ABDULLAH RASHED AWADH AL-AMERI B. ENG. (HONS) ELECTRICAL & ELECTRONICS ENGINEERING JANUARY 2015

ENHANCEMENT ANALYSIS OF IMMUNE FLUORESCENT CELL IMAGES

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UNIVERSITI TEKNOLOGI PETRONAS
TRONOH, PERAK
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by

Abdullah Rashed Awadh Al-Ameri

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A Project Dissertation Submitted to the

Department of Electrical & Electronics Engineering

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in Partial Fulfillment of the Requirement for the

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CERTIFICATION OF APPROVAL

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Approved by:

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ZAZILAH BT MAY
PROJECT SUPERVISOR

UNIVERSITI TEKNOLOGI PETRONAS
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January 2015

CERTIFICATE OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and the acknowledgments, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

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ABDULLAH RASHED AWADH AL-AMERI

ABSTRACT

There are different patterns of immune fluorescence cells, which serve in determining different autoimmune disease. Hence, clearly identifying the features of the figures in the image will assist in automating the classification of these patterns. This project aims to enhance the quality of the Hep2-cell images obtained from Indirect Immune Fluorescence (IIF) Test. The enhancement of the quality in this project will be focused on enhancing the contrast, reducing the noise, and sharpening the edges of images. This enhancement will have a real serious impact on the stages coming after, which are patterns recognition and automatic classification. Creating an automatic battern classification system will improve the diagnostic process of the autoimmune disease instead of handling it manually. Consequently, many disadvantages of the manual interpretation can be overcome, such as level of expertise, time consuming and prone to mistakes. This research analyzed the performance of three enhancement approaches namely wavelet transform filter, diffusion filter, and wavelet transform filter combined with diffusion filter. The combination of wavelet transform filter with diffusion filter produced better result. However, the diffusion filter produced best result among all the three enhancement approach of the indirect immune fluorescence images. The recommendation for the future work is to explore an automatic determination of noise variance in the image when wavelet transform filter is being applied.

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Finally, the author expresses again his deepest gratitude to all individuals whoever contributed in the success and completion of this project.

TABLE OF CONTENTS

ABSTRACT iv
ACKNOWLEDGMENT v
List of Tables: viii
List of Figures: ix
CHAPTER 1: INTRODUCTION 1
1.1. Background Study 1
1.2. Problem Statement 2
1.3. Objectives 3
1.4. Scope of Study 3
CHAPTER 2: LITERATURE REVIEW 4
2.1. Indirect Immune Fluorescence Test (IIFT) 4
2.2. Image Enhancement 5
2.3. Image Quality Assessment Methods 8
2.4. Previous Related Work 9
2.5. Critical Analysis of Literature Review 10
CHAPTER 3: METHODOLOGY 12
3.1. Methodology: 12
3.2. Key milestone 13
3.3. Gantt chart 15
3.4. Flow Chart 16
3.5. Tools 19
3.6. Schedule of the project 20
CHAPTER 4: RESULTS AND DISCUSSION 21
4.1. Image patterns 21
4.2. Image noising 22
4.3. Image enhancement 23
4.4. Performance measurement 27

4.5. Performance analysis 29
CHAPTER 5: CONCLUSION AND RECOMMENDATION 32
REFRENCES 33
APPENDIX 35

List of Tables:

Table 3. 1: FYP1 schedule

Table 3. 2: FYP2 schedule

Table 4. 1: Performance measurement of noisy image

Table 4. 2: Performance measurement of the wavelet transform filter

Table 4. 3: Performance measurement of the combination of the wavelet transform and diffusion filters

Table 4. 4: Performance measurement of the diffusion filter

List of Figures:

Figure 1. 1: Different Nuclear and Cytoplasmic Patterns Obtained from the IIF Test

Figure 2. 1: Median filter

Figure 3. 1: General flow of the research

Figure 3. 2: Flow of the project approach

Figure 3. 3: Process details

Figure 4. 1: Sample of centromere pattern

Figure 4. 2: Sample of nuclear pattern

Figure 4. 3: Addition of white Gaussian noise to the original image

Figure 4. 4: Output of wavelet transform filter

Figure 4. 5: Output of the combination of wavelet transform filter and diffusion filter

Figure 4. 6: Output of the diffusion filter

Figure 4. 7: Signal to Noise Ratio (SNR)

Figure 4. 8: Root Mean Square Error (RMSE)

Figure 4. 9: Peak Signal to Noise Ratio (PSNR)

Figure 4. 10: Structural Similarity Index Metric

CHAPTER1

INTRODUCTION

1.1. Background Study

Researches stated there is approximately five to seven percentage of population in the world suffers from one of auto-immune diseases. Nevertheless, there are more than 60 auto-immune diseases are recognized. The immune diseases are, in fact, done by an unwanted autoimmune response from human body against the cell structures of the human body. It happens due to wrong interpretation of cell structures and fighting them as foreign bodies. As a result, these diseases contribute to severe impairment of tissue and organs and often the course of the disease are continuing.

The diagnosis of these autoimmune diseases is done by using antinuclear auto-antibodies (ANA). Then, Indirect Immune Fluorescence (IIF) Test is used as an imaging method for the detection purpose of antinuclear auto-antibodies. The auto-antibodies in the patient's blood are identified by staining the affected cell structures. However, there are many different nuclear and cytoplasmic patterns can be obtained from the IIF test characterized by a set of auto-antibodies (Fig). The physicians suspect the diagnosis by analyzing the results manually using fluorescence microscope. Thus, the pattern interpretation strongly depends on how reliable is the experience level of the doctor.

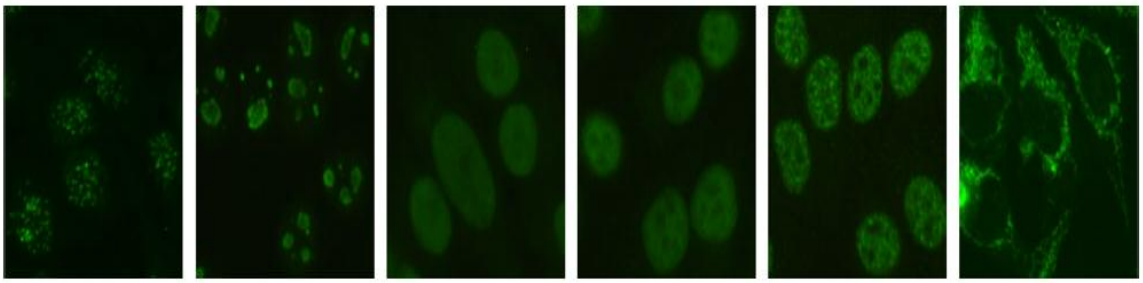

FIGURE 1. 1: Different Nuclear and Cytoplasmic Patterns Obtained from the IIF Test

Therefore, there are several disadvantages of manually interpreting of IIF results such as level of expertise, time consuming, prone to errors and physical fatigue of the physician. Moreover, poor standardization may lead to difficulties in cell interpretation.

Different patterns of immune fluorescence cells determine different disease. The differences in the patterns are due to each pattern possesses essential features differ from other features of other patterns. Yet, for automatic classification of these patterns, the features of the patterns must be distinguished distinctly. Hence, the quality of the cell image must be more enhanced. [1-4]

1.2. Problem Statement

There are more than 60 known auto-immune disease infect about five to seven percent of the world's population. The most utilized methods for auto-immune disease diagnosis is Indirect Immune Fluorescence (IIF) Test. The results show different patterns of the cells. Different patterns differentiate different disease. Nevertheless, the interpretation of the patterns is done manually by at least two expert physicians. [1]

In that respect are various disadvantages of manual interpretation such as level of expertise, time consuming and prone to errors. The subjectivity of diagnosis affects quality of diagnosis, due to dependency on the experience and expertise of the physician which varies from one doctor to another. [5]

Moreover, the accuracy of diagnosis affected by the physical fatigue of the physician and low level of standardization lead to incompatibility and difficult interpretation of IIF test results[6].

1.3. Objectives

The main aim of this project is to enhance the quality of the Hep2-cell image. This objective is subjected to the following:

- To review and critically analyze current enhancement techniques.
- To enhance fluorescent cell images by improving the quality of the images using several approaches in order to reduce the noise and enhance the contrast and the edges of the image.
- To evaluate the enhancing performance of the selection approaches over the indirect immune fluorescence images.

1.4. Scope of Study

The scope of this project focuses on enhancing the quality of the Hep2-cell image using different techniques. There are many different techniques practiced to enhance the image quality. However, this project will focus on noise reduction, contrast and edge enhancement. The enhancement will be managed with help of Matlab and image processing toolbox. Then, the results will be evaluated using different quality image assessment criteria and the validation will be checked by the experts.

CHAPTER 2

LITERATURE REVIEW

This chapter introduces a short brief about medical image processing and quality assessment methods of the enhancing approaches. This chapter contains an overview and background studies, followed by the discussion on the previous published works related to the field.

2.1. Indirect Immune Fluorescence Test (IIFT)

The indirect immune fluorescence images are increasingly applied as a method for auto-immune disease diagnosis. All the same, the interpretations and analysis of this kind of images are still at a depressed point of automation comparing with other medical imaging techniques.

In IIFT, by staining the biological tissue with antibodies, which linked to a fluorescent chemical compound, the IIF image will be obtained. The distribution pattern of the antibodies is the main information for diagnosing analysis. [4]

The IIF classification is performed manually and usually consists of the next steps:

- Categorization of the fluorescence intensity step, it is performed according to guidelines established by the Center of Disease Control and Prevention.
- Recognition of mitotic cells step, where the well is discarded if the number of mitotic cell is under certain threshold usually 1 or 2.
- Categorization of the staining pattern step, the physicians play their part in recognizing the staining patterns and link them to the corresponding autoimmune disease. [7]

Unfortunately, IIFT method is still strongly dependent on the experience and expertise of the physicians. As a solution of this limitation, the researchers are trying now a day to

bring forth an advance with complete automatic procedures to increase the reliability and reduce the time cost.[5]

2.2. Image Enhancement

Converting the image from one form to another, for instance digitizing or scanning, cause some decreasing in the quality of visualizing the features of the original image. Hence the obtained image must undergo some enhancement image processes. [8-10]

During the image formation using an image device, it may, subject to a noise and it may lead to blurring and distortion of the image. Consequently, effecting the quantitative and visual analysis of the image.

The captured noise in fluorescence microscopy image is due to various reasons. The extrinsic noise can be caused by miss focus, instrumental error or environmental factors. Whereas, intrinsic noise could be induced by the detection of photons.

There are various restoration methods, but some of them are not suitable for enhancing fluorescence images due to certain limitations. Therefore, before proceeding with this project the author performed some reviews in the current enhancement techniques practices to increase the quality of the medical images.

The image enhancement is basically to improve the information in the image for human viewer or to provide a high quality input of automated image processing. There are many techniques and can be divided into two main categories[11]:

(i) Spatial Domain Methods: the image pixels are manipulated to get the desired enhancement.
(ii) Frequency Domain Methods: the image is transferred into frequency domain by through computing the Fourier transform. Then inverse the Fourier transform after the performing the enhancement the operations in the frequency domain.

2.2.1. Median filter

It is similar to averaging filter. It produces a pixel determine by the median of the surrounding pixels rather than mean. Therefore, it has less sensitivity to the critical values comparing with the mean. Moreover, it can remove the outliers without decreasing the sharpness of the image[12]. Figure 2.1 shows median filter 3-by-3.

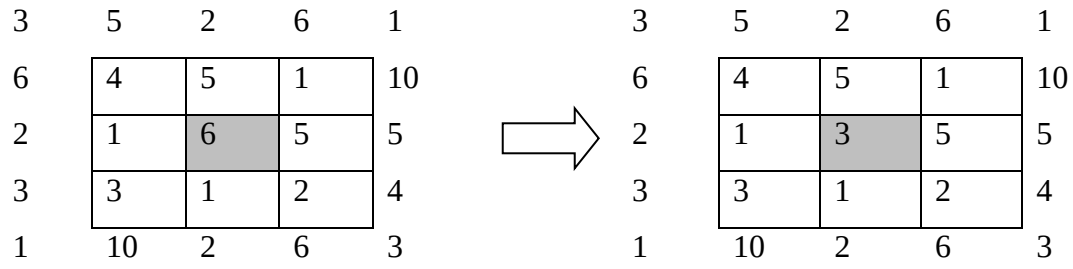

FIGURE 2. 1: Median filter

2.2.2. Diffusion filter technique

It is a recent proposed method in the image processing, therefore it is still not used too much. It can reduce the unwanted intensity in the image and enhance the contrast of the edges with degrading much information.

2.2.2.1. Diffusion filter algorithm

The diffusion filter is governed by partial differential equation (PDE)[13], equation 2.1

$$[f_t(x,y)] = div[c(x,y).\nabla f_t(x,y)] \quad (2.1)$$

$f_t(x,y)$ Denotes the noisy image at time t. whereas $c(x,y)$ is denoting the diffusion coefficient.

The diffusion coefficient is determined by the following equation 2.2

$$c(x,y) = g(|\mu(x,y)|) = \frac{1}{1+\left(\frac{|\mu(x,y)|}{\gamma}\right)^2} \quad (2.2)$$

The edge at pixel (x,y) is estimated through $\mu(x,y)$ which depends on the edge threshold γ . It enhances the image while preserving the edges. The nonlinear diffusion PDE can be shown in Equation 2.3

$$\frac{\partial}{\partial t}[f_t(x,y)] = \frac{\partial}{\partial x}\left[c(x,y).\frac{\partial}{\partial x}f_t(x,y)\right] + \frac{\partial}{\partial y}\left[c(x,y).\frac{\partial}{\partial y}f_t(x,y)\right] \quad (2.3)$$

2.2.3. Wavelet transform technique

In signal processing it is very critical to discover the suitable representation of the data that will be processed. Therefore, usually the signal is decomposed and transformed into another domain which is considered as a key role in image processing.

2.2.3.1. Wavelet transform filter algorithm

The wavelet transform filter is implemented through forward wavelet transform (FDWT) or decomposition. The decomposition is governed by the following equation 2.4

$$A_j(x,y) = f(x,y) \otimes H(y) \otimes H(x)$$

$$W_j^H(x,y) = f(x,y) \otimes H(y) \otimes G(x) \quad (2.4)$$

$$W_j^V(x,y) = f(x,y) \otimes G(y) \otimes H(x)$$

$$W_j^D(x,y) = f(x,y) \otimes G(y) \otimes G(x)$$

$f(x,y)$ Denotes the noisy image, $\otimes$ is the convolution operation. H and G are the low pass and high pass filters of one dimensional signal respectively. The image is decomposed into four frequency sub-bands which are low frequency approximation denoted as A_j and three high frequencies denoted as horizontal (H), vertical (V), and diagonal (D) orientations.

The reconstruction or the inverse wavelet transform (IDWT). Equation 2.5 illustrates how the reconstruction is governed. Where $f_t(x,y), f_{t+1}(x,y)$, denote the original image

and reconstructed image respectively. $f(x,y)\otimes \mathrm{GH(x,y)}$ Is separable convolution of $f(x,y)$ with $H(y)$ and $G(x)$ [14].

$$f_{t+1}(x,y) = [f_t(x,y)\otimes \mathrm{HH(x,y)}]\otimes \widetilde{HH}(x,y) + [f_t(x,y)\otimes \mathrm{GH(x,y)}]\otimes \widetilde{GH}(x,y) + [f_t(x,y)\otimes \mathrm{HG(x,y)}]\otimes \widetilde{HG}(x,y) + [f_t(x,y)\otimes \mathrm{GG(x,y)}]\otimes \widetilde{GG}(x,y) \quad (2.5)$$

2.3. Image Quality Assessment Methods

The quality measurements are very critical in image processing. The performance strength can be analyzed by evaluating the similarity between the output of the proposed enhancement method and the reference images[15]. The most common quality measures are signal-to-noise ratio (SNR), mean square error (MSE), peak signal-to-noise ratio and structural similarity index metric (SSIM).

2.3.1. Signal to noise ratio

It is computed by identifying the ratio of the signal power to the noise power. The higher SNR the clearer signal. SNR can be calculated by following equation 2.6

$$(SNR)_{dB} = \frac{var(avg(I_{denoised}))}{var(avg(I_{original}))} \quad (2.6)$$

2.3.2. Mean square error

It compares the two signals and evaluate the similarity to produce a score describing the level of the distortion between them [16]. MSE can be calculated by the following equation 2.7

$$MSE = \frac{1}{NM}\sum_{i=1}^{N}\ \sum_{j=1}^{M}\left(I_{original}(i,j) - I_{denoised}(i,j)\right)^2 \quad (2.7)$$

2.3.3. Peak signal to noise ratio

It is defined as the ratio between the maximum power of the signal and the power of the noise affects the signal[17]. PSNR can be calculated by the following equation 2.8

$$PSNR = 20log_{10}\frac{255}{RMSE} \quad (2.8)$$

2.3.4. Structural similarity index metric

It is a recent proposed method introduced in the image processing. It evaluates the similarity between two sets of images in terms of luminance, contrast and structure[18]. SSIM can be calculated using the following equation 2.9

$$SSIM(x,y) = \frac{(2\times\overline{x}\,\overline{y}\ +C1)(2\times\sigma_{xy}+C2)}{(\sigma_x^2+\sigma_y^2+C2)\times((\overline{x})^2+(\overline{y})^2+C1)} \quad (2.9)$$

Where $\overline{x}$, $\overline{y}$, σ_x^2 , σ_y^2, and σ_{xy} are the average of x, the average of y, variance of x, variance of y, and the standard deviation of x and y respectively.

$C_1 = (k_1L)^2, C_2 = (k_2L)^2$ are variables to stabilize the division. L is the dynamic range and k_1 =0.01 and k_2 = 0.03.

2.4. Previous Related Work

WHE in combination with Perona-Malik filter have been done to reduce the noise of medical images. The approach effectively remove the artifacts while preserving the contrast. The PSNR values show that the WHE method with PM filter performs better than the transform domain approach with PM filter. [19]

Transform domain approach with Perona-Malik filter have been done to reduce the noise of medical images. The approach effectively removes the artifacts while preserving the contrast. This approach performs better than the transform domain approach with PM filter. [14].

Edges enhancements had performed in wavelet domain median filtering and scaling techniques. The edges of the enhanced images were detected using canny to enhance the edges of retinal images. The approach Wavelet domain scaling has better enhanced than median filtering approach. LOG filter performed grater edge detection than canny filter. It is very suitable to enhance the edges of medical images [13].

The steps of the diffusion algorithm have been studied to come up with best parameters choice at each step. It scheme has been evaluated using several images with different scale of noise. The results show that the most difficult images to be enhanced using diffusion are those with many details and texture[20].

A brief description on the digital images and medical images has been presented. In addition, extensive review has been done on the denoising of the medical images as well as on the classification of the medical image into Radiographic, Ultrasound, MRI or CT image [21].

2.5. Critical Analysis of Literature Review

It is obvious that before starting any pattern recognition method the obtained image must undergo enhancement processes by restoring the image and remove the noise but in the meantime preserving the edges and contrast. In the literature, some methods have been reviewed to find and select the recommended method for fluorescence image enhancement.

After reviewing the latest enhancement techniques of medical images it is very important to select an approach to enhance the quality of the image while at the same time preserves the detailed information of the image. It is obvious that enhancement approaches based on wavelet transform perform better for enhancing the quality of the medical images due to its ability to preserve the high frequencies and the details of the image.

Therefore, wavelet transform filter and diffusion filter are two algorithms used in this project due to their high performance in enhancing images with less degradation.

CHAPTER 3

METHODOLOGY

3.1. Methodology

3.1.1. Research

The first step to start with this project is to have a brief insight on the topic. By reviewing the researches and taking some online courses, it will assist to get the basic idea on the techniques and method of image enhancement. Image enhancement is very significant in digital image processing. There are a lot of approaches to enhance the image quality with different own advantages and side to improve. Moreover, image enhancement is also applied in many other applications such as satellite imaging as well as military based activities. Hence, it is very critical to review the most appropriate techniques for enhancing the medical images.

3.1.2. Critical analysis on enhancement approaches

In the literature review, there are numerous of outstanding enhancement approaches such as local enhancement based on histogram equalizations, spatial domain methods, frequency domain methods, diffusion filter and discrete wavelet transform. Critical analysis on the literature review suggests to use discrete wavelet transform and diffusion filter due to their high performance in reducing the noise and sharpening the image with less degradation. Discrete wavelet transform will help in reducing the noise. Then, the diffusion filter is applied to sharpen the denoised image.

3.1.3. Preparing the enhancement algorithm

After the enhancement techniques have been finalized, the project will be implemented with developing the algorithm of the enhancement. This project will be carried out using Matlab with benefit of image processing toolbox which is accessible freely in the web. Enhancement algorithm is a decisive phase because it affects the output and poor algorithm outcome results in unreliability of the automated image classification.

3.1.4. Evaluation of the enhancement algorithm

Once the proposed enhancement algorithm is applied, the results will undergo the quality assessment. The assessment criteria are based on the difference between the original image and the enhanced, denoised image. Hence, in this project, the evaluation will depend on the Signal to Noise Ratio (SNR), Peak Signal to Noise Ratio (PSNR), and the structural similarity index (SSIM) methods.

3.1.5. Optimization of algorithm

After evaluating the result of the proposed algorithm, changes will be done according to the performance assessment results. In the segment, it is required to analyze the coding so that it well-suited with the desired output.

3.2. Key milestone

3.2.1. Extensive research

Extensive literature review has been done to study the early development of the enhancement techniques and its reliability in the image processing. In this project, it has been focused on reviewing the enhancement approaches which are more reliable and they could be applied for enhancing the Hep2-Cell images. Overall, literature analysis

had assisted on increasing the understanding of applying the enhancing techniques in medical image processing.

3.2.2. Enhancement method and algorithm

Based on the literature analysis, the selected method for enhancing the immune fluorescent images is based on the wavelet transform as well as the partial differentiation. Therefore, the algorithm has been developed based on wavelet transform, wavelet transform combined with diffusion filter, and diffusion filter exclusively.

3.2.3. Implementation of algorithm

Developing the algorithm has been done using Matlab. The Hep2-Cell images have been taken from publically available data base.

3.2.3.1. Code compiling to M.file

Once the code is developed, it is compiled to M.file to be used.

3.2.3.2. Testing the noise code

To verify and debug the coding in adding noise to original image phase.

3.2.3.3. Testing FDWT code

To verify and debug image decomposition phase.

3.2.3.4. Testing IDWT code

To verify and debug image reconstruction phase.

3.2.3.5. Testing diffusion filter code

To verify and debug the diffusion filter phase.

3.2.3.6. Testing image quality assessment code

To verify and debug the quality assessment phase.

3.2.4. Algorithm improvement

Definitely, there will be always room to improve the enhancing method in order to improve the image quality.

3.2.5. Documentation and reporting

The researches materials and algorithm are being properly documented in different types of reports as a reference for future.

3.3. Gantt chart

Refer to the Appendix.

3.4. Flow Chart

Figure 3.1 below shows the general flow of the overall processes in conducting the research.

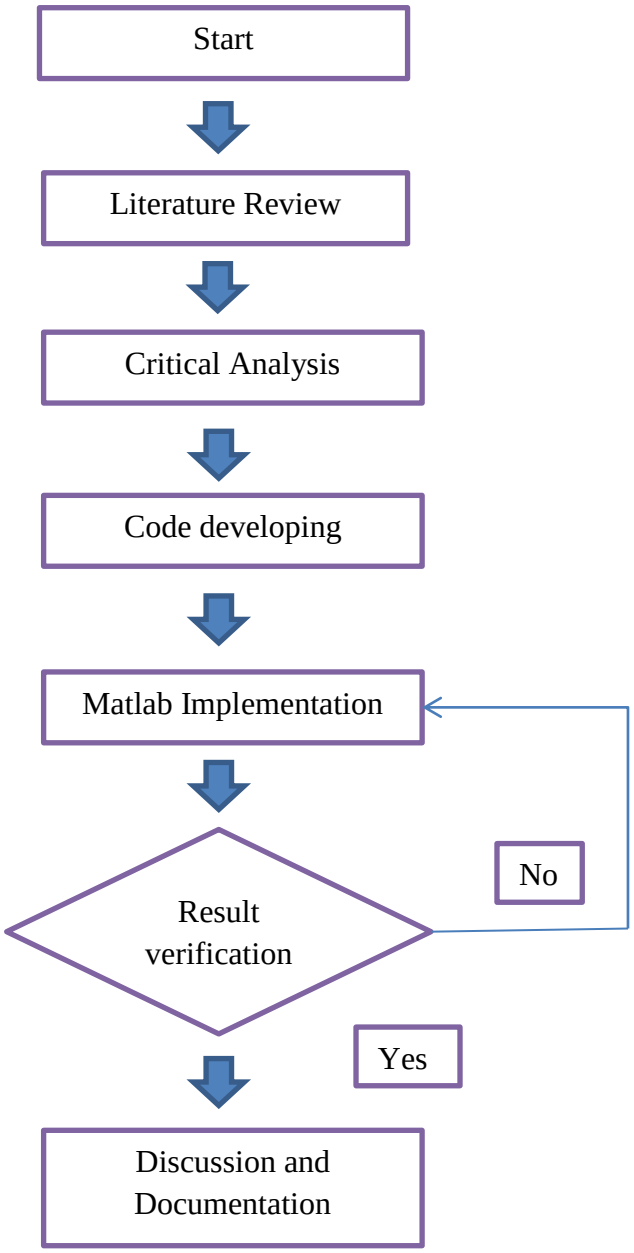

FIGURE 3. 1: General flow of the research

Figure 3.2 below shows the work flow of the developed algorithm in this project.

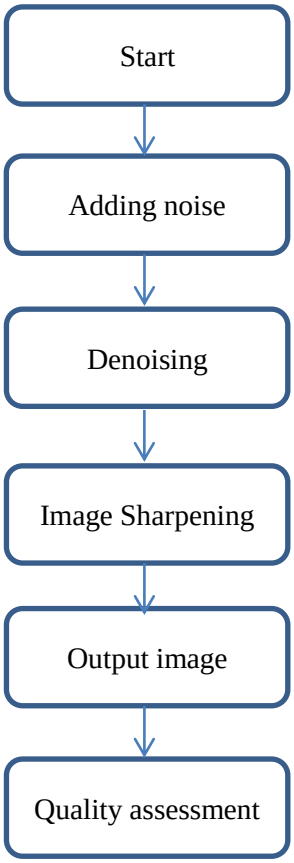

FIGURE 3.2: Flow of the project approach

Figure 3.3 below shows the detailed processes included in this enhancing approach.

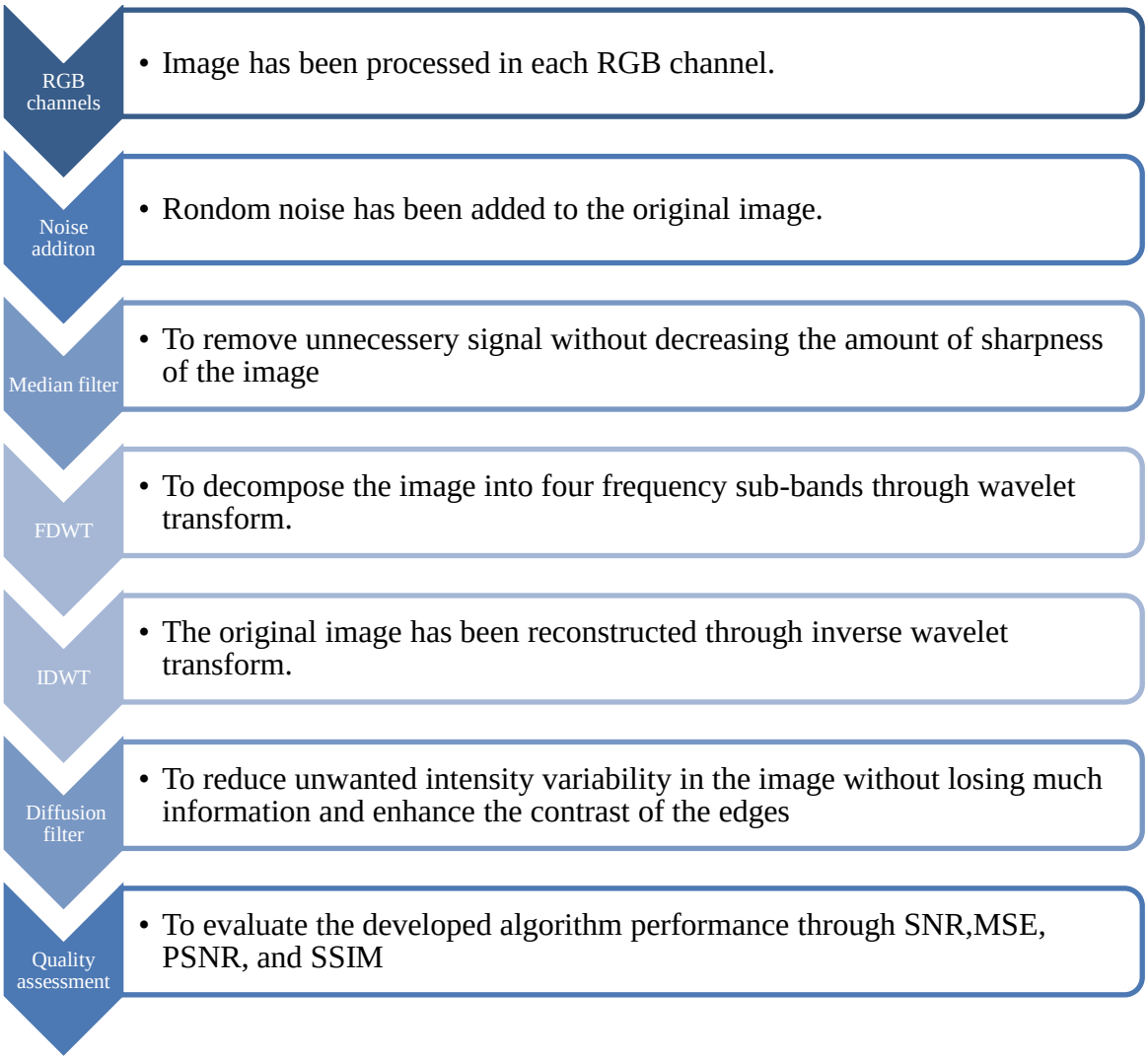

FIGURE 3.3: Process details

3.5. Tools

In this project the immune fluorescent cell images have been obtained from accessible data base. For software, Matlab has been used to enhance the images through the selected algorithm.
Below is the summary:

i. Hardware
   a. Computer.

ii. Software
   a. MATLAB R2014.

3.6. Schedule of the project

Table 1 and table 2 display the scheduled plan of this research.

TABLE 3.1: FYP1 schedule

Title selection	Week 1-2
Extended proposal	Week 7
Proposal defense	Week 8
Draft interim report	Week 13
Final interim report submission	Week 14

TABLE 3.2: FYP2 schedule

Progress report	Week 8
ELETREX	Week 9
Draft report	Week 13
Final report	Week 14
Technical paper	Week 14
VIVA	Week 15
Dissertation (hard bound report)	Week15

CHAPTER4

RESULTS AND DISCUSSION

This chapter introduces the result of the proposed approach to enhance the Indirect Immune Fluorescence (IIF) images with different staining patterns. It shows the analysis of both enhancing methods wavelet transform and diffusion filter, then wavelet combined with diffusion filter. The result were evaluated through these assessment criteria SNR, PSNR, MSE, and SSIM.

4.1. Image patterns

The type of autoimmune disease is diagnosed by identifying the staining pattern. In this project, centromere and nuclear types of patterns have been used to evaluate the performance of the proposed methods.

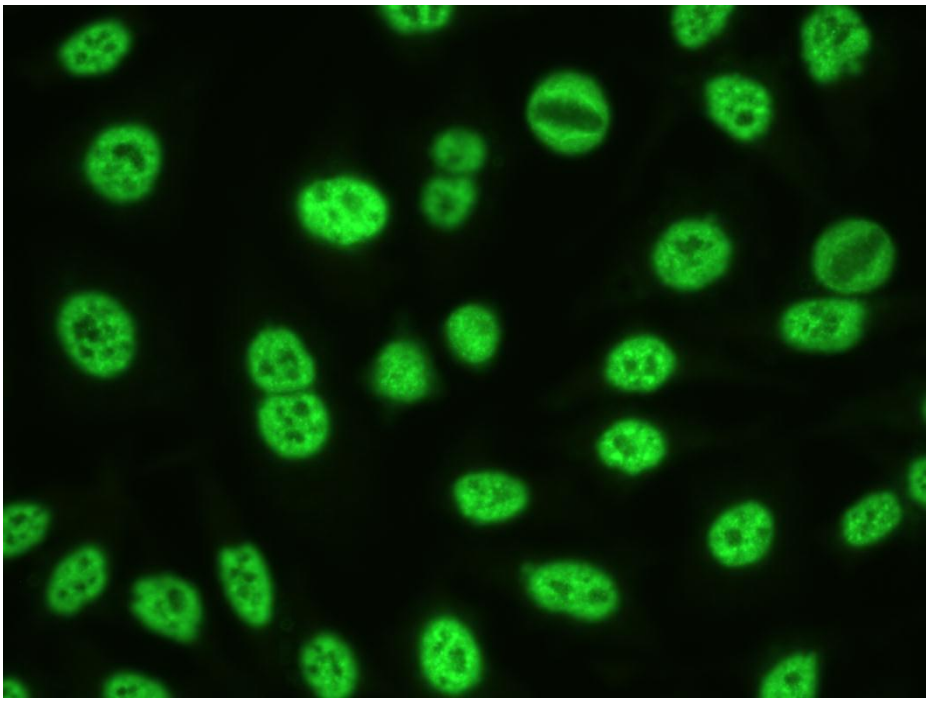

FIGURE 4. 111: Sample of centromere pattern

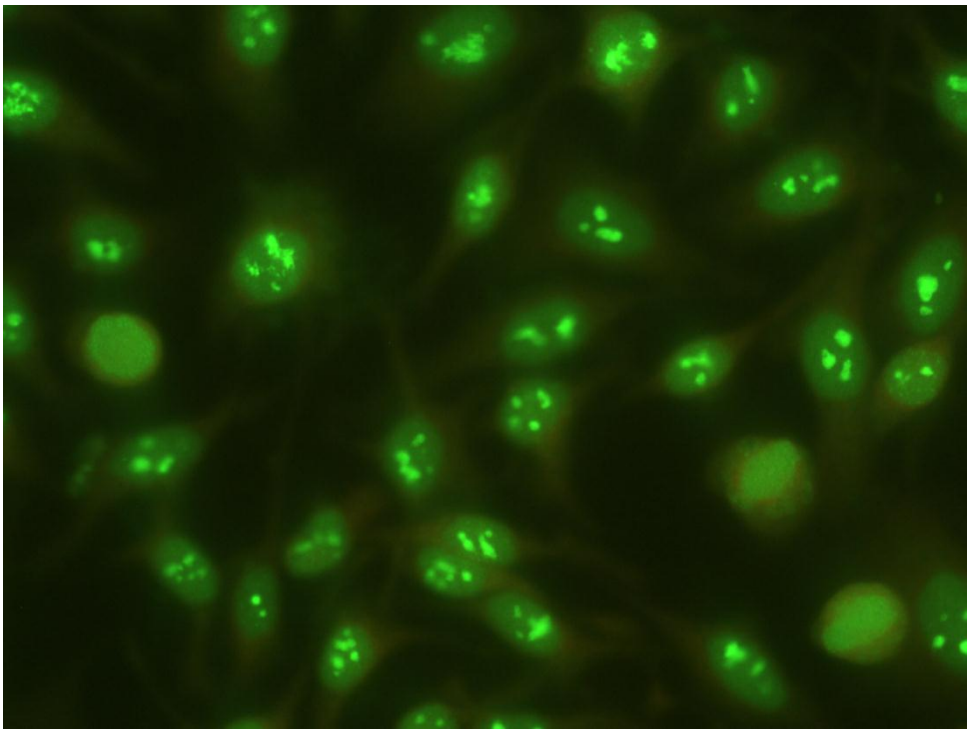

FIGURE 4.2: Sample of nuclear pattern

Figure 4.1 and figure 4.2 show clear images of nuclear and centromere patterns. The centromere pattern is several speckles distributed throughout the interphase nuclei. Whereas, nuclear pattern is normally less than six in number of large speckles within the nucleus per cell.

4.2. Image noising

The original images have been introduced to a noise. Figure 4.3 shows the addition of the white Gaussian noise to the original image. Then the noised image has been processed by the proposed methods. The performance depends on the efficiency of the used method to remove the noise and recover back the original image.

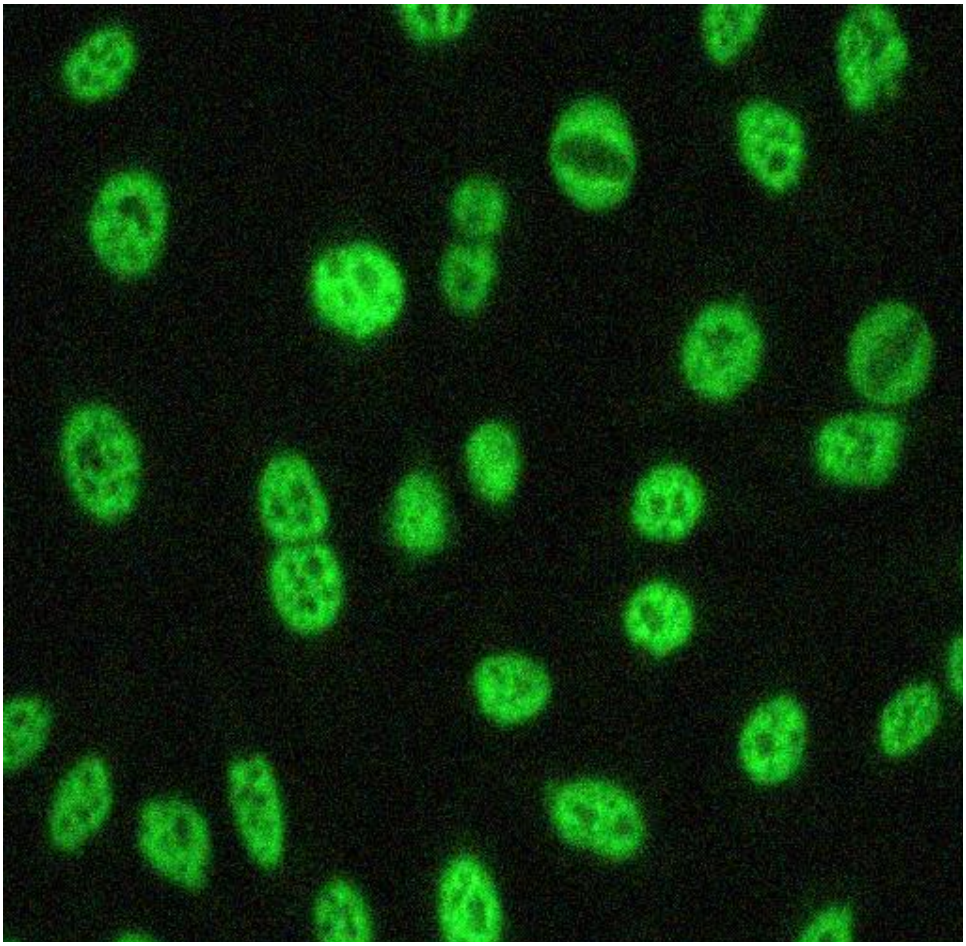

FIGURE 4.3: Addition of white Gaussian noise to the original image

4.3. Image enhancement

The noisy image has been passed through three different proposed approaches to remove the noise and recover the original image.

4.3.1. Wavelet transform filter

Figure 4.4 shows the output of the first proposed method which is wavelet transform filter. This method is enhancing the image in several decomposition of frequency sub-bands.

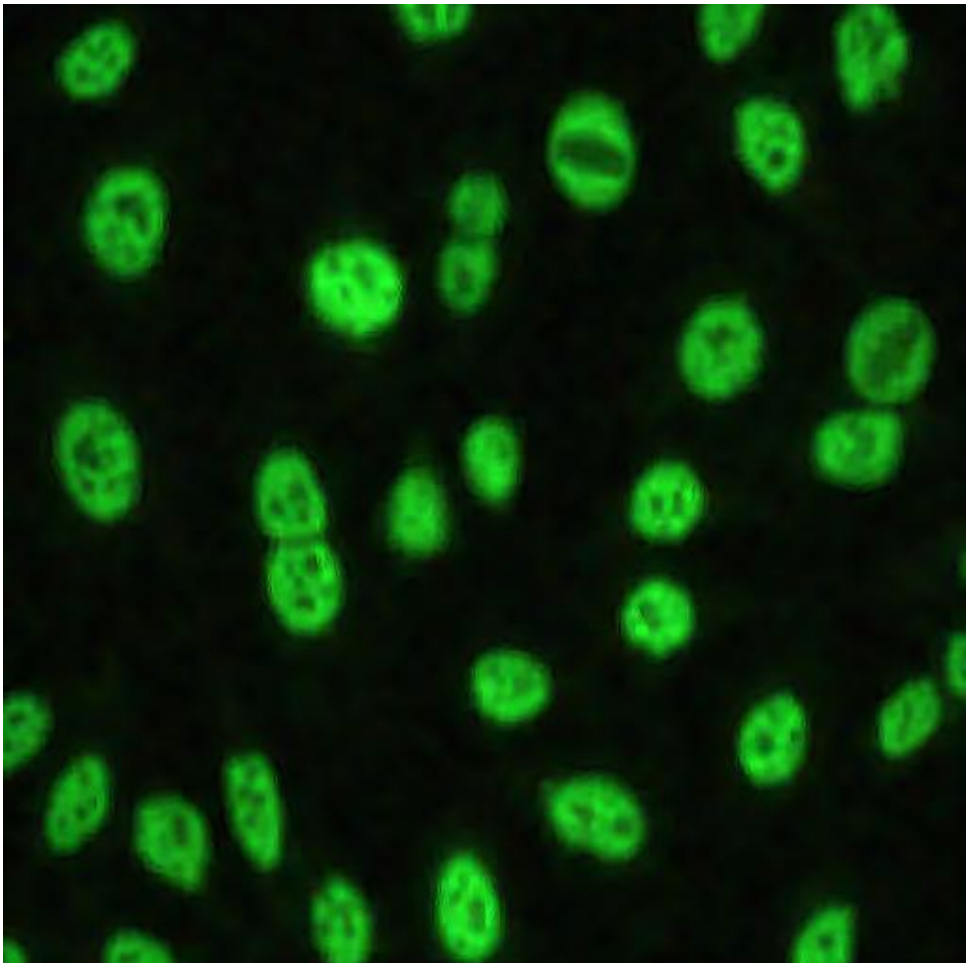

FIGURE 4.4: Output of wavelet transform filter

4.3.2. Wavelet transform filter combined with diffusion filter

Figure 4.5 shows the output of performing diffusion filter after wavelet transform filter has been applied. The output result clearly shows there is more enhancement over the output of performing the wavelet transform only.

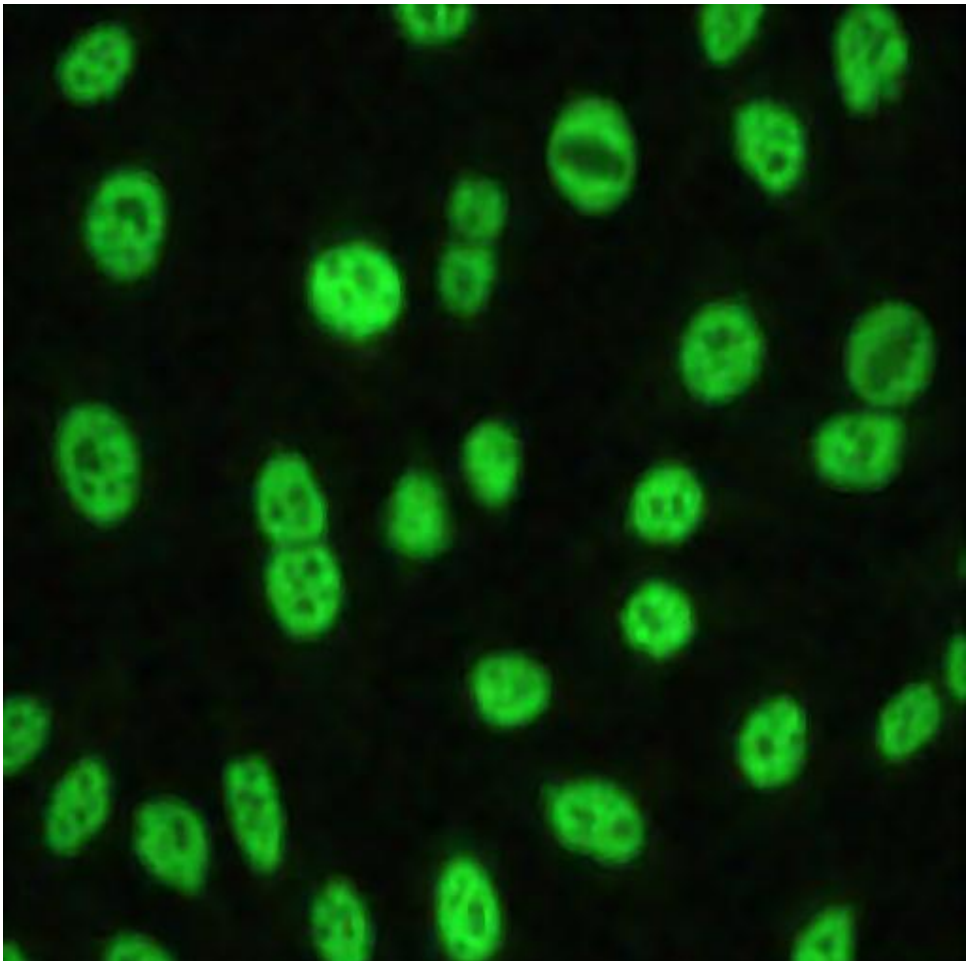

FIGURE 4.5: Output of the combination of wavelet transform filter and diffusion filter

4.3.3. Diffusion filter

Figure 4.6 shows the output result of the applying the diffusion filter to the noisy image. It is obvious that the noise has been removed and the quality of the image has been enhanced and the contrast becomes higher. It is also clear that the edges has been enhanced without much degradation in the image structure.

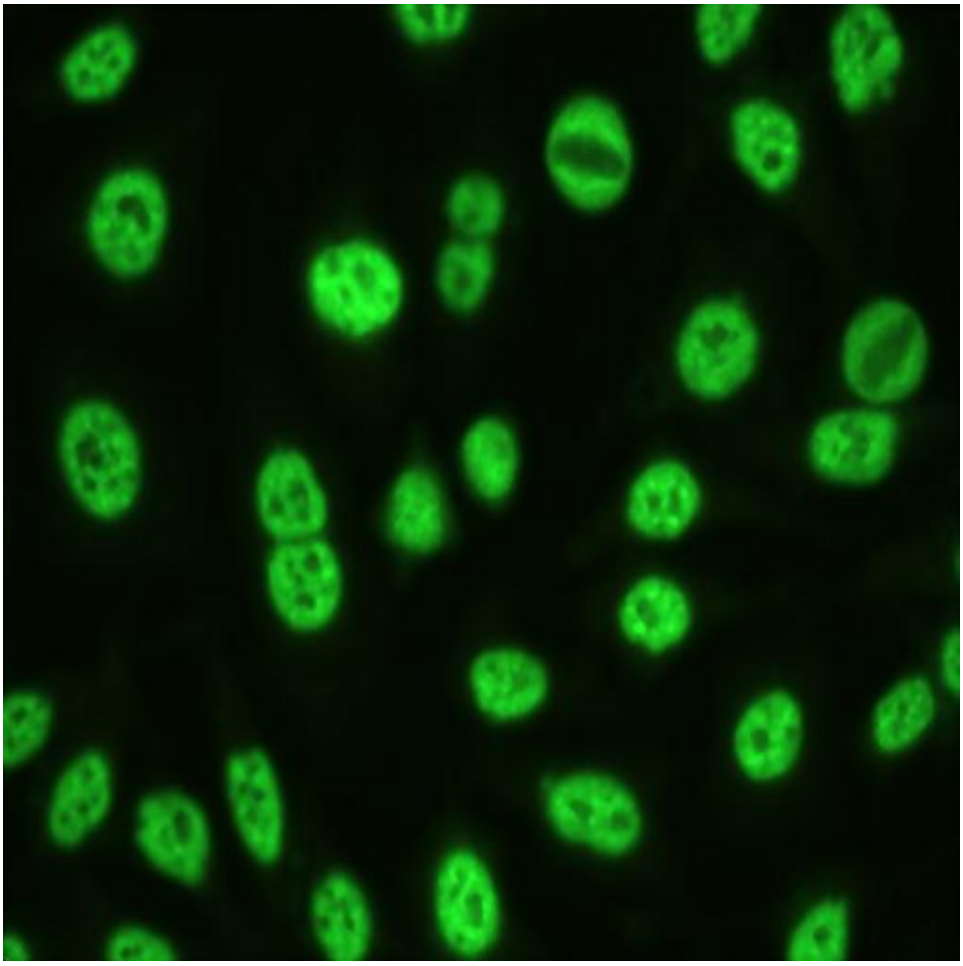

FIGURE 4.6: Output of the diffusion filter

4.4. Performance measurement

Table 4.1 shows the values of the measurement criteria after the original images have been introduced to the noise. It displays the values of SNR, PSNR, RMSE and SSIM.

TABLE 4.1: Performance measurement of noisy image

Image	SNR	RMSE	PSNR	SSIM
Cen1	-1.64	63.48	12.11	0
Cen2	-1.92	66.08	11.76	0
Cen3	-3.16	58.62	12.8	0
Cen4	-2.45	76.07	10.54	0
Cen5	-2.1	70.26	11.23	0
Cen6	-1.97	68.21	11.49	0
Cen7	-2.47	71.27	11.11	0
Cen8	-2.32	57.34	13	0
Nuc1	-3.66	57.58	12.96	0
Nuc2	-4.24	60.03	12.6	0

Table 4.2 displays the values of the assessment criteria after the wavelet transform filter has been applied to the noisy images. The increasing in the SNR, PSNR, and SSIM is very obvious in the output. In addition, to the decreasing in the RMSE it is clearly shown that there is much more enhancement has been done using wavelet transform method.

TABLE 4.2: performance measurement of the wavelet transform filter

Image	SNR	RMSE	PSNR	SSIM
Cen1	20.19	0.02	82.33	0.91
Cen2	20.18	0.02	82.31	0.91
Cen3	14.82	0.03	80	0.83
Cen4	19.56	0.02	81.01	0.89
Cen5	20.36	0.02	82.07	0.90
Cen6	19.68	0.02	81.54	0.90
Cen7	18.64	0.02	80.84	0.89
Cen8	17.06	0.02	81.19	0.88
Nuc1	16.56	0.02	82.5	0.90
Nuc2	16.38	0.02	82.68	0.90

Table 4.3 shows the values of the assessment criteria after the wavelet transform filter combined with diffusion filter have been applied to the noisy images. The values of the SNR, PSNR, and SSIM increased more comparing to result of applying the wavelet transform only. Moreover, there is more decreasing in the RMSE as well. The combination shows better enhancement than the first enhancing approach.

TABLE 4.3: Performance measurement of the combination of the wavelet transform and diffusion filters

Image	SNR	RMSE	PSNR	SSIM
Cen1	20.78	0.02	82.98	0.92
Cen2	20.65	0.02	82.84	0.92
Cen3	14.56	0.03	79.83	0.84
Cen4	19.92	0.02	81.42	0.91
Cen5	21.21	0.02	82.97	0.92
Cen6	20.19	0.02	82.1	0.91
Cen7	19.2	0.02	81.46	0.91
Cen8	17.17	0.02	81.38	0.89
Nuc1	17.47	0.02	83.52	0.92
Nuc2	17.32	0.02	83.74	0.92

Table 4.4 displays the values of the assessment criteria of the output of the diffusion filter. It is shown that there is more increase in the SNR, PSNR, and SSIM comparing to the pervious tow methods. There is also much decreasing in the RMSE. Therefore, it is very clear that diffusion filter produced better enhancement to the noisy images comparing to the using of the wavelet transform approach.

TABLE 4.4: performance measurement of the diffusion filter

Image	SNR	RMSE	PSNR	SSIM
Cen1	28.42	0.01	90.54	0.99
Cen2	28.05	0.01	90.19	0.99
Cen3	19.03	0.02	84.29	0.95
Cen4	27.06	0.01	88.5	0.98
Cen5	29.64	0.01	91.34	0.99
Cen6	27.56	0.01	89.41	0.99
Cen7	25.21	0.01	87.46	0.98
Cen8	22.74	0.01	86.94	0.97
Nuc1	25.53	0.01	91.53	0.98
Nuc2	25.14	0.01	91.52	0.98

4.5. Performance analysis

The obtained results show that combining wavelet transform filter with the diffusion filter produce better result than applying wavelet transform filter exclusively. However, the performance of the diffusion filter is very high comparing to the other two methods. Moreover, diffusion outputs show the speckles of the enhanced Indirect Immune Fluorescence (IIF) images clearly comparing to wavelet transform approaches. Figures 4.7, 4.8, 4.9, 4.10 below show the performance comparison of the three approaches.

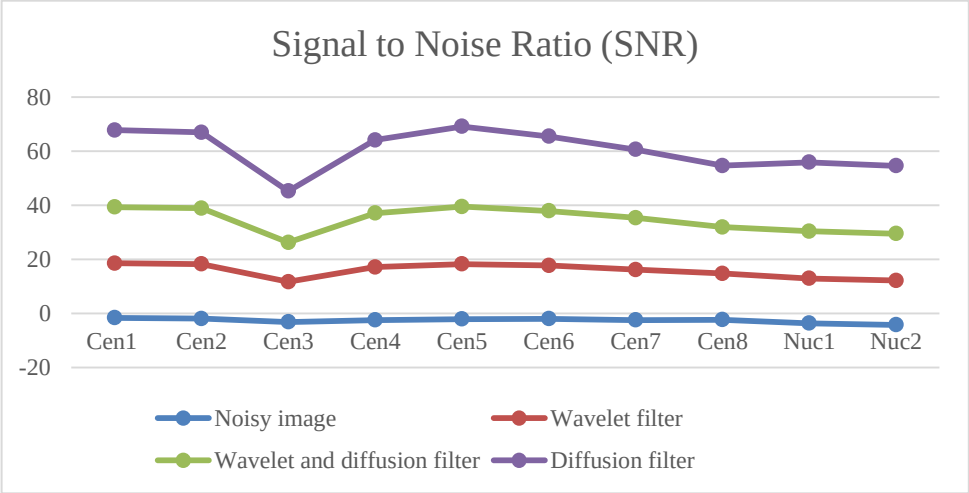

FIGURE 4.7: Signal to Noise Ratio (SNR)

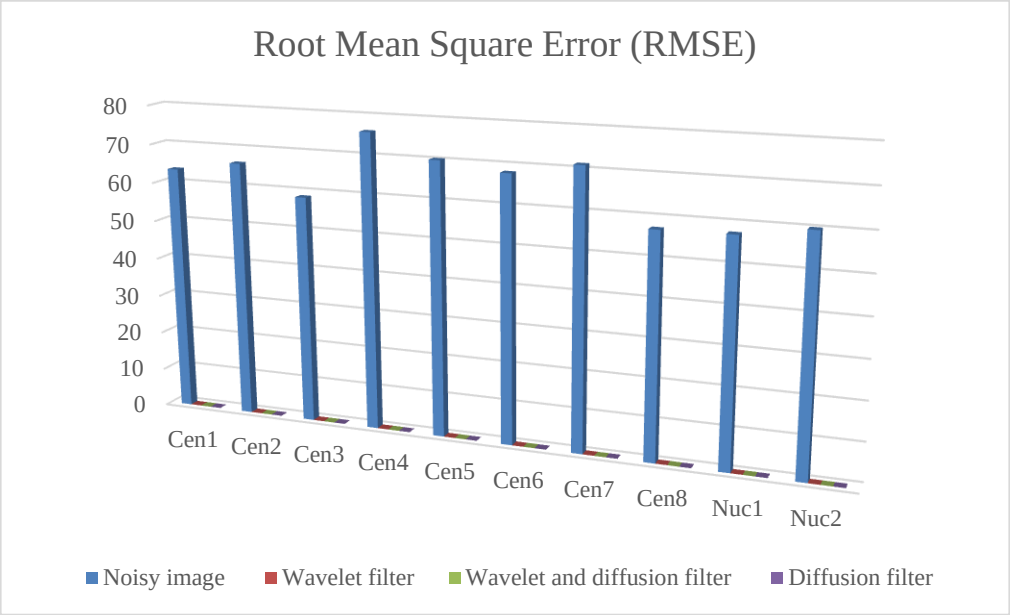

FIGURE 4.8: Root Mean Square Error (RMSE)

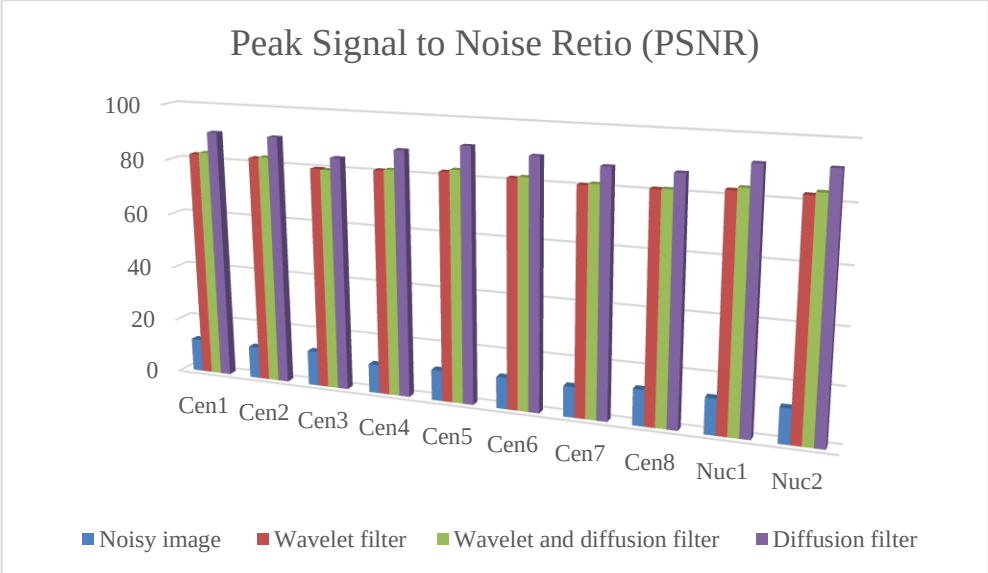

FIGURE 4.9: Peak Signal to Noise Ratio (PSNR)

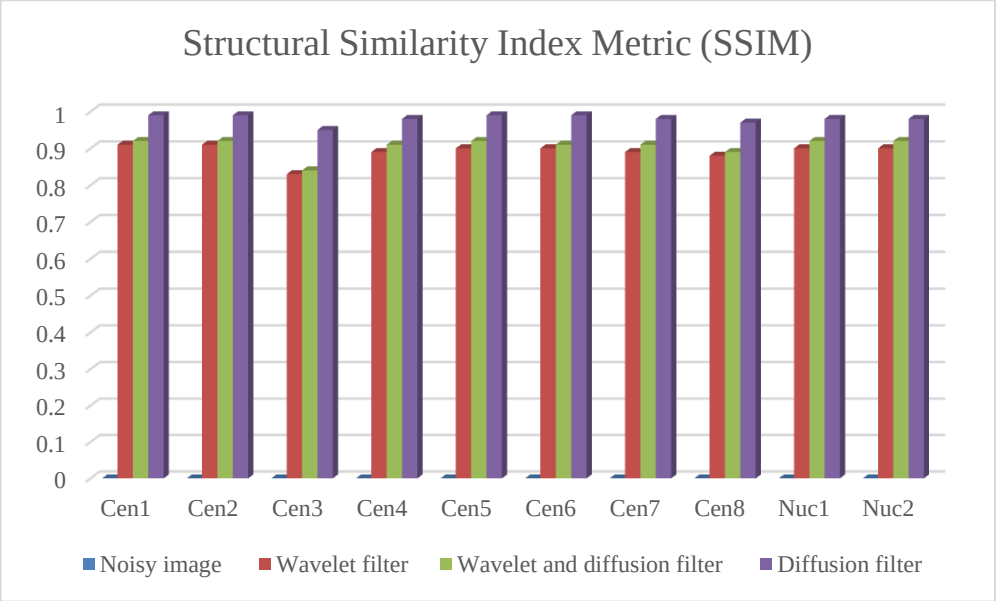

FIGURE 4.10: Structural Similarity Index Metric

CHAPTER 5

CONCLUSION AND RECOMMENDATION

The diagnosis of the auto-immune disease widely depends on the immune fluorescence test. However, the interpretation of obtaining image is still done manually and that has limitation due its dependency on the experience level of the physicians and time consuming. Therefore, there is a strong need for automatic processes for pattern recognition but that need to enhance the image quality to preserve the essential feature of original image to make the pattern recognition and classification more reliable. [22].[19] In this project, we have used wavelet enhancement approaches in order to reduce the noise and enhance the contrast and information details of the Hep2-cell images.

Based on the result and performance analysis, wavelet transform filter has enhanced the images with average SSIM of 89% which indicated that it enhanced the noisy image much more. However, the combination of the wavelet transform with diffusion filter produced better result with average SSIM of 90%. While the diffusion filter is coming first and best enhanced approach among all the three proposed approaches with average SSIM of 98%. Moreover, the speckles of the enhanced Indirect Immune Fluorescence (IIF) images were clearly shown when the diffusion filter is being applied.

The recommendation for the future work, when the project is proceeded towards the auto classification processing it is better to explore an automatic method to explore the noise variance in the image when wavelet transform filter is being applied.

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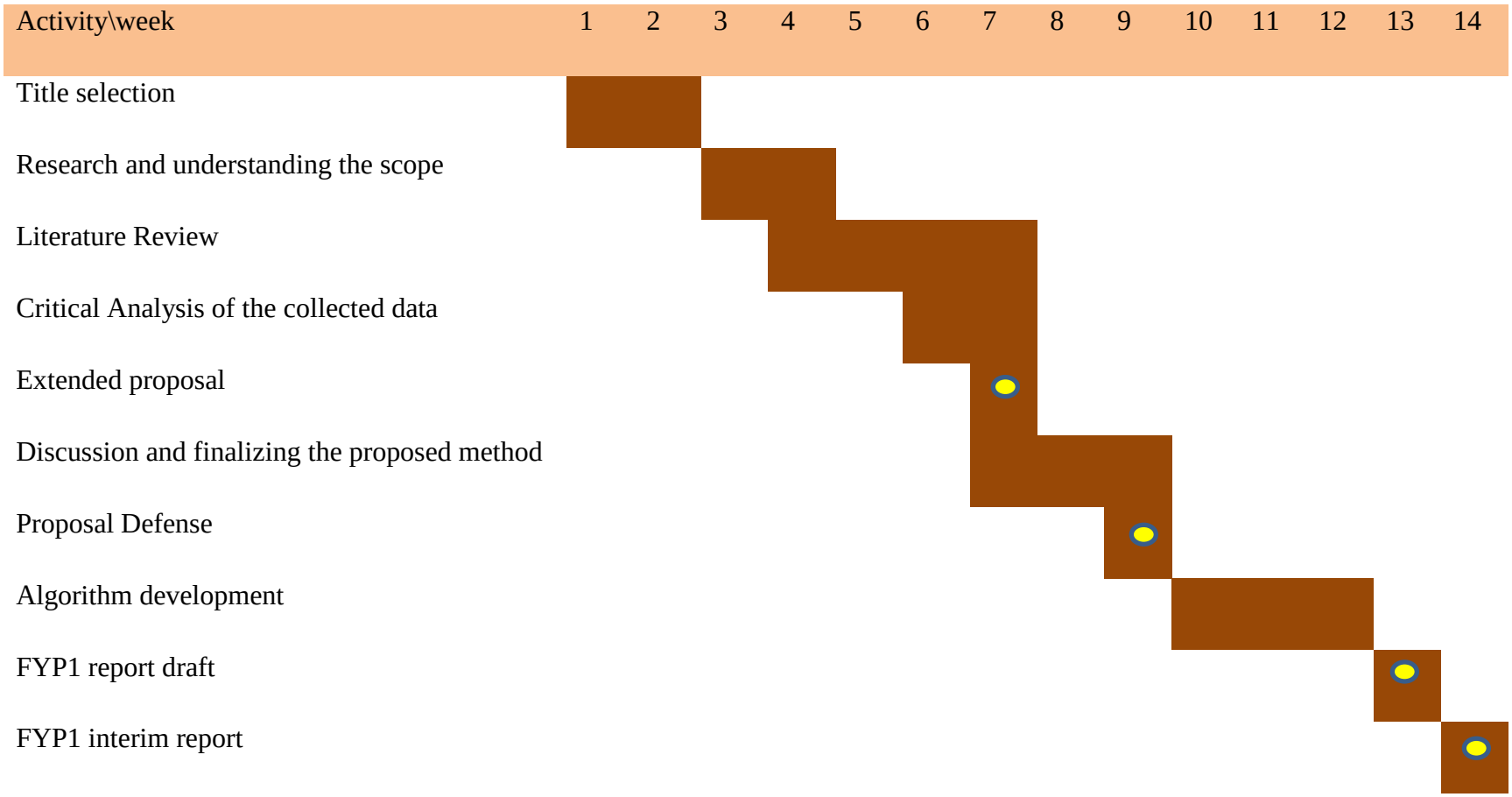
APPENDIX

Final Year Project 1 Gantt Chart



Key milestone

Final Year Project 2 Gantt Chart