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Enhanced Median Filter for Low Density Salt and Pepper Noise Removal in Lead Frame Image

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Abstract

In Digital Image Processing, image filtering technique plays a vital role. It is one of important steps in image enhancement and restoration. Generally, this filtering technique is applied to remove noise, preserve the edges and details of the image for later image processes. Noises that usually corrupted the digital image such as Salt & Pepper, Gaussian, Speckle, and Poisson Noise are critical issues in filtering process where the quality and originality of the pixels in images can be degraded. Lead Frame image is not excluded in having noise during image acquisition. This paper proposed an enhanced Median Filter (PMF) technique to low density of Salt and Pepper noise since Lead Frame inspection in under controlled environment. This technique used 3x3 sub-mask that pad with replicate method. The median value of '+' neighbors will be used as the new pixel in the image. PMF technique has been test with several other filtering techniques and the performance is measured by using Mean Square Error (MSE) method. The execution times are also recorded. The result shows that the proposed technique can efficiently remove salt and pepper noise with low value of MSE and time taken for the PHF to execute is also the lowest among the compared techniques.

Keywords: median filter; salt and pepper noise; lead frame image.

INTRODUCTION

In semiconductor industry, Vision System has been applied to inspect their product such as Lead Frame (Figure 1). Lead Frame is a thin layer of metal inside a chip package that carry signal from the die to outside. During Lead Frame inspection by using Vision System, the input image acquired by using camera or other imaging system is often unable to be used directly. This is because the image is corrupted by noise. Noise is unwanted and random signal that mainly come from light levels and sensor temperature [1]. In [2], the major factors that affect the amount of noise are environmental conditions, dust particles present in the scanner, interference in transmission channel and low light and sensor temperature. Noise in digital image has various type such as Salt and Pepper, Gaussian, Speckle and Poisson [3].

Noise has many negative effects to Vision System such as image distortion [4] and reduce the visual quality of image [5]. Vision System will have a problem in analyzing those image that the essential information in the image is corrupted or destroy by noise. Therefore, numbers image filtering techniques have been introduced to overcome this problem.

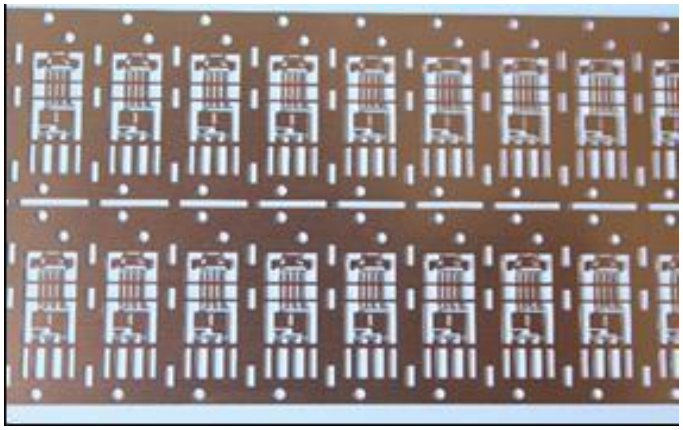

Figure 1: Example of a Lead Frame input image.

Image filtering techniques are applied to reduce the quantity of noise [5], restore the originality of image, interpolation and re-sampling [6]. As highlights in [6], filter is chosen based on the nature of the task performed, behavior and type of the data. Since there is lack of proper study on Lead Frame Image, it is hard to select a suitable filter for lead frame image that has small size and reflective surface. Even though image filtering technique is applied in Lead Frame image inspection, noise is still not completely remove.

Therefore, this research is conducted to focus on developing image filtering technique to remove Salt and Pepper noise by using enhanced Median Filter for Lead Frame image. This investigation focuses on low density Salt and Pepper noise since Lead Frame inspection is conducted in controlled environment which mean noise that affected the image captured is very low. This technique was compared to other seven image filtering techniques and the performance parameter is analyzed by using Mean Square Error (MSE) method. The execution time for each filtering technique is also recorded to determine the quality algorithm of the filter.

RELATED WORKS

Salt and Pepper Noise

One of the important problems in image processing is removing noise [1]. Salt and Pepper noise is among a common noise in image. This noise is also known as shot noise, impulse noise, spike noise [6] and according to [2], it is called data drop noise because this noise statistically drops the original data values. This noise will cause an image to has a random black and white pixel appeared. The causes of this noise are dead pixels, analog to digital converter errors, bit errors in transmission, memory cell failure and camera's sensor cells malfunction [1], [6]. The probability density function of this Salt and Pepper noise can be written as the following:

$$p(z) = \begin{cases} Pa, \ for\, z = a \\ Pb, \ for\, z = b \\ 0\ otherwise \end{cases} \quad (1)$$

If b>a, intensity of 'b' represents the white dot in the digital image and intensity of 'a' represents the black dot.

Median Filter

Median Filter or Med is normally proposed to remove Salt and Pepper noise [7]. This filter is a nonlinear filter and a well-known noise removal and smoothing operator [8]. As mention in [9], non-linear filter is better in removing noise compared to linear filter which tends to blur the edge although linear filter is more simple and easy to implement. Median filter can preserve sharp edges and fine details in digital images. An experiment was conducted in [10] to ensure Median filter can execute well in removing Salt and Pep-per noise. Cameraman image was used to investigate Median filter performance and the outcome shows that this filter is the best Salt and Pepper noise removal when compared with Minimum filter, Maximum filter, Minimum Maximum filter, Mean filter and Weight Median filter. In [7], a simulation on median filter also shows that this filter outperforms Low Pass filtering technique in removing different density of Salt and Pepper noise. Basically, this filter works by calculating the median value from surrounding neighbor-hood of pixel 'p' and replacing the pixel 'p' with the median value [11]. It can be defined as the following equation:

$$med(p) = median\{f(p), where\ p \in N_8(p)\} \quad (2)$$

where med(p) is the output pixel of the Median Filter at image point 'p', median{.} is the median operator, f(p) is the input image of point 'p' and N8 is the 8 neighborhood pixel of point 'p'.

Minimum Filter

Besides Median Filter, another non-linear filter that commonly applied in image processing is Minimum Filter or known as Min Filter. This filter will intensify the dark values of the pixel in image by increasing its area. This technique is identical to the dilate function that operates the darkest area in the surrounding pixel and expand the region. Min Filter will choose the minimum value of the 8-neighbourhood pixels of pixel 'p' and replace it at the pixel 'p' and works well with salt noise [10]. The output gmin(p) of Min Filter at image point 'p' can be defined as:

$$\min(p) = \min\{f(p), where\ p \in N_8(p)\} \quad (3)$$

where min(p) is the output pixel of the Min Filter at image point 'p' minimum{.} is the minimum operator, f(p) is the input image of point 'p' and N8 is the 8 neighborhood pixel of point 'p'.

Maximum Filter

The reverse of Min filter is Maximum Filter or known as Max Filter. Unlike Min Filter, this filter is good in removing pepper noise [10]. Maximum value of the 8 neighborhood pixels of pixel 'p' will be selected and it is substituted at pixel 'p'. The definition of Max Filter can be written as:

$$g\_\max(p) = \max\{f(p), where\ p \in N_8(p)\} \quad (4)$$

where max(p) is the output pixel of Max Filter at image point 'p', maximum{.} is the maximum operator, f(p) is the input image of point 'p' and N8 is the 8 neighborhoods pixels of point 'p'.

Hybrid Median Filter

Hybrid Median Filter (HMF) is an improved version of Median Filter. Similar to Median Filter, HMF is also a nonlinear filter that commonly used in image processing to remove noise especially Impulsive noise and Salt and Pepper noise [12]. But, the performance of this filter is better than median filter in removing noise and preserving edges and corners. This technique works by replacing the pixel value of point 'p' from the value of median of this three value: a) median of '+' neighbors b) median of 'x' neighbors c) pixel value of point 'p'. After these three steps ranking operation technique was created, it is widely used and improved ever since by others [13], [14], [15] with aims to remove different types of noise better. In [16], HMF performance was tested with rice image and it can remove Impulse noise efficiently and smooth compared to median filter. Although the results show that HMF can preserves edges, preserves brightness difference and it is simple to understand, this filter was said to has high computation cost. HMF can be ex-pressed as:

$$hmf(p) = median\begin{Bmatrix} median\{f(p), where\ p \in +_5(p)\} \\ median\{f(p), where\ p \in x_5(p)\} \\ f(p) \end{Bmatrix} \quad (5)$$

where hmf(p) is the output pixel of the HMF technique at image point 'p', median{.} is the median operator, f(p) is the input image of point 'p', +5 is the '+' neighbors of point 'p' and X5 is the 'x' neighbors of point 'p'.

If point 'p' has (i, j) coordinate, then '+' neighbors of point 'p' are at coordinate (i-1, j), (i+1, j), (i, j-1) and (i, j+1) while 'x' neighbors of point 'p' are at coordinate (i+1, j+1), (i+1, j-1), (i-1, j+1) and (i-1, j-1).

Hybrid Cross Median Filter

One of the improvised image filtering techniques based on HMF is Hybrid Cross Median Filter (HCMF). This HCMF is a nonlinear filter and was introduced by [12] in 2011 to remove Gaussian noise from medical image. HCMF can be interpreted as the following:

$$hcmf(p) = median\begin{Bmatrix} median\{f(p), where\ p \in L_3(p)\} \\ median\{f(p), where\ p \in R_3(p)\} \\ f(p) \end{Bmatrix} \quad (6)$$

where hcmf(p) is the output pixel of the HCMF technique at image point 'p', median{.} is the median operator, f(p) is the input image of point 'p', L3 is the LT neighbors of point 'p' and R3 is the RT neighbors of point 'p'.

As stated in equation (6), HCMF functions by deciding the median value from three steps that are median value of pixel of LT neighbors of point 'p', median value of pixel of RT neighbors of point 'p' and value of pixel of point 'p'. If point 'p' has (i, j) coordinate, then LT neighbors are at point (i-1, j-1) and (i+1, j+1) while RT neighbors are at point (i+1, j-1) and (i-1, j+1).

Hybrid Min Filter

Besides that, Hybrid Min Filter (HminF) also played a crucial role in image processing and vision system. This filter can remove salt noise in image [12]. Knee image was experimented by [17] using this filter to analyze the performance in removing impulse noise. Generally, the HminF will take the minimum value from median value of pixel of LT neighbors of point 'p', median value of pixel of RT neighbors of point 'p' and pixel value of point 'p'. The mini-mum value is then replaced into the pixel value of point 'p'. HminF can be formulated as:

$$H\min F(p) = \min\begin{Bmatrix} median\{f(p), where\ p \in L_3(p)\} \\ median\{f(p), where\ p \in R_3(p)\} \\ f(p) \end{Bmatrix} \quad (7)$$

where HminF(p) is the output pixel of HminF filter at image point 'p', min{.} is the minimum operator, median{.} is the median operator, f(p) is the input image of point 'p', L3 is the LT neighbors of point 'p' and R3 is the RT neighbors of point 'p'.

Hybrid Max Filter

Next is Hybrid Max Filter or HMaxF. This technique is suitable for Pepper noise [12]. Unlike Max Filter, the determination of new pixel of point 'p' is by taking the maximum value from median value of pixel of LT neighbours of point 'p', median value of pixel of RT neighbours of point 'p' and pixel value of point 'p'. This technique can be mathematically written as:

$$H\max F(p) = \max\begin{Bmatrix} median\{f(p), where\ p \in L_3(p)\} \\ median\{f(p), where\ p \in R_3(p)\} \\ f(p) \end{Bmatrix} \quad (8)$$

where HmaxF(p) is the output pixel of the HmaxF filter at image point 'p', maximum{.} is the maximum operator, median{.} is the median operator, f(p) is the input image of point 'p', L3 is the LT neighbors of point 'p' and R3 is the RT neighbors of point 'p'.

Hybrid Min Max Filter

In 2012, removing Salt and Pepper noise in digital image has become an active research area and another good Salt and Pepper noise removal was developed known as Hybrid Min Max Filter or HMMF [17]. This technique was developed based on the idea of HminF and HmaxF. First, HminF is applied to the digital image and then HmaxF will be executed from the outcome of the first step. Mathematically, this filter can be concluded as the following expression:

$$\begin{aligned} g(p) &= \min\begin{Bmatrix} median\{f(p), where\ p \in L_3(p)\} \\ median\{f(p), where\ p \in R_3(p)\} \\ f(p) \end{Bmatrix} \\ hmmf(p) &= \max\begin{Bmatrix} median\{g(p), where\ p \in L_3(p)\} \\ median\{g(p), where\ p \in R_3(p)\} \\ f(p) \end{Bmatrix} \end{aligned} \quad (9)$$

where hmmf(p) is the output pixel of HMMF filter at image point 'p', median{.} is the median operator, minimum{.} is the minimum operator, maximum{.} is the maximum operator, f(p) is the input image of point p, g(p) is the first output pixel image of HMMF technique, L3 is the LT neighbors of point 'p' and R3 is the RT neighbors of point 'p'.

By using knee image as an input image, this hybrid HMMF technique can remove Impulse noise better than Hybrid Fuzzy Max Filter, Median Filter, Mean Filter, Hybrid Mean Median Filter and Enhanced Hybrid Median Filter [17]. Another investigation in 2014 shows that this technique performs better than Wiener filter in re-moving Gaussian noise in brain image, Speckle noise in dog image and Impulse noise in Lena image.

Hybrid Sigma Filter

Other than that, another hybrid technique called Hybrid Sigma Filter or HSF was proposed to remove Gaussian and Salt and

Pepper noise in medical image [15]. This HSF technique has been concluded as a good noise removal in medical image. HSF will take the median of median value of pixel of sigma neighbours of point 'p', median value of pixel of all neighbours of point 'p' and value of pixel of point 'p' and then replaced into pixel value of point 'p'. This HSF can be written as:

$$HSF(p) = median\begin{Bmatrix} median\{f(p), where\ p \in N_8(p)\} \\ median\{f(p), where\ p \in \varepsilon_5(p)\} \\ f(p) \end{Bmatrix} \quad (10)$$

where HSF(p) is the output of HSF filter at image point 'p', median{.} is the median operator, f(p) is the input image of point 'p', N8 is the 8 neighbors of point 'p' and ε5 is the sigma neighbors of point 'p'.

If point 'p' has (i, j) coordinate, then sigma neighbors are at point (i-1, j), (i+1, j), (i, j-1) and (i-1, j-1).

PROPOSED METHOD

This research has developed an enhanced Median Filter or Proposed Median Filter (PMF) based on Median Filter that popular for its ability to remove Salt and Pepper noise. Replicate padded and 3x3 sub mask are used in PHF algorithm. This filter works by calculating the median value from '+' neighborhood pixel and replaces the pixel with the median value calculated (Figure 2).

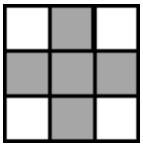

Figure 2: Figure shows the '+' neghbours pixel in 3x3 sub mask.

If point 'p' has (i, j) coordinate, then '+' neighbors of point 'p' are at coordinate (i-1, j), (i+1, j), (i, j-1) and (i, j+1). This PHF can be concluded as the following:

$$PMF(p) = median\{f(p), where\ p \in +_5(p)\} \quad (11)$$

where PMF(p) is the output of PMF technique at image point 'p', median{.} is the median operator, f(p) is the input image of point 'p' and +5 is the '+' neighbors of point 'p'.

The algorithm of PMF technique can be written as follows:

1. Read the original image,
2. Convert the original image from RGB to grayscale,
3. Determine the 3x3 sub-mask with padded replicate,
4. Find the median of '+' neighbors,
5. Replace the center pixel value with the median of '+' neighbors.

Since there is no unique algorithm to determine the enhancement in digital image [15], the performance of PMF technique has been analyzed and compared to other hybrid techniques by using statistical method that is Mean Square Error (MSE) method [18]. This MSE method used will basically indicates the average difference between the original image and the predicted image. MSE method formula is as follows:

$$MSE = \frac{1}{MN}\sum_{i=1}^{M}\sum_{j=1}^{N}(X_{i.j} - X'_{i.j})^2 \quad (12)$$

where X(i,j) is the desired output image, X'(i,j) is the predicted output image and M and N are the total number of pixels in the horizontal and the vertical dimensions of the image respectively. The lower the value of MSE shows that the better performance of the technique used.

RESULTS AND DISCUSSION

The PMF filtering technique has been tested on a sample of 3 different types of lead frame images with each image is tested 20 times and the average of MSE were taken. The performance of PHF has been compared to the performance of other seven other filtering techniques of Med filter, HMF, HCMF, HminF, HmaxF, HMMF and HSF. Salt and Pepper noise with different density was added to the input images of all eight filtering techniques. All experiments have been conducted by using Matlab R2014a and computer used for simulations was an Intel Core i7-6700K CPU with 4.00 GHz working frequency and 8G RAM.

Table 1 shows the results of the average MSE values for 20 times execution of first lead frame image (Lead1 Image) when Salt and Pepper noise with different densities were added.

Table 1: Average MSE Value for Lead1 Image Tested to Different Density of Salt and Pepper Noise Papers.

Filter	MSE Value for Each Density ($x10^4$)				
	0.02	0.04	0.06	0.08	0.10
Noise	20.1744	40.1654	58.9638	78.6599	98.8196
Med	5.2705	5.6506	6.1329	6.6203	7.5834
HMF	1.6129	2.5209	3.3946	4.3852	5.6291
HCMF	2.9630	6.7052	10.7830	17.0592	23.6985
HminF	16.9003	30.0459	43.3939	57.3505	71.7117
HmaxF	11.9390	22.2627	32.0278	42.2126	53.7900
HMMF	6.9531	9.0271	11.1535	13.5549	16.5259
HSF	2.8874	3.5777	4.3647	5.1324	6.1833
PMF	1.2523	1.6263	1.9843	2.5103	3.3488

Based on Table 1, the results show that PMF has the lowest amount of MSE value compared to other techniques. This proves that PMF has the best performance in removing Salt and Pepper noise while HminF has the poorest performance than HmaxF and HMMF. HMF has second lowest MSE value followed by HSF, HCMF and Med Filter. Only HMF has almost similar performance with PMF technique, while the others' MSE values are more than double compared to PMF.

The results of the average MSE values for 20 times execution of second lead frame image (Lead2 Image) when Salt and Pepper noise with different densities were added are calculated and shown in Table 2.

Table 2: Average MSE Value for Lead2 Image Tested to Different Density of Salt and Pepper Noise Papers.

Filter	MSE Value for Each Density ($x10^4$)				
	0.02	0.04	0.06	0.08	0.10
Noise	14.8063	29.7578	44.9702	58.9915	74.2473
Med	3.7381	3.7660	3.7857	3.7447	4.1747
HMF	1.2608	1.5203	1.8341	2.0802	2.8120
HCMF	2.4405	3.9012	7.2094	10.8033	16.7014
HminF	10.2367	19.1807	28.5045	37.2374	46.1532
HmaxF	10.1359	17.6891	25.7393	33.2928	42.8159
HMMF	4.1251	4.7036	5.4773	6.1954	7.1041
HSF	1.7702	1.9104	2.0419	2.3514	2.7869
PMF	1.1759	1.3114	1.4433	1.5132	2.0343

By referring to Table 2, HminF has the highest MSE value for each density of Salt and Pepper noise followed by HmaxF and HMMF. The proposed PMF technique works well in removing Salt and Pepper noise by producing the lowest value of MSE. For Lead2 image, the MSE value for PMF has no significant different with the second lowest MSE value which is HMF technique and the third lowest MSE value that is HSF.

Next, for the third Lead Frame Image (Lead3 Image), the calculated average MSE values for 20 times execution are shown in Table 3.

Table 3: Average MSE Value for Lead3 Image Tested to Different Density of Salt and Pepper Noise Papers.

Filter	MSE Value for Each Density ($x10^4$)				
	0.02	0.04	0.06	0.08	0.10
Noise	12.0338	23.8890	36.3498	47.1291	59.7061
Med	3.4303	3.7091	3.9135	4.1781	4.4509
HMF	1.0895	1.3401	1.8278	2.0284	2.6815
HCMF	1.7600	3.0626	6.3285	9.1916	13.9057
HminF	8.8156	16.4584	24.7558	30.7539	39.8873
HmaxF	8.3578	13.8159	20.0495	27.5693	33.1247
HMMF	3.9849	4.6489	5.6050	6.0672	7.4947
HSF	2.2758	2.5638	2.7984	3.0274	3.3210
PMF	1.0216	1.1500	1.4701	1.5708	1.8939

According to Table 3, PMF can be classified as the best filtering technique to remove low density of Salt and Pepper noise compared to Med, HMF, HCMF, HminF, HmaxF, HMMF and HSF because PMF has low MSE value which indicates that the average different of the original image and the filtered image using PHF are not much. The unacceptable amount of MSE is recorded by HminF and HmaxF with more than ten times higher value compared to PMF.

The execution time for each filtering technique was also recorded and put in Table 4.

Table 4: Average Execution Time for Each Type of Filter.

Filter	Execution Time (s)
Noise	2.1422
Med	2.7448
HMF	2.7316
HCMF	2.6876
HminF	2.7121
HmaxF	3.7478
HMMF	2.7827
HSF	2.0241
PMF	2.1422

The lowest amount of time needed to filter an image is PMF technique. It is because of its simplicity of algorithm that does not re-quire all neighborhood pixels to be processed. It only takes '+' neighbors to execute the program and can save time for a system that uses this filtering technique. The highest execution time is recorded by HMMF technique. This is due to

its complex and long algorithm (combination of HminF and HmaxF) that need a few steps before finding a new pixel to be replaced. PMF's execution time is quite identical with Med Filter since it is developed based on Med Filter. Other techniques take around 0.5s later that PMF and Med Filter and have almost similar value to each other for about 2.7s.

The following figures show the examples of original image, noisy image, PMF output image and HminF output image. Figure 3 shows the example of original image that was taken from Lead1 image and converted to grayscale image to be processed. Salt and Pepper noise is then added to the original image.

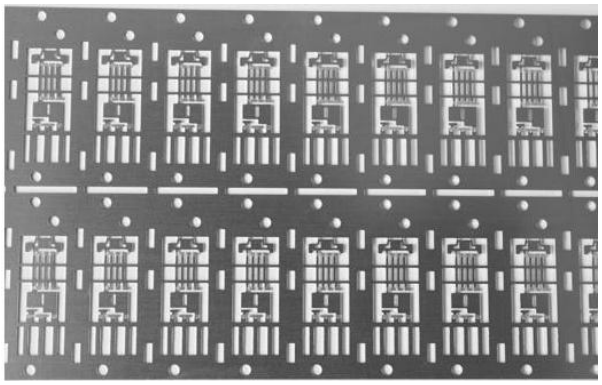

Figure 3: Example of original image of Lead Frame in grayscale.

Black and white dots can be seen in the image shown in Figure 4. Those dots are known as Salt and Pepper noise. Image filtering technique is applied to remove the dots.

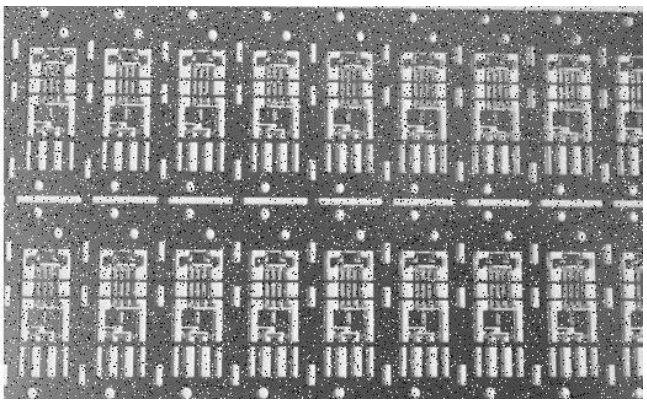

Figure 4: Example of Salt and Pepper noise in image with density of 0.08.

From human vision perspective, PMF output image (Figure 5) has good view and almost the same as the original image which indicates that this PHF technique can remove Salt and Pepper noise efficiently and recover the image as the original image. The black and white dots or pixels are eliminated from the image.

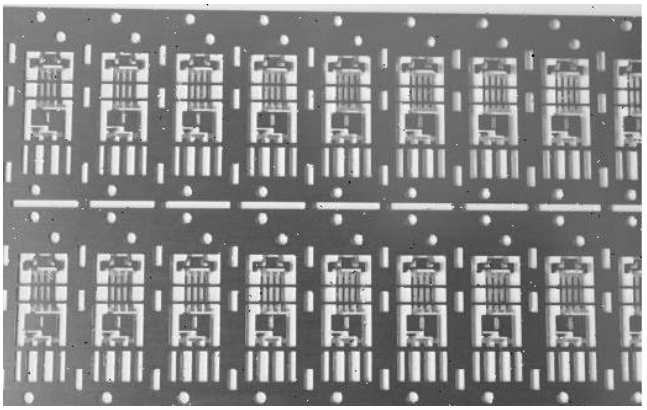

Figure 5: Filtered image by using PHF technique.

The poorest performance among the techniques compared is HminF (Figure 6). In the image, black dots are obviously seen everywhere.

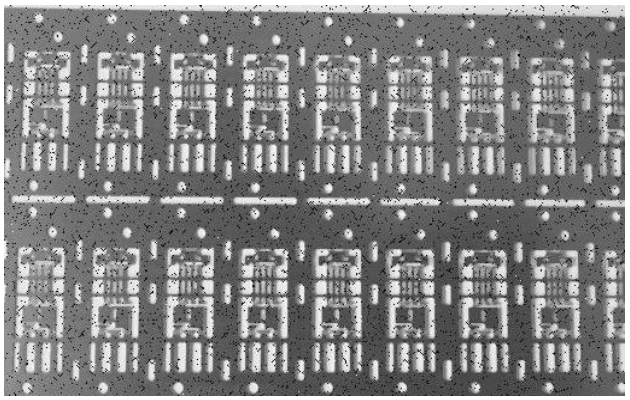

Figure 6: Black dots are still appeared after HminF technique applied.

Salt and Pepper noise is one of the common noise in image that can affect the Vision System inspection. For example, in Figure 4, it is quite confusing for human or machine to determine whether the black dots appeared are dust particles or noises and the white dots appeared are holes or not. Therefore, PMF is a good technique to overcome this problem.

CONCLUSION

The PMF filtering technique has been tested on a sample of 3 different types of lead frame images with each image is tested 20 times and the average of MSE is calculated and presented in the table. This investigation shows that PMF has the best performance com-pared to Med Filter, HMF, HCMF, HminF, HmaxF, HMMF and HSF with the lowest value of MSE that indicates this filter can remove Salt and Pepper noise efficiently. Besides that, PMF also has the lowest execution time among others. Low processing time indicates that the algorithm in the filtering technique is good and can save time

in Vision System. Therefore, PMF can be concluded as the good technique in removing low density of Salt and Pepper noise. This technique should be implemented in Vision System that has good environment control and need fast processing time. Lead Frame inspection is a suitable example to apply this technique.

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