COMBINATION OF GABOR AND BUTTERWORTH FILTERS IN FAST FOURIER TRANSFORM ALGORITHM FOR FABRIC IMAGE ENHANCEMENT

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ABSTRACT

Fabric is a prominent material that is used and will continuously be used in the textile field. The studies on fabrics may involve the production of fabrics, the usage of fabrics, the defects of fabrics, and the reactions of fabrics to obstacles. This research implements the combination of Gabor and Butterworth filters in the Fast Fourier Transform algorithm on fabric images to study how they react to obstacles or image noise. A filter acts as a medium in image processing techniques as it can enhance input images, hence improving the results for further processing such as image segmentation. The aim of this research is to investigate and analyse the different effects of combining the Gabor and Butterworth High-pass Filter or Gabor and Butterworth Low-pass Filter on fabric images. All algorithms will be implemented using MATLAB R2018B. Evaluations of the results are by visual examination and by calculating the Peak Signal-to-Noise Ratio (PSNR) value. The results showed that the combination of the Gabor and Butterworth High-pass Filter produced better noise removal ability, which is supported by high values of PSNR.

Keywords: *Butterworth Filters, Fabric, Fast Fourier Transform, Gabor Filter, Image Processing.*

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1. Introduction

Carl Friedrich Gauss stated that mathematics is "the Queen of the Sciences" and the knowledge of mathematics has been widely used in a lot of core fields such as image processing. Image processing algorithms strongly use the background of mathematics, for instance, Histogram Equalization, Fuzzy C-means algorithm, Discrete Cosine Transform, and many more. These algorithms are processed using computer programs and applications such as C++, JAVA, MATLAB, Python, SciLab, Maple, and others. Fourier Transform is one of the powerful mathematics tools which is widely used in science and engineering (Vashisht & Bhatia, 2019). The Fourier transformation is an algorithm which consists of the sine and cosine components. It is also applied in image processing. Fourier transform can be divided into two categories which are the Discrete Fourier Transform (DFT) and the Periodic Fourier Transform.

The DFT is applied in an image that can be transformed into a vector or matrix form into a frequency domain (Ching & Khoo, 2021). Meanwhile, the Fast Fourier Transform (FFT) is implemented from DFT that translates an image as an input in a spatial domain and produces an image as an output in the frequency domain. This research focuses on the investigation of filter combinations that effectively reduce noise or also known as noise removal. Additionally, there are several noises that are employed in image processing, such as gaussian noise, salt and pepper noise (Gokilavani et al, 2016).

Fabric is an important raw material to produce products such as clothing, furniture, curtains, and many more. In order to sustain the lifetime of the fabric, certain precautions must be considered such as fabric defection detection. One of the crucial reasons defection detection should be acted on is to check the condition of the fabric and its quality so that appropriate analysis can be made. This method has been widely used in the textile industry where researchers in this field focus on understanding the condition of every type of fabric (Mohamed & Faouzi, 2013). Research by Brad et al. (2017) briefly explained that observing the condition of a fabric, which is also known as fabric defect, usually, has been done manually by a human. Hence, this arises uncertainty due to the difference in every human perspective and observation. Thus, the process of detecting a defect in a fabric became inconsistent, therefore resulting in a less accurate analysis of the fabric. In addressing this matter, the application of computer vision is found to be suitable as a second eye to the human version to create a more objective analysis (Brad et al., 2017). Figure 1.2.1 displays different versions of fabric defects in pictorial form.

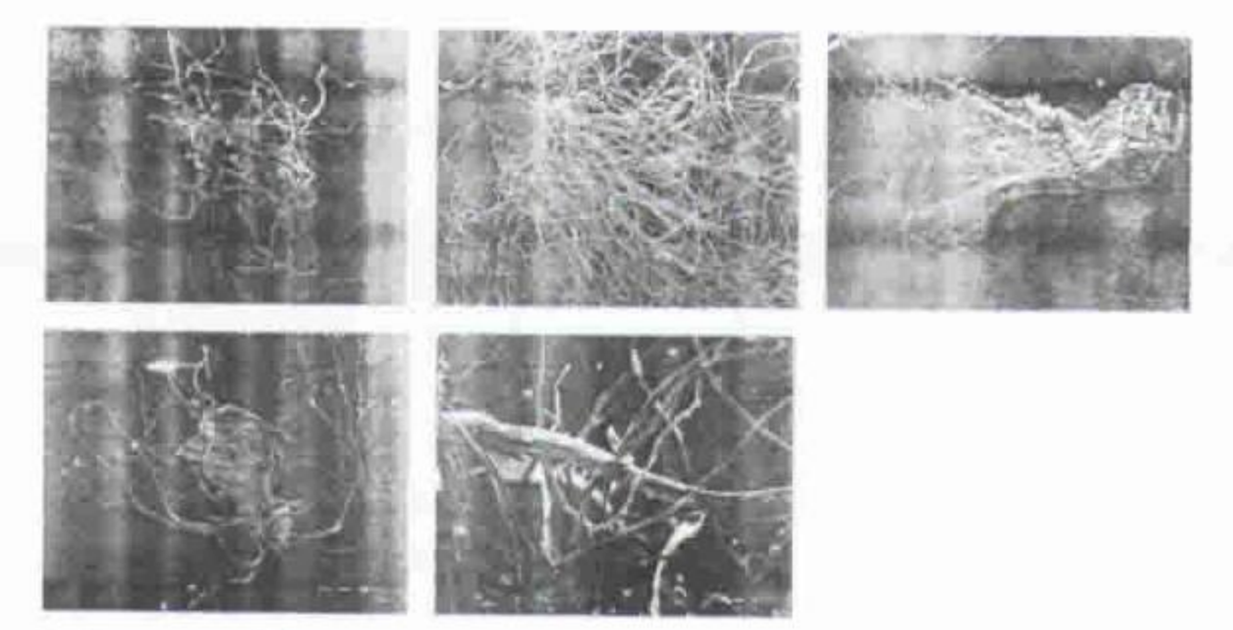


Figure 0.1 Different Types of Fabric Defects Samples

The quality of the fabric is greatly concerned in the textile industry as fabrics are the raw materials to produce a variety of products. Image processing can be defined as obtaining an image as an input and applying respective algorithms to the image to produce an enhanced image as an output that can be analysed further. In other words, image processing comes in very handy especially in the textile field because it enables a high-technology method to conduct the detection of fabric defection (Ozkaya et al., 2018). However, the outcome of the image processing also greatly depends on the level of difficulty to detect fabric. Fabric rubbing is one of the major contributing variables in this research. Fabric rubbing is a crucial technique for evaluating fabrics to understand their characteristics and how they respond to different environments. Research by Rashid et al (2012) states that the evaluation of surface dye transfer from the test fabric to a piece of broad cotton against which it is rubbed is frequently done using the fastness test to rubbing. The test can be performed in a dry or wet environment. The evaluation can be done by many ways, for instance by visual inspection, by calculating the Mean-Squared Error (MSE) and Peak Signal-to-Noise Ratio (PSNR), Dakshayani et al. (2022).

2. Methodology/Implementation

2.1 Flowchart of the Research

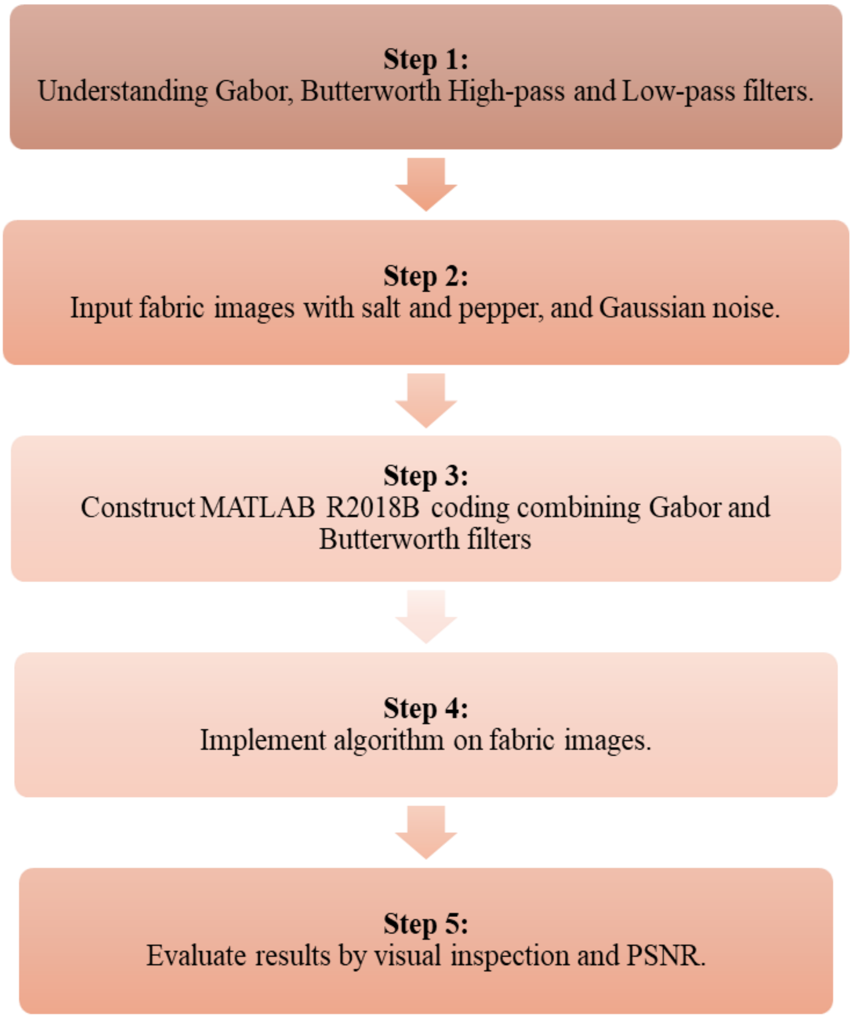


Figure 2.1.1 Flowchart of the Research

Step 1: Understanding Butterworth High-pass and Low-pass Filters

The very first step of this study is acquiring a solid understanding of the term's meaning, usage, and prior research in order to gain further knowledge. Butterworth high-pass and low-pass filters can be distinguished from one another based on how much frequency is employed in the frequency domain. Research by Dogra and Bhalla (2014) explained that a low-pass filter only considers the low-frequency components of the digital image and eliminates the high-frequency components. In connection with this, another research by Makandar and Halalli's (2015) concluded that the primary application of a low-pass filter in image processing is image smoothing. Dogra and Bhalla (2014) and Makandar and Halalli (2015), research on high-pass filters and their application in image enhancement both clarified what a high-pass filter is and how it works. It has been asserted that a high-pass filter has been used for image sharpening since it only allows high-frequency components of digital images to pass through. The definition of both low-pass and high-pass filters was explained by Dogra and Bhalla (2014) and Makandar and Halalli (2015) and it has been summarized in Figure 2.1.2.

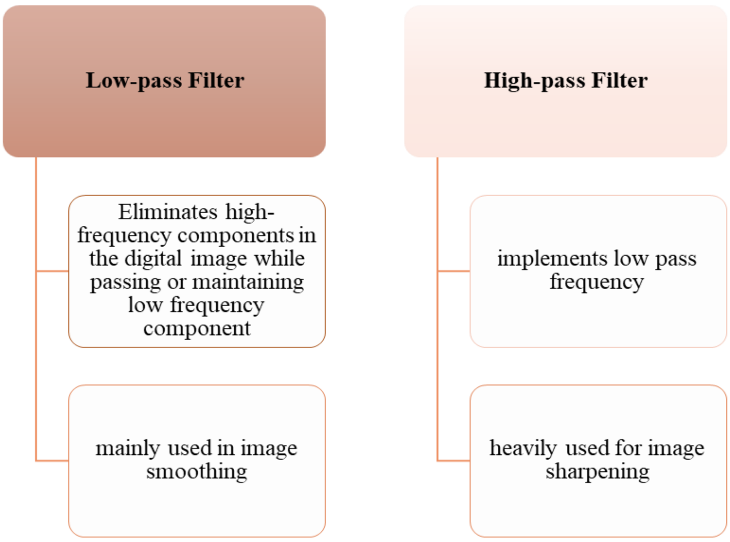


Figure 2.1.2 Differences Between High-pass and Low-pass Filters

Step 2: Input fabric images with salt and pepper and Gaussian noise.

According to research by Silvestre-Blanes et al. (2019), a variety of samples have been put into good use, the first of which was the fabric in its original condition and the second of which had a fabric flaw. This is important so that a comparison may be done at the end to determine whether the filters were effective or vice-versa. Fabric rubbing samples used in this research were obtained by a PhD student currently studying in UiTM Shah Alam. Figure 2.1.3 illustrates the fabric samples that were subjected to fabric rubbing and were scanned using a portable telescope for fabric analysis in the textile industry.

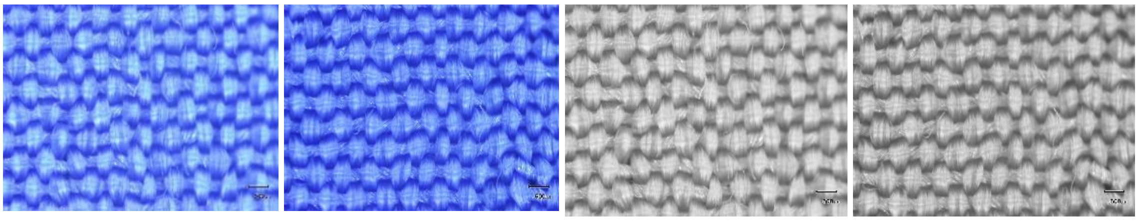


Figure 2.1.1 Samples of Fabric Defects Due to Rubbing

Research by Chen et al. (2022) stated that a common interference that appears in a corrupted digital image is salt noise. In addition to that, it additionally disturbs each pixel randomly by the impulse value that results from the interference noise that was captured in the digital image. On the other hand, pepper was announced as a type of noise that corrupts the image acquisition sensor. Because of this, salt and pepper noise distort digital images, or, to put it another way, it obscures textures and useful information that are not advised when using image enhancement techniques. When a digital image has salt and pepper noise, it has the advantage of allowing the noise to be in the image and contains distinct sets of values that are simple to detect in the contaminated digital image. Figure 2.1.4 displays the fabric samples from Figure 2.1.3 after applying the salt and pepper noise. The commands used in MATLAB R2018B are also listed below.

```
imgSP = imnoise(img2,'salt & pepper',0.02);
```

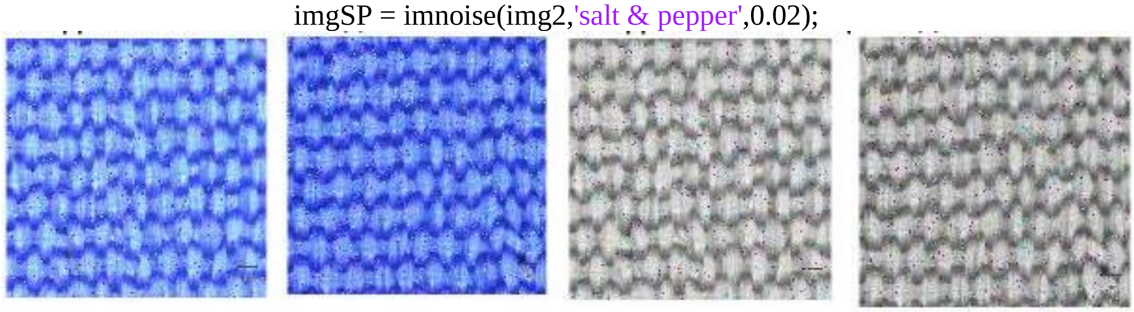


Figure 2.1.2 Salt and Pepper Noise Added to the Fabric Samples

Research by Elaiyaraja et al. (2022) claimed that several types of noise, including impulsive noise, Gaussian noise, speckle noise, and Poisson noise, are applied in image processing. Gaussian noise can be explained as the addition of a zero mean Gaussian distribution value to each image pixel that can identify the presence of gaussian noise, which is always present during the acquisition of images. Figure 2.1.5 displays the fabric samples from Figure 2.1.3 after applying the gaussian noise. The commands used in MATLAB R2018B are also listed below.

```
sig=100;
V=(sig/256)^2
imgGaussion = imnoise(img2,'gaussian',0,V);
```

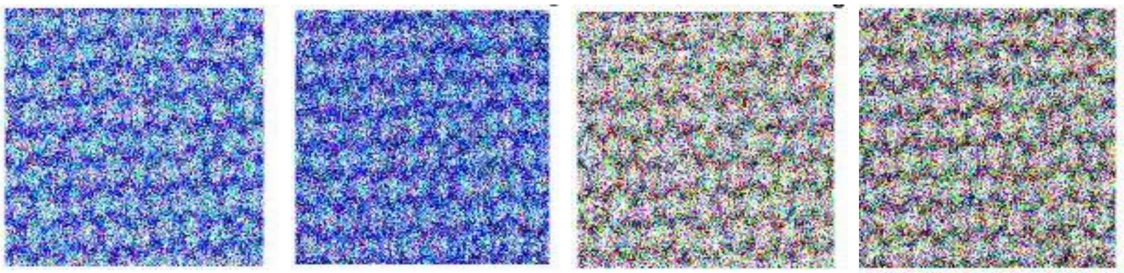


Figure 2.1.3 Gaussian Noise Added to the Fabric Samples

Step 3: Construct MATLAB R2018B coding combining Gabor and Butterworth filters.

The next step is to utilize a powerful mathematics software, MATLAB R2018B, to conduct and construct a full coding script for the first filter in this study, which is the Gabor filter. By understanding the concept aligned with image processing, FFT is a technique that enables the transformation of an image in its spatial domain to its frequency domain, and a detailed process in FFT can be seen below. In the following step, a full coding script will be tested by using MATLAB R2018B for Butterworth High-pass and Low-pass filters followed by the Fast Fourier Transform coding.

Step 4: Implement algorithm on fabric images

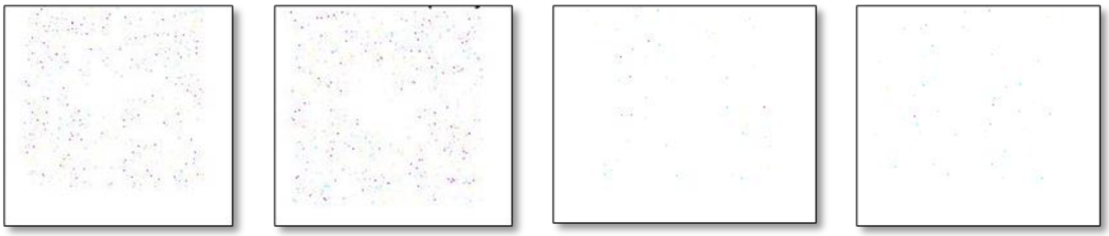
Research by Pandey et al. (2015) explained that FFT converts the image from one domain to the other so that filters can be applied and can be converted back to its original image. Equation 1 and 2 shows the mathematical formula of FFT and its inverse FFT. Figure 2.1.6 show the results obtained in MATLAB R2018B after transforming the images from Figure 2.1.5 into the frequency domain.

$$F(x,y) = \sum_{m=0}^{M-1}\sum_{n=0}^{N-1} f(m,n)e^{-2j2\pi\left(x\frac{m}{M}+y\frac{n}{N}\right)} \tag{1}$$

$$f(m,n) = \frac{1}{MN}\sum_{m=0}^{M-1}\sum_{n=0}^{N-1} F(x,y)e^{j2\pi\left(x\frac{m}{M}+y\frac{n}{N}\right)} \tag{2}$$

The commands used in MATLAB R2018B that represents the above equations are:

```
fftImage = fft2(imgSP);
Y = fftshift(fftImage);
FD = real(log(Y));
```



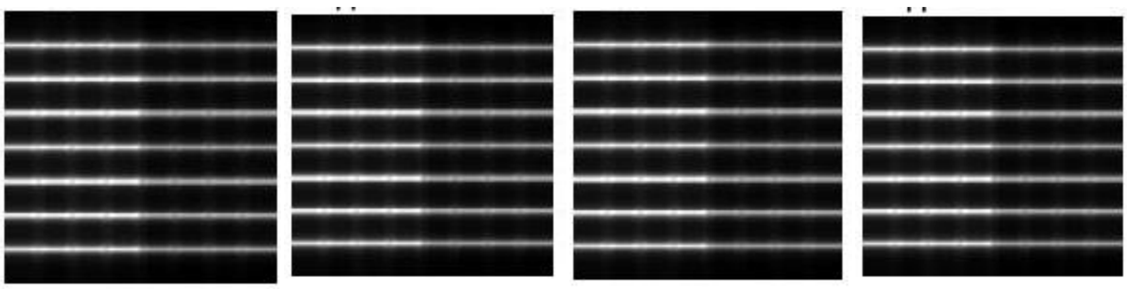
(i) (ii) (iii) (iv)

Figure 2.1.4 Transformed into FFT Frequency Domain, (i) Gabor and BLPF with salt and pepper noise, (ii)Gabor and BHPF with salt and pepper noise, (iii) Gabor and BLPF with gaussian noise and (iv) Gabor and BHPF with gaussian noise.

Research by Gokilavani et al. (2016) explained that the Gabor filter is a linear filter used for edge detection in image processing. Gabor filters' representations of frequency and orientation are comparable to those of the human visual system and have been shown to be very useful for representing and differentiating textures. In order to extract texture information from an image that is important for creating an output image of high quality, the Gabor filter technique is utilised in the image processing process when FFT is performed (Chen & Zhang, 2004). The commands used in MATLAB R2018B that represent Gabor filter are as below:

```
A = checkerboard(20);
wavelength = 2;
orientation = 100;
g = gabor(wavelength,orientation);
outMag = imgaborfilt(A,g);
```

The wavelength, λ, which acts as a parameter, as the number of λ increases, the blurriness in the image increases. On the other hand, a different parameter is used that alters the surface area of the image, which is also known as the orientation, and it can be represented as the following symbol, θ, (Gokilayani et al., 2016).



(i) (ii) (iii) (iv)

Figure 2.1.5 Applied Gabor Filters, (i) Gabor and BLPF with salt and pepper noise, (ii) Gabor and BHPF with salt and pepper noise, (iii) Gabor and BLPF with Gaussian noise and (iv) Gabor and BHPF with Gaussian noise

BLPF removes the high-frequency elements from the digital image and only considers the low-frequency ones. In relation to this, it has been concluded that the main use of a low-pass filter in image processing is image smoothing, Makandar and Halalli, (2015). On the other hand, BHPF is widely used in image processing techniques for image sharpening. To be exact, the main purpose of this filter is to elevate the fine little details in the digital image and during the process, it will also focus on the edges. Contrary to BLPF, this filter ignores the low-frequency components that were to be found in the digital image and maintains the high-frequency component. Basically, it acts as the reverse algorithm of the low pass version filter.

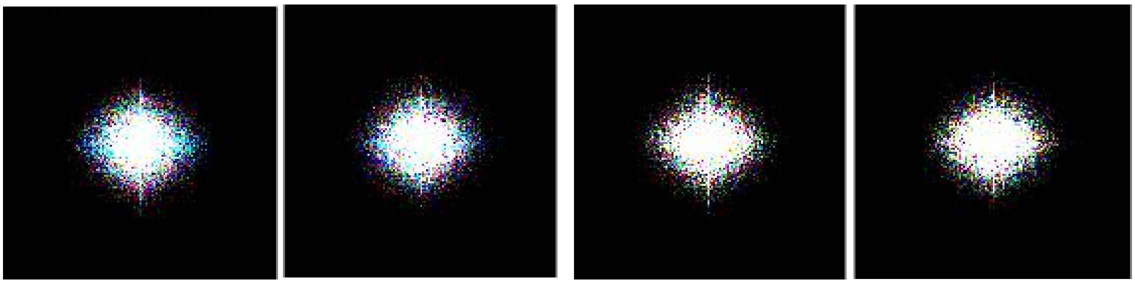
$$H(u,v) = \frac{1}{1 + \left[\frac{D_0}{D(u)}\right]^{2n}} \tag{3}$$

where D_0 is the positive constant for the cut-off frequency and n is the order of the filter, Sayed et al. (2016).

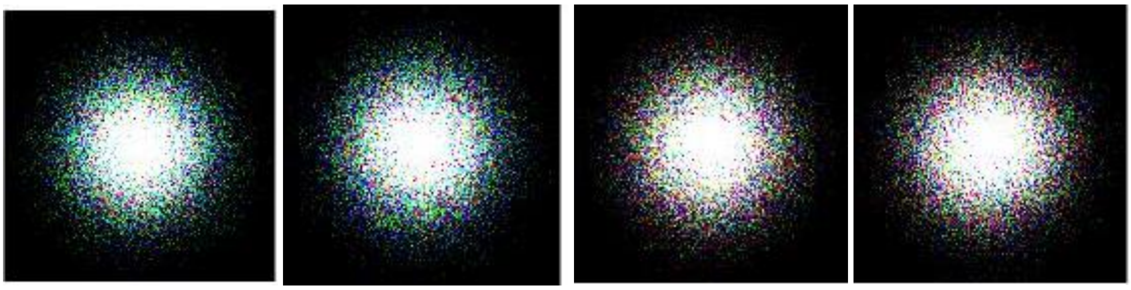
Equation 3.2.3 show the mathematical approach in the BHPF. As the image undergoes this filter, it will pass through the frequency components that are greater than the positive constant and the frequency that is less than it will be eliminated. Figure 4.4.1 show the results obtain after applying BLPF to the digital image of the fabric sample. The commands used in MATLAB R2018B are listed below:

```
function D = butterworthLPFilter(L,rows,columns)
n=1;
D0=10;
[p q]=meshgrid(-floor(columns/2):floor(columns/2)-1,-floor(rows/2):floor(rows/2)-1);
D = sqrt(p.^2 + q.^2);
hhp = 1 ./ (1 + ((D ./ D0).^(2 * n)));
size(L)
size(hhp)
D=L.*hhp;
end
```

The difference between BLPF and BHPF is when the number of D_0 changes. According to Sayed et al. (2016), D_0 refers to the cut-off frequency in the algorithm. BLPF implements a lower amount of D_0 while BHPF chooses a higher amount. Figure 3.2.8 $(i) - (iv)$ show the fabric sample that has applied BLPF that contains salt and pepper noise while $(v) - (vii)$ contains Gaussian noise. Figure 3.2.9 displays the $(i) - (iv)$ show the fabric sample that has applied BHPF that contains salt and pepper noise while $(v) - (vii)$ contains Gaussian noise.

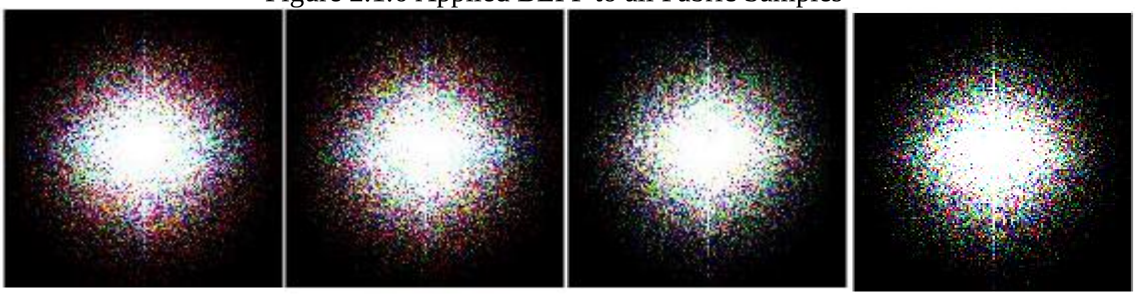


(i) (ii) (iii) (iv)

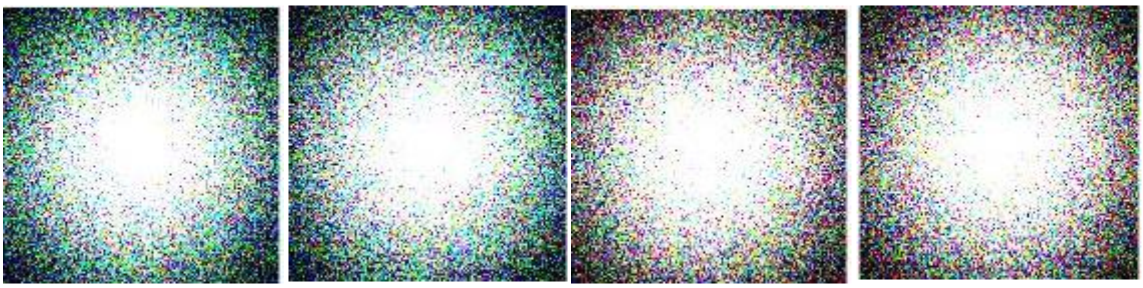


(v) (vi) (vii) (viii)

Figure 2.1.6 Applied BLPF to all Fabric Samples



(i) (ii) (iii) (iv)



(v) (vi) (vii) (viii)

Figure 2.1.7 Applied BHPF to all Fabric Samples

Step 5: Evaluate results by visual inspection and PSNR.

The evaluation process involves the application of both visual inspection and PSNR. Research by Dakshayani et al. (2022) shared that the ratio between the original image and the compressed or reconstructed image is calculated. The peak error is represented by PSNR. An image with a higher PSNR value is of better quality. Equation 4 show the PSNR equation that was used in the evaluation process. The command used in MATLAB R2018B used are also listed below.

```
ref = real(BLPFilter);
[peaksnr, snr] = psnr(imgSP, ref);
fprintf('\n The Peak-SNR value is %0.4f', peaksnr);
```

$$PSNR = 10\, log_{10}\left(\frac{R^2}{MSE}\right) \tag{4}$$

where MSE stands Mean- Squared Error and R is the maximum pixel value in the input, which is the fabric sample images, Dakshayani et al. (2022).

The average squared error between the original image and the compressed image is calculated by MSE. Better, higher-quality photos with fewer errors are produced with a lower MSE value. To differentiate image quality, Mean Squared Error and Peak-SNR are both used. MSE can be calculated by using Equation 5.

$$MSE = \frac{\sum_{M,N}[I1(m,n) - I2(m,n)]^2}{M \times N} \tag{5}$$

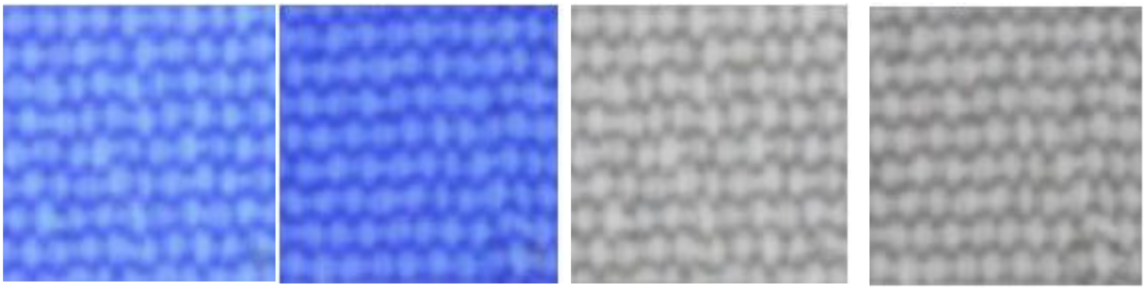
where M and $N$are are presented as the rows and columns of the image respectively, $I1$ is for the original image, while $I2$ is for the compressed image, in this case, the added noise image of the fabric samples, Dakshayani et al. (2022). Below show the commands used in MATLAB R2018B is calculate the MSE value of every image result.

```
err = immse(real(BLPFilter), imgSP);
fprintf('\n The mean-squared error is %0.4f\n', err);
```

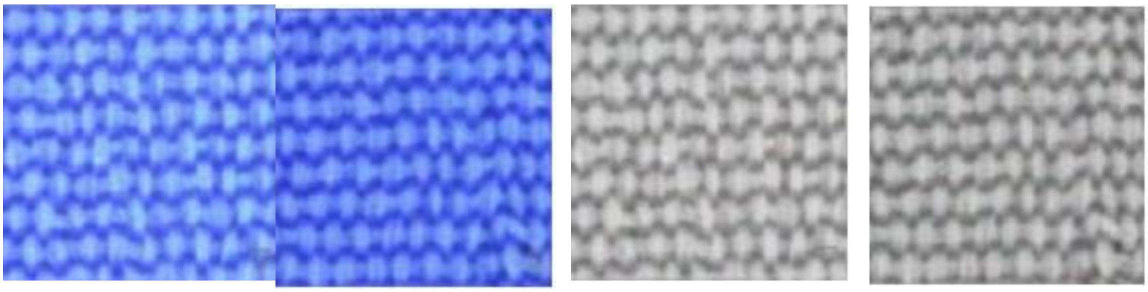
3. Results and Discussion

3.1 Results of Combination of Filters in MATLAB R2018B

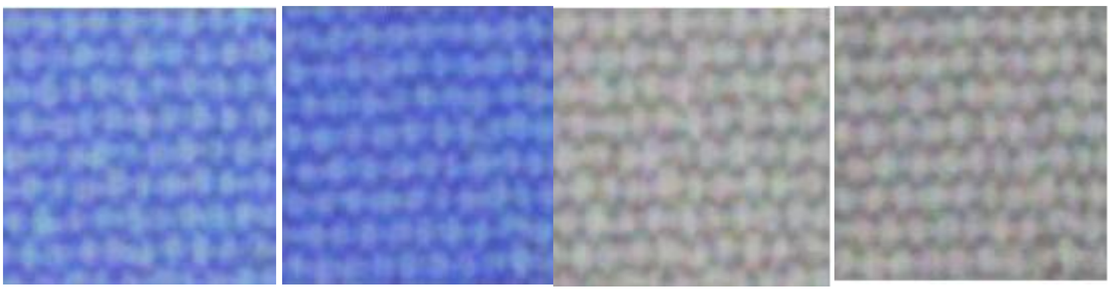
In this research, we applied the evaluation by visual inspection and by the statistical analysis using the Peak Signal-to-Noise Ratio (PSNR) value, which determined that the combination of Gabor and Butterworth High-Pass Filter was able to produce a much clearer output. This result is consistent with the statement by Khan et al. (2016) which stated that a higher order filter excels at addressing the high-frequency elements that can be found in digital images. Figure 3.1.1 displays the output fabric image results obtained using MATLAB R2018B.



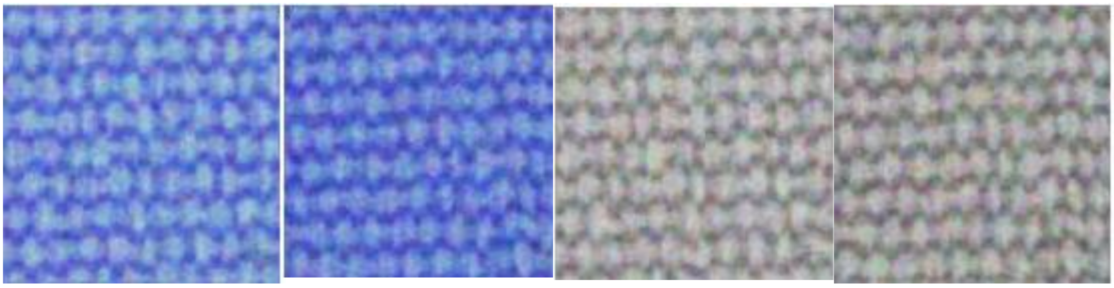
(a) (b) (c) (d)



(e) (f) (g) (h)



(i) (j) (k) (l)



(m) (n) (o) (p)

Figure 3.1.1 Results of Final Output in MATLAB R2018B, $(a) - (\mathrm{d})$ Gabor and BLPF, $(e) - (\mathrm{f})$ Gabor and BHPF (Salt and Pepper Noise) and $(i) - (\mathrm{l})$ Gabor and BLPF, $(m) - (\mathrm{p})$ Gabor and BHPF (Gaussian Noise)

Figure 3.1.2 – 3.1.5 displays the original image of the fabric samples, two types of noises are added, salt and pepper and gaussian noise, applied Gabor with BLPF and Gabor with BHPF for Fabric Sample 1,2,3,4 respectively.

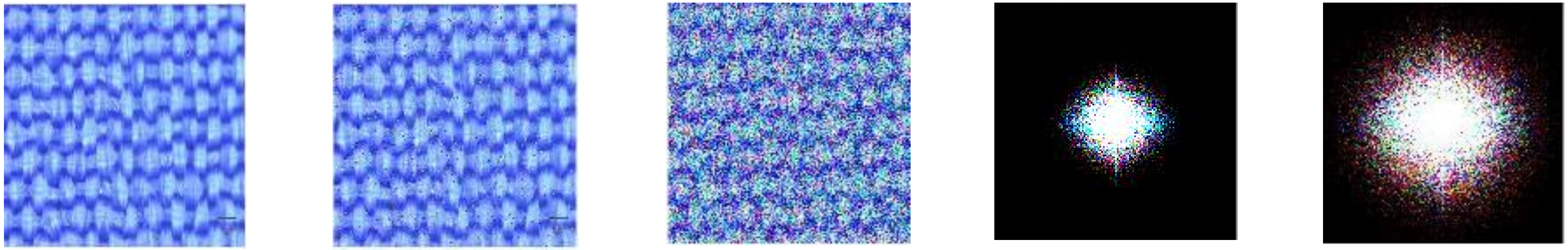


Figure 3.1.2 Results of Fabric Sample 1

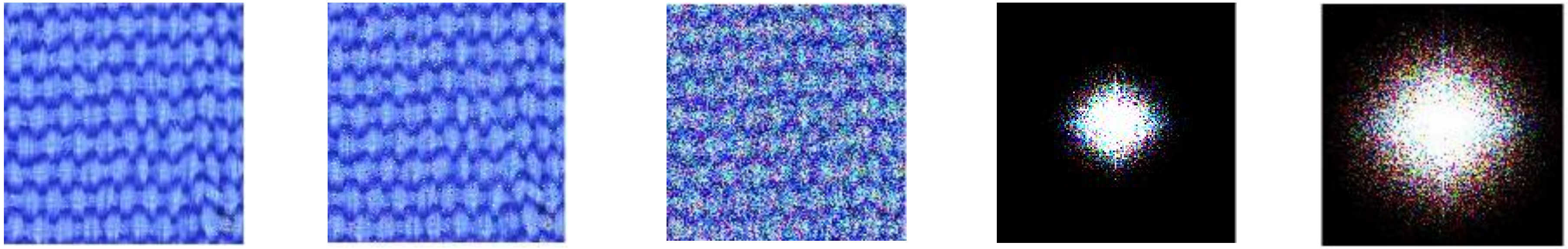


Figure 0.3 Results of Fabric Sample 2

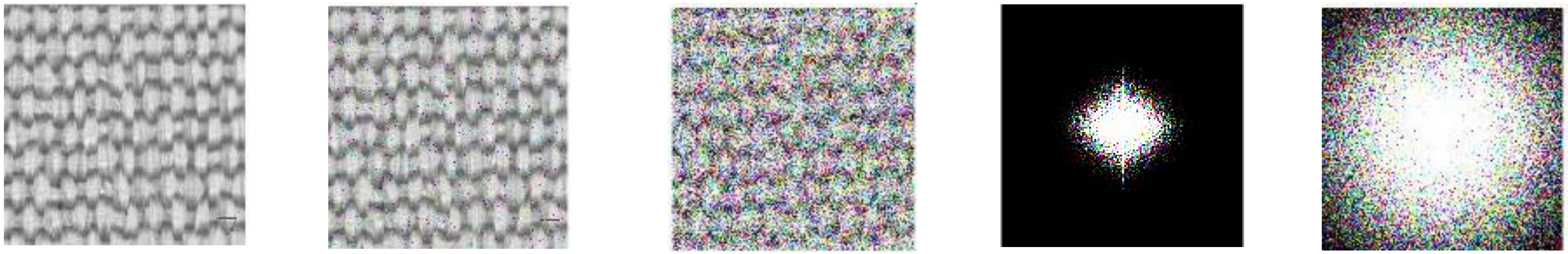


Figure3.1.4 Results of Fabric Sample 3

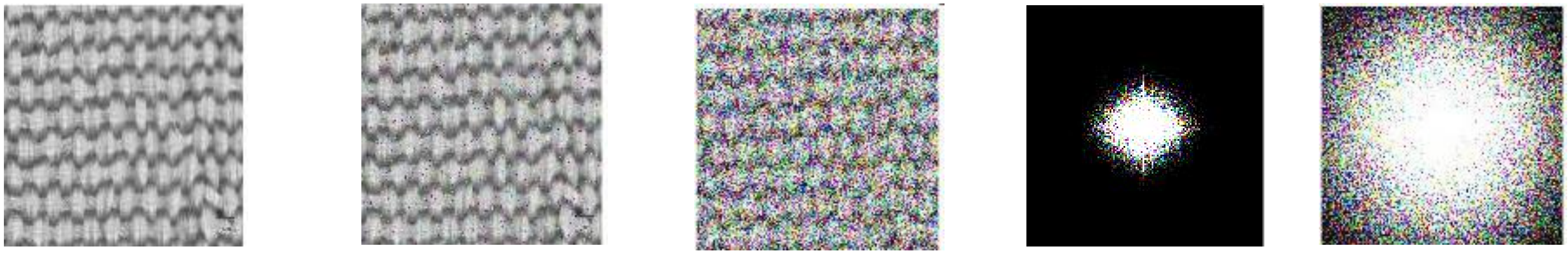


Figure 3.1.5 Results of Fabric Sample 4

3.2 Results of Mean-Squared Error and Peak Signal-to-Noise Ratio in MATLAB R2018

Following the implementation of visual inspection in 3.2, a detailed comparison of the values obtained in MATLAB R2018B has been made in order to determine which combination of filters operates effectively. Table 3.2.1 shows the filter combinations that were utilised together with the selected noise as well as the Mean-Squared Error and Peak Signal-to-Noise Ratio values that were produced using MATLAB R2018B.

Table 3.20.1 Combination of Filters used, Noise, Value of Mean-Squared Error and Value of Peak Signal-to-Noise Ratio

Result	Combination of Filters	Noise	Mean-Squared Error, (MSE)	Peak Signal-to-Noise Ratio, (PSNR)
(a)	Gabor with BLPF	Salt and Pepper	0.0124	18.9858
(b)	Gabor with BLPF	Salt and Pepper	0.0120	19.2368
(c)	Gabor with BLPF	Salt and Pepper	0.0122	19.1530
(d)	Gabor with BLPF	Salt and Pepper	0.0122	19.1133
(e)	Gabor with BHPF	Salt and Pepper	0.0082	20.9089
(f)	Gabor with BHPF	Salt and Pepper	0.0081	20.8834
(g)	Gabor with BHPF	Salt and Pepper	0.0077	21.1503
(h)	Gabor with BHPF	Salt and Pepper	0.0073	**21.2715**
(i)	Gabor with BLPF	Gaussian noise	0.0821	10.8376
(j)	Gabor with BLPF	Gaussian noise	0.0829	10.8139
(k)	Gabor with BLPF	Gaussian noise	0.0901	10.4577
(l)	Gabor with BLPF	Gaussian noise	0.0940	10.2809
(m)	Gabor with BHPF	Gaussian noise	0.0730	11.3665
(n)	Gabor with BHPF	Gaussian noise	0.0735	11.3208
(o)	Gabor with BHPF	Gaussian noise	0.0800	10.9766
(p)	Gabor with BHPF	Gaussian noise	0.0832	10.8029

Research by Dakshayani et al. (2022) demonstrated a greater PSNR value results in better digital image quality. The calculation of PNSR value of each output obtained is displayed in Figure 4.2.1. By observing the values in Figure 4.2.1, most values of the combination of Gabor and BHPF provide relatively higher results compared to the combination of Gabor and BLPF. Since a greater value of PNSR provides a greater quality of the image, it can determine exactly which of the following combination are more accurate. The combination of Gabor and

Butterworth High-Pass Filter with salt and pepper noise has produced the highest values of PNSR at 21.2715.

4. Conclusion and Recommendations

As a result of this research, the combination of the Gabor and Butterworth Filters was able to improve fabric images with salt and pepper, and Gaussian noises. Also, the comparison of using the Gabor and Butterworth High-Pass Filter and Gabor and Butterworth Low-Pass Filter showed that the Butterworth High-Pass filter resulted to better image enhancement of the fabric images. This is verified by visual examination and the higher Peak Signal-to-Noise Ratio (PSNR) value. This result is also consistent with the statement by Khan et al. (2016) which stated that a higher order filter excels at addressing the high-frequency elements that can be found in digital images. All objectives of this research are achieved, that is to we are able to develop a noise removal algorithm by combining the Gabor and Butterworth filters in the Fast Fourier Transform algorithm, implement the Gabor with both Butterworth High-pass and Low-pass filters, and evaluate the results using visual inspection and PSNR statistical analysis. Understanding the application of image processing techniques for the textile industry is the primary goal of this research. Nowadays, dealing with digital images is commonplace because of how quickly technology has advanced in this area. To ensure that the experiment and subsequent research can profit from this research, the algorithm being utilized must be on par with the user. The results of several different sorts of mathematical methodologies have been used, implemented, and contrasted. Future research of the results utilizing digital software is strongly advised considering the results, allowing for a more in-depth study of the digital image especially in textile.

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