the Gaussian distribution.

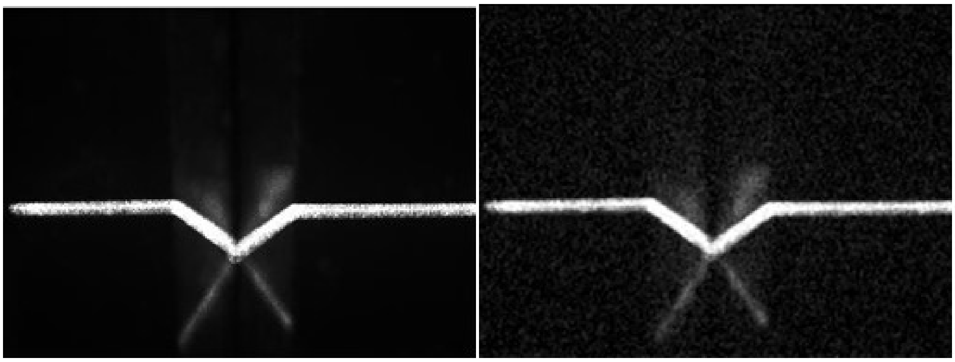
Wiener filter is generally used to produce an estimate of a desired or target random process by linear time-invariant filtering an observed noisy process, assuming known stationary signal and noise spectra, and additive noise. Thus, Wiener filter is the optimal linear filter for the removal of additive noise. The equation of the Wiener filter is given as follows.

$$\hat{I}(u,v)=\frac{H^*(u,v)I_D(u,v)}{H^*(u,v)H(u,v)+K} \tag{3}$$

Where $H(u,v)$ is a point spread function. $H^*(u,v)$ is the convolution operator of the point spread function. And $I_D(u,v)$ is the degraded image while K is a constant.

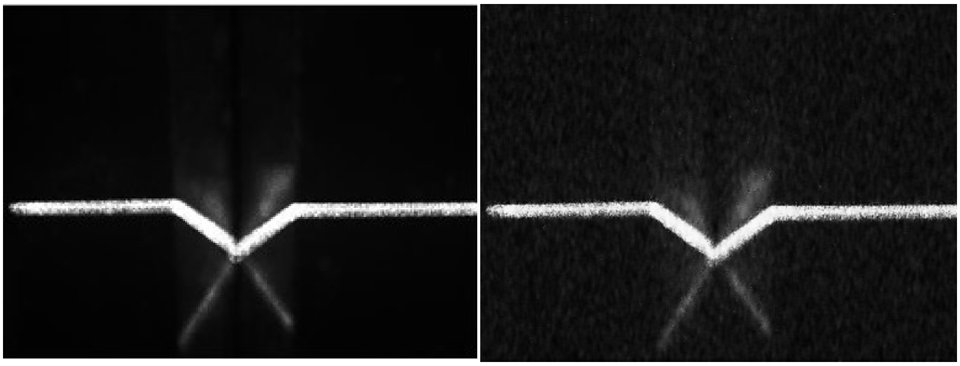
Median filter is selected while the noise in the image is dotting randomly but has a certain value in the image, such as “salt and pepper" noise which appear as white and black dots superimposed on an image. The algorithm replaces the value of a pixel by the Median of the gray levels in the neighbourhood of the pixel. The filter window or neighbourhood may be chosen as rectangle, circle, cross or cirque. Suppose that the pixel values in neighbourhood are put into a sequence $d_1,d_2,d_3,\ldots, dn$ and it becomes $d_{i1} \le d_{i2} \le d_{i3} \ldots \le d_{in}$ after sorted in ascending order or in$d_{i1} \ge d_{i2} \ge d_{i3} \ldots \ge d_{in}$ in descending order, then its Median value is:

$$D_{median}=Med\{d_i\}=\begin{cases} d_{i(n+1)/2} & ,n \quad is \quad odd \\ \frac{1}{2}\left[d_{i(n/2)}+d_{i(\frac{n}{2}+1)}\right] & ,n \quad is \quad even \end{cases} \tag{4}$$



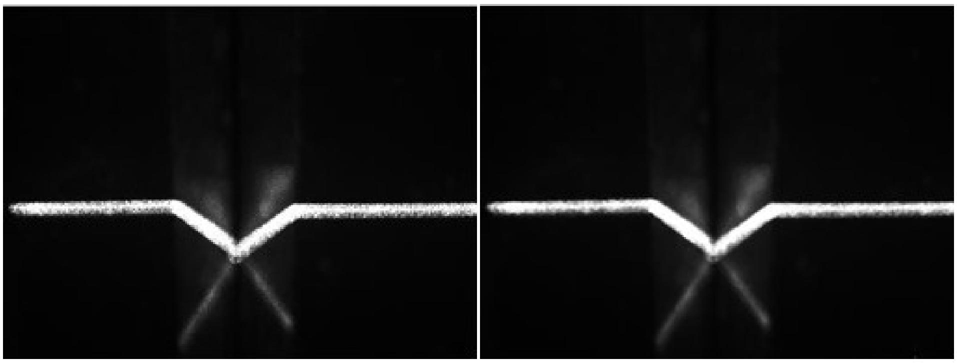
(a) Original image(b) Gaussian filter.

Fig. 4.Seam tracking image by Gaussian filter



(a) Original image(b) Gaussian filter.

Fig. 5.Seam tracking image by Wiener filter



(a) Original image(b) Gaussian filter.

Fig. 6.Seam tracking image by Median filter

Commonly utilised algorithms in image processing were verified with the original image taken from the CCD camera as shown in Figs. 4-6. They presented the results of removing noise by the Gaussian, Wiener and Median filter. Gaussian and Wiener filter was found to blur the image without removing the noise effectively. However, the

Median filter was proven to be superior to Gaussian filter since the filtered image showed clearer laser band with less noise.

4. Results and Discussion

In this research, the seam image captured from the CCD camera was processed by three filters, i.e., Gaussian filter, Wiener filter and Median filter. In this section, evaluation of proposed filters was carried out. To evaluate the filters effectiveness quantitatively, four main statistical techniques were used: MSE, RMSE, PSNR and SNR [21-22]. If the values of the MSE and RMSE are smaller and the values of the PSNR and SNR are higher, normally the enhancement effect of that particular filter is better than others. The four statistical algorithms were implemented in filtered image which in 290×387 pixel size. MSE is common used as a quantitative parameter for noise reduction. For a two-dimensional M×N image, the MSE is defined as follows:

$$\rho = MSE = \frac{1}{K}\sum\left[f(i,j) - g(i,j)\right] \tag{5}$$

where $f(i,j)$ is the original image and $g(i,j)$ is the output filtered image, K is image size $(K=M\times N)$.

RMSE is widely employed to find the total amount of difference between images. It's obtained by the root of average difference of the image pixels intensities.

$$RMSE = \sqrt{\frac{\sum\left[f(i,j) - g(i,j)\right]^2}{MN}} \tag{6}$$

PSNR is the ratio between the maximum possible power of a signal and the power of the reduced noise that affects its representation. Calculation form of PSNR is presented as following.

$$SNR = 20\log_{10}\frac{255}{RMSE} \tag{7}$$

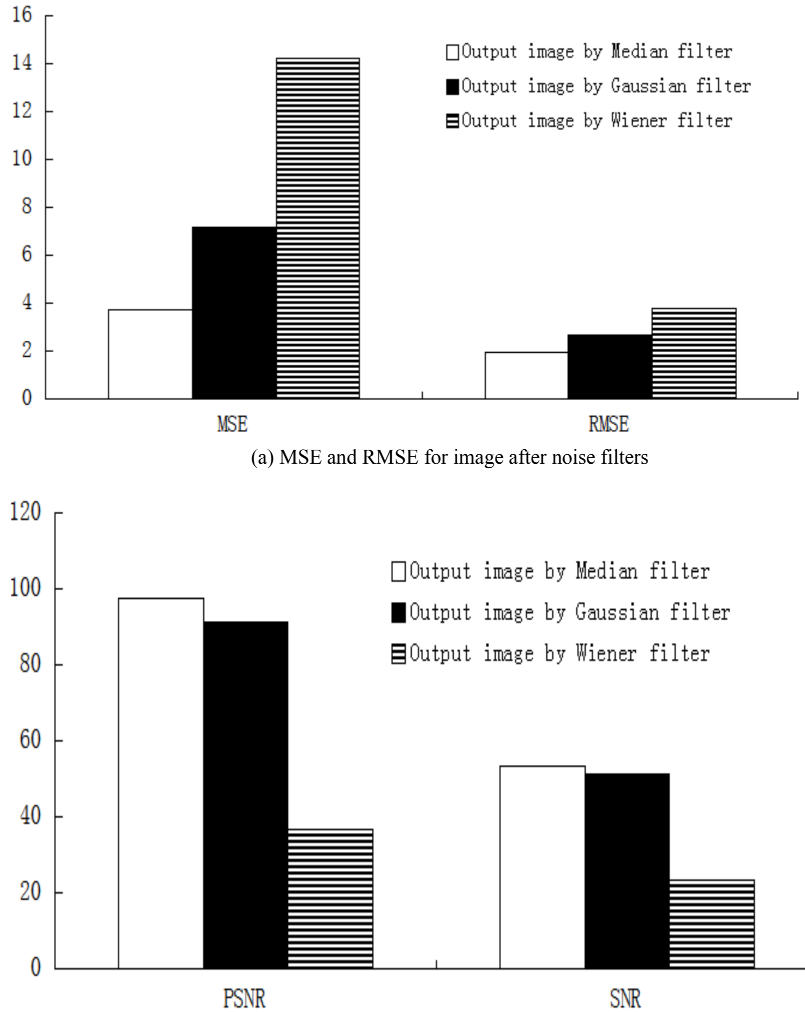
SNR is a measurement to quantify how much a signal has been corrupted by noise. The SNR is obtained by computing the ratio between the maximum possible power of a signal and the power of the reduced noise that affects its representation.

$$\rho = SNR = 10\log_{10}\frac{\sum f(i,j)^2}{\sum\left[f(i,j) - g(i,j)\right]^2} \tag{8}$$

Compression between the noise reduction results by above three filters were presented in Table 1 and Fig. 7. It could be found that not only the Median filter has lower MSE and RMSE values than those of Gaussian filter and Wiener filter, but also the values of the PSNR and SNR are higher. As a result, the Median filter can be considered to have a better enhancement effect than the other two filters.

Table 1.Statistical comparison for the Gaussian, Wiener and Median filters

Comparison for image after noise filters			
Filter Type	Median	Gaussian	Wiener
MSE(dimensionless)	3.737	7.169	14.235
RMSE(dimensionless)	1.933	2.676	3.773
PSNR(dB)	97.641	91.136	36.59
SNR(dB)	53.213	51.188	23.43



(a) MSE and RMSE for image after noise filters

(b) PSNR and SNR for image after noise filters

Fig. 7.Evaluation of noise filters' effect

On the other hand, the calculating time by Median filter was near 0.11s, much less than that by Gaussian and Wiener filters. The maximum storage that are used for image processing by Median filter was 3.3Mb, which is smaller than that by Gaussian and Wiener filters as shown in Table 2.

Table 2.Comparison of image processing performance by normal algorithm with modified Hough algorithm

Noise filter	Time [s]	Max. Storage [MByte]
Gaussian filter	0.193699	3.637
Wiener filter	0.239867	4.976
Median	0.106895	3.348

5. Conclusions

Image processing is the key technology in GMA welding based on vision sensor, which use computer algorithms to perform image processing on digital figures. Based on the laser vision sensor, noises captured from the CCD camera were mainly impulse noise, or salt and pepper noise. The choice of algorithms in the image processing has significant impact on the precision of image processing results.

In this study, an investigation on Gaussian, Wiener and Median noise filtering algorithms for the image processing has been carried out. Overall, Median filter was proved to performed better and was selected to remove or reduce the noise within the captured images. In comparison to other two filters, the results produced not only lower MSE and RMSE values, but also produced higher PSNR and SNR. The computing time was shorten near a half (0.107s) and memory cost was cut down to less than others (3.348MB), comparing to the Gaussian filter and Wiener filter.

The optimal algorithm is capable of removing the noise effectively in the complexity of welding environment. Ultimately, it can be implemented in hardware for its less computational time and memory cost.

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