الإهداء

إلـــى نـــور القلـــوب وقـــرة العيـــون وشـــفاء الصـــدور... ســـيدنا رســـول الله (صلى الله عليه وسلم)

أيـــامٌ مضـــت مـــن عمـــري بـــدأتها بخطـــوة وهـــا أنـــا اليـــوم أقطـــفُ ثمـــارَ جُهـــدي وســـهري, وأُهـــدي هـــذا الجهـــدَ المتواضـــعَ إلـــى مـــن كنـــتُ لهـــمُ الأمـــلَ الـــذي راودهُـــم فـــي حيـــاتِهم فحلمـــوا أن يرونـــي فـــي مثـــلِ هـــذا اليـــوم إلـــى أمـــي وأبـــي, إلـــى مـــن شـــاركوني حلـــوَ الحيـــاةِ ومُرهـــا إلـــى أخـــواتي وأخـــوتي, إلـــى رفيـــقِ عمـــري, إلـــى أخـــواتي اللـــواتي لـــم تلـــدهنَّ أمـــي إلـــى صـــديقاتي الغاليـــات, مبـــاركٌ لنـــا ولأهلنـــا والحمـــد لله الـــذي حقـــق الحُلُـــمَ الجميـــلَ...(عبير محتسب).

إلـــى مـــن جـــرع الكـــأس فارغـــا ليســـقيني قطـــرة حـــب..إلى مـــن كلـــت أناملـــه ليقـــدم لـــي لحظـــة ســـعادة ...إلـــى مـــن حصـــد الأشـــواك عـــن دربـــي ليمهـــد لـــــي طريـــــق العلـــــم.. والـــــدي العزيـــــز ...إلـــــى مـــــن أرضـــــعتني الحـــــب والحنـــــان...إلى رمـــــز الحـــــب وبلســـــم الشـــــفاء..والدتي الحبيبـــــة...إلى القلـــــوب الطـــاهرة الرقيقـــة والنفـــوس البريئـــة إلـــى ريـــاحين حيـــاتي إخـــوتي... إلـــى روح جـــدي شـــهيد معركـــة الكرامـــة .....محمـــد خليـــل هرينـــي (عريـــب هريني).

إلى من أتنفس الصعداء بوجودهم ..إلى من تعبوا لسعادتي ..من لا تكفيني حروفي لشكرهم ..والديّ العزيزين ..إلى ساكن القلب .. إلى الروح التي رافقتني في رحلتي فكانت سنداً وعوناً .. زوجي الغالي ..إلى من يحملون في صدورهم ذكريات طفولتي وشبابي .. إلى من فرحهم فرحي ..أخي وأخواتي ..إلى الذين ضاقت السطور لذكرهم ..وسعد القلب لمعرفتهم ..صديقاتي .. إلى أرضنا الطاهرة التي احتضنتنا بين ربوعها.. فلسطين..إلى من أهم أكرم منا جميعا ..شهداء فلسطين ..إلى الأسود خلف الزنازين ..الأسرى الأبطال .. إلى كل من ساعدنا ولو بدعوة في ظهر الغيب (نجلاء بزايعة)

إلى الذين بذلوا كل جهدٍ وعطاء لكي نصل إلى هذه اللحظة ونخص بالذكر الدكتور الفاضل موسى ارفاعية ..إليكم جميعاً نهدي هذا النجاح .

الشكر والتقدير

لا يسعنا بعد إتمام هذه الدراسة إلا شكر الله تعالى الذي أعاننا على إتمام هذا العمل .
وانه لمن دواعي السرور و عظيم الامتنان أن نتقدم بجزيل الشكر و التقدير وفائق الاحترام لكل من ساهم و ساعدنا في إتمام هذا العمل و نخص بالذكر الدكتور الفاضل موسى ارفاعية مشرف المشروع .

فريق البحث

Abstract:

The ability to diagnose many of the severe diseases, such as cancer and heart problems, is a challenge for physicians and radiologists. Recently, a wide range of technologies are being used to increase the accuracy of physicians' diagnoses. Positron Emission Tomography (PET) is an important nuclear medicine imaging technique which enhances the effectiveness of diagnosing many diseases. The raw-projection data, i.e. the sinogram, from which the PET is reconstructed, contains a very high level of Poisson noise. Radiologists face difficulties when reading and interpreting PET images because of the high noise level. The later may lead to erroneous diagnoses. Finding a suitable de-noising technique for PET images has attracted many researchers in the last two decades as this can significantly alleviate the problem. In this work, we compare and investigate four type of filters for enhancing PET image: The Perona and Malik, construction curvature motion, Gaussian, and wavelet fillers, The group of our research used matlab

for implementing and running the filters then we will make a quantitative comparison using three measuring approach PSNR, NR, and correlation.

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List of abbreviations

PET	Positron Emission Tomography
PSNR	Peak Signal-to-Noise Ratio
NV	Noise Variance
AF	Anisotropic Diffusion

Chapter One

Introduction

Contents:

1.1 Introduction

1.2 Study Objectives

1.3 Study Importance

1.4 Methodology

1.5 Study Schedule

1.1 Introduction:

PET image is a type of nuclear medicine scan, that need very sensitive instrument called a PET camera, which shows internal body organ function [13].

A PET scan is a test to show the flow of blood to a part body, how the tissues are using nutrients such as oxygen, and If the cells are normal or not. It is commonly used to diagnosis number of diseases such as cancer, hard disease, Alzheimer disease, epilepsy, heart disease, brain disease. The PET is a functional imaging approach used to study the metabolism and physiology of the brain, furthermore.

Enhancement algorithms are used to reduce image noise and to increase the contrast of the regions of interests, in this study we will explain several types of filters which can used to enhancement the PET image, and make a comparison to decide and investigate which is the best overall

The group of our research used matlab for implementing and running the filters then we will make a quantitative comparison using three measuring approach PSNR, NR, and correlation.

1.2 Study aims and objectives:

This research aims to introduce the best PET image de-noising ,by make a comparison between filters which may use in de-noising for PET image to study the effects of the filters to enhance the PET medical image in order to achieve ideal image to detect diseases. To achieve this objective, this requires achieving the following sub objectives:

- Using matlab environment to apply the filters on the PET image
- Using the results to make a comparison between filters.

1.3 Study Importance:

This project aims to help physicians for better diagnosing patients using PET image and decrease the false positive and false negative results, which are mainly caused from the high-level of the Poisson noise. The result of the research will help to make the right decision by finding the best enhanced.

1.4 Research Methodology:

In this work we demonstrate qualitative and through simulations that the performance of the proposed method substantially surpasses that of well-known methods, both visually and in terms of statistical measures. The validation of the proposed filter employs simulated PET data of a slice of the thorax, which allows generating multiple realizations of the noisy data. The used methods for comparing the filters results are: Peak Signal to Noise Ratio (PSNR), Noise Variance (NV), and Correlation ,this section mentioned in more details in chapter three .

1.5 Research Schedule:

This section shows the time needed by every task in the Research. The Table (1.1) represents the work schedule:

Table (1.1): study schedule.

Task Number	Task Name	Expected Time Needed in week
1	Planning	7
2	Literature Review	4
3	Methodology & Programming	7
4	Testing	18
5	Finding Results	4
6	Report Study	28

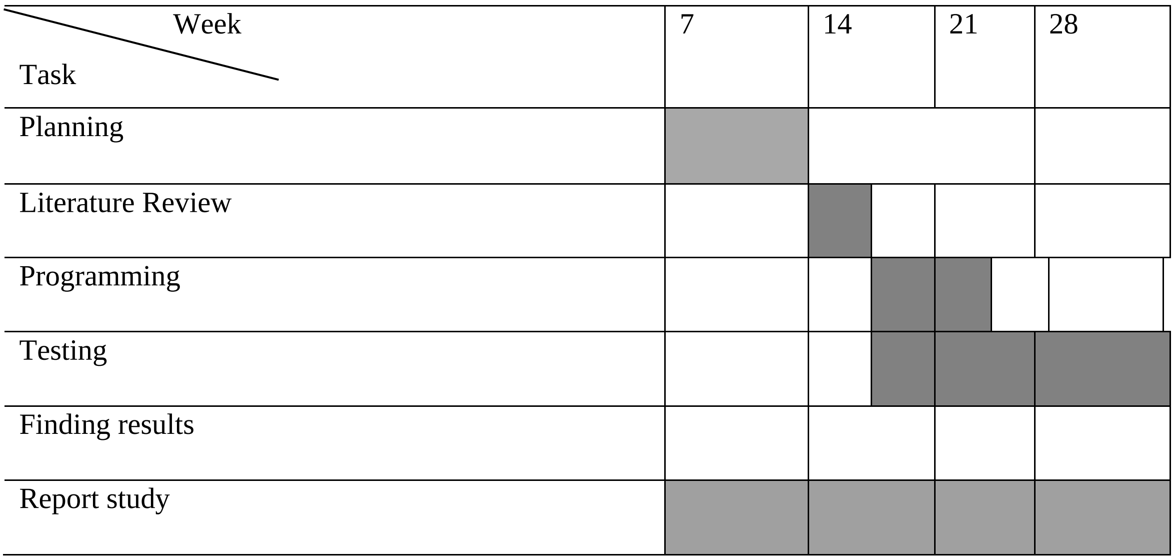


Figure (1.1): Grant chart for study schedule.

Chapter two

Theoretical background

Contents

2.1 PET image:

PET image is a type of nuclear medicine scan, that need very sensitive instrument called a PET camera, that's shows internal body organ function [13], a- PET scan is a test to show the flow of blood to a part body, how the tissues are using nutrients such as oxygen, and if the cells are normal or not. And it is commonly used to diagnosis number of condition such as cancer, hard disease, Alzheimer disease, epilepsy, heart disease, brain disease. The PET is a functional imaging approach used to study the metabolism and physiology of the brain, also this technology used to analyze alcohol's effects on various neurotransmitter systems.

How is a PET scan performed in order to detect the area of cancer in the body?

The patient will be injected with small amount of a radioactive drug called a tracer; the tracer is injected into the blood through a vein. Then patient need a rest and relaxation up to 1 hour while the radioactive drug moves in the blood, because the cancer cells need a lot of energy compare with other cells, its take all most of the tracer . So the tracer accumulates in areas of diseased tissue in the body. The patient still on his/her back, and the table move the patient to the center of PET scanner as the following picture shows, then the PET camera take pictures of body. As shown in figure (2.1) The PET scanner consists of an array of detectors that emit signals, by these signals PET scanner detect area of disease. After that the computer attached to the camera creates two and three dimensional images of the area being examined. After produce the image the interest area will be clear (which contains high level of radioactive. This process takes 45 to 90 minutes. After the test the patient drink 8 to 10 glasses of liquids to remove the radioactive drug from the body.

Figure 2.1: PET image scanner [14].

The PET scan answers number of important questions:

1. Is it really cancer?
2. Has the cancer spread?
3. What treatment is likely to be most effective?
4. Is the treatment working?
5. Has the cancer returned?

Drawback of PET:

1. Low spatial resolution.
2. The blurring nature of PET images.
3. High noise-to-signal ratio.

In other hand, the woman who are pregnant or breastfeeding should not have a PET scan because it causes a risk for their babies, and should be consider that no pregnant, breastfeeding women, babies and young children should stay away in the location where PET image scan and from the person who had a PET scan for few hours after the scan.

2.2 Image De-noising:

Noise is undesired information that contaminates the image, de-noising“ is the first step to be taken before the images data is analyzed. It is necessary to apply an efficient de-noising technique to compensate for such data corruption”. Image de-noising still remains a challenge for researchers because noise removal introduces artifacts and causes blurring of the images.

Removing noise from the original signal is still have a problem for researchers, There have been several published algorithms and each approach has its assumptions, advantages, and limitations.

2.3 Background:

2.3.1 Anisotropic Diffusion Filter

Removing noise from data is the first step in data analysis. De-noising methods should not only reduce the noise, but do so without blurring or changing the location of edges. We have several filters aim to get this goal like Perona and Malik.[1]

Anisotropic Diffusion Filter which introduced by Perona and Malik in 1987 is a numerical technique for de-noising digital image noise without removing significant of the image content, like edges, line, or any important information of the image.

The idea behind the use of the diffusion equation in image processing the use of Gaussian filters in multi-scale image analysis.

Perona and Malik propose nonlinear Anisotropic Diffusion Filtering equation:

$$I\ (t) = \mathrm{div}(c\ (t, x, y)\ delta\ I) \qquad (2.1)$$

When c (t, x, y) is the edge stopping, x is the gradient magnitude .In the case of c(t, x, y) = 1, the filter of the image unable to distinguish the boundary region, so at the result the image will be loss of image detail. Perona has improved it and give an image function g(x):

$$g(x) = 1/1+(x/k)(x/k) \qquad (2.2)$$

Or

$$g(x) = \exp((x/k)(x/k)) \qquad (2.3)$$

Anisotropic Diffusion Filter used in 3D computer graphic in which the number of texture samples generated changes depending on the angel that surface relative to the camera.

2.3.2 Gaussian Filter:

Gaussian Filter is used for smoothing the images and de-nosing it. Gaussian provides gentler smoothing and preserves edges better than other filters like mean filter.

Gaussian function for 1D:

$$G(x) = \frac{1}{\sigma\sqrt{2\pi}} e^{\frac{(x-\mu)^2}{2\sigma^2}} \tag{2.4}$$

, μ: mean and σ : standard deviation.

$$G(x) = \frac{1}{\sigma\sqrt{2\pi}} e^{-\frac{x^2}{2\sigma^2}} \tag{2.5}$$

The mean $\mu = 0$.

2.3.3 Wavelet transform

Wavelet transform was developed from Fourier transform. Fourier transform represents a signal as a sum of cosine and sine functions, whereas wavelet transform represents a signal as a sum of translations and dilations of a band-pass function, $\boxtimes_{j,k}$, called a wavelet. In other words, although the Fourier transform represents a signal in the frequency domain alone, the wavelet transform provides a spatial-frequency representation of a signal. A simple decomposition of an original discrete signal *f*(*x*) with a given wavelet, $\boxtimes_{j,k}$, can be written as the expansion:

$$f(x) = \sum_k \sum_j d_j(k) . \boxtimes_{j,k}(x) \tag{2.7}$$

In Eq. 1, the functions $\boxtimes_{j,k}$are orthonormal basis elements generated by dilated (*j*) and translated (*k*) versions of the band-pass functions $\boxtimes_{j,k}$ in the following way:

$$\boxtimes_{j,k}(x) = 2^{\frac{j}{2}} \boxtimes(2^j x - k) \tag{2.8}$$

$d_j(k)$ In Eq. 1 are called the wavelet coefficients and are simply given by the scalar products of the original signal with the $\boxtimes_{j,k}$basis elements:

$$d_j(x) = (f, \boxtimes_{j,k}) = \sum_x f(x) . \boxtimes_{j,k}(x) \tag{2.9}$$

The wavelet coefficients $d_j(x)$ indicate elements of the decomposed signal at position k and within frequency band j, where j is usually referred to as the decomposition/resolution level, or simply the level. As the level *j* increases, the range of frequencies covered by $\boxtimes_{\mathrm{j,k}}$shifts from higher to lower frequency.

Theoretically, Equations (1–3) give an explicit formula to compute $d_j(f)$ given the signal $f(x)$ to be operated on. However, if there are a large number of levels (covering all frequency bands), there will correspondingly be the same number of wavelet coefficients, and the transform would not be practical. A signal $f(x)$ can be decomposed using multi resolution analysis (MRA) by introducing a low-pass scaling function $\boxtimes_{\mathrm{j,k}}$ to Eq. 1 as follows:

$$f(x) = \sum_k \sum_{j=1}^{J} d_j(x).\psi_{\mathrm{j,k}}(x) + \sum_k C_J(k).\phi_{J,k}(x) \qquad (2.10)$$

Where the second term on the right side of Eq. 4 represents low-frequency components of the signal. The scaling function $\boxtimes_{\mathrm{j,k}}$ is defined by satisfying the following relationship with the wavelet $\boxtimes_{\mathrm{j,k}}$,

$$\boxtimes(x) = \sum_n q_n \phi(2x - n).$$

$$\boxtimes(x) = \sum_n q_n \phi(2x - n). \qquad (2.11)$$

Where q_n, p_n are called two-scale sequences and peculiar sequences of the given wavelet $\boxtimes_{\mathrm{j,k}}$. Thereafter, $\phi_{J,k}$ are generated in the same way as the $\psi_{\mathrm{j,k}}$ in Eq. 2 with ψ replaced by $\boxtimes_{\mathrm{j,k}}$. The scaling coefficients $C_J(k)$ in Eq. 4 indicate elements of the decomposed signal at position *k* and within the lowest frequency band *J*, and are defined as follows:

$$C_J(k) = \left(f, \phi_{J,k}\right) \qquad (2.12)$$

Equations (1–6) describe MRA for the one-dimensional (1D) situation. To apply MRA to biomedical imaging, the approach must be generalized to 2D.

2.3.4 Curvature motion:

By curve (u)(x), we denote the curvature, i.e. the signed inverse of the radius of curvature of the level line passing by x. When Du(x) 6= 0, this means

$$\text{curve }(u)=\frac{\text{uxxu2 y} - \text{2uxyuxuy} + \text{uyyu2}}{(u_x^2+u_y^2)^{\frac{3}{2}}} \qquad (2.13)$$

This method noise is zero wherever u behaves locally like a one variable function, u(x; y) = f(ax +by +c). In such a case, the level line of u is locally the straight line with equation ax +by +c = 0 and the gradient off may instead be very large. In other terms, with anisotropic filtering, an edge can be maintained.

2.4 Literature review:

In much medical imaging application, noise is often smooth away but also blurs edges in signals and images. Recently, image processing techniques have shown certain strength at reducing noise, enhancing edges, and removing ringing artifacts in clinical images. So, noise must be reduced very effectively with very little resolution loss, most sharp edges are preserved, and some of them are being enhanced.

2.4.1 Anisotropic Diffusion Filter:

An anisotropic diffusion algorithm was developed by Perona & Malik (1987), they suggested employing the equation of anisotropic filter for edge enhancement. That's done by selectively smoothing regions with low gradient.

(Shlomo Greenberg and Daniel Kogan)[3] show that the structure-adaptive anisotropic filter can be effectively applied to applications, such as fingerprint image enhancement.

(Guido G, et al.)[4] propose a process based on anisotropic diffusion in order to improve the magnetic resonance image (MRI) quality.

(Olano,et al.)[5] present algorithm based on Anisotropic filter to enables anisotropic texturing on any current MIP map graphics hardware supporting MIP level and to reduces blurring by allowing differing degrees of filtering in different directions. The algorithm computes anisotropic filter footprint parameters per vertex.

2.4.2 Gaussian Filter:

(Jayaraman, S, et al. ,2009)[6] describe Gaussian filter in their study with Gaussian filters are a class of linear smoothing with weights that are chosen according to the shape of Gaussian function, the Gaussian kernel is used for smoothing purposes.

The Gaussian filter is a very good filter to removing noise drawn from a normal distribution; Gaussian smoothing is a special class of averaging.

The researchers listed the following characteristics in their book that make the Gaussian function good and useful in image processing:

i. Gaussian functions are rotationally symmetric in two dimensions. The term " rotationally symmetric " means that the Gaussian smoothing filter affects the image with the same smoothing amount in all directions.

ii. The Fourier transform of a Gaussian function is itself a Gaussian function. It has a single lobe in the frequency spectrum. High frequency noise is often corrupted images, and the desirable features of the images will be distributed in the low and high frequency spectrum. The single lobe in the Fourier transform of a Gaussian means that the smoothened image will not be corrupted by contributions from unwanted high frequency signals, while most of the desirable signal properties will be retained.

iii. The degree of the smoothening is governed by variance . A larger implies a wider Gaussian filter and greater smoothening.

iv. Two dimensional Gaussian functions are separable. This property implies that large Gaussian filters can be implemented very efficiently. Two dimensional Gaussian convolution can be performed by convolving the image with a one dimensional Gaussian and then convolving the result with the same one dimensional filter oriented orthogonal to the Gaussian used in the first stage.

2.3.4 Wavelet transforms:

Wavelet transform: "Mathematicians theorized its use in the early 1900's.the wavelet transform deals with scale analysis, that is, by creating mathematical structures that provide varying time/frequency/amplitude slices for analysis. This transform is a portion (one or a few cycles) of a complete waveform". Wavelet used in image processing for example it used in de-noising and feature extraction.

The first reference to the wavelet returns when Alfred Haar wrote his dissertation titled "On the theory of the orthogonal function systems" in 1909 [12].His research on orthogonal systems of functions led to the development of a set of rectangular basis functions. The Haar wavelet was named on the basis of this set of functions, and it is also the simplest wavelet family developed still this date. After that, in order to compress images, the Haar basis function was applied.

The era of the wavelet research began when Jean Morlet accessed to the resulting waveforms of varying widths were called by Morlet the "Wavelet".

Since then, show the increasing number of activities on wavelet transform and its applications in many fields, these include image processing, speech processing, as well as signal analysis in manufacturing.

2.3.5 Mean Curvature Motion:

Here have been a number of researchers who have considered the use of nonlinear curvature based equations for various problems in computer vision and image processing.

(A.Yezzi, 1998)[7] in his paper Modified Curvature Motion for Image Smoothing and Enhancement, he explained the curvature motion, mean curvature of surface (*x; y; u*(*x; y*)). To simplify the formulation of mean curvature, we consider a level set function *Á*(*x; y; z*) = *u*(*x; y*) ¡ *z*. Then its zero level set *f*(*x; y; z*) : *Á*(*x; y; z*) = 0*g* corresponds to the surface *z* = (*x; y*).Therefore, the mean curvature of the surface *z* = *u*(*x; y*) can propose the related variation model for one dimension signal de-noising, or curve de-noising. For convenience, still denote the noisy signal and clean signal function by *f* and *u* respectively. They are defined on an interval *I* = [*a; b*]. As in this case, the mean curvature becomes:

(T. Chan,etl,2005)[8] in their study Image mentioned that besides removing noise efficiently, they offer a model that is capable of keeping corners, edges as well as image grey-scale intensity contrasts.

Chapter Three

Methodology

Contents:

3.1 Introduction

Measuring the quality of the image is a complex process because the human's opinion is affected by physical and psychological parameters. Image quality evaluation plays an important role in the field of image processing. Many techniques are proposed for measuring the quality of the image but none of it is considered to be perfect for measuring the quality. Many studies have been done on image quality measurements based on different techniques such as pixel-difference, correlation, edge detection.

In the evaluation of the image quality there are two methods the subjective and the objective method. Subjective methods are based on

human opinion and operate without reference to explicit standard. But the objective evaluation uses automatic algorithms to assess the quality of the image without human interfere.

This chapter deals with the comparison of the de-noising techniques, namely, Peak Signal-to-Noise Ratio, Noise variance, and correlation.

3.1.1 Peak Signal-to-Noise Ratio (PSNR)

PSNR is a statistical measure of error, used to determine the quality of the filtered image. Its represent the ratio of a signal power to the noise power corrupting [9]. See the following equastion:

$$PSNR(t) ==\log_{10} \frac{card(\Omega)}{\sum_{p\in\Omega} |I(p)-u(p)|} \qquad (3.1)$$

Obviously, one sees that the higher the PSNR, the better the quality. In the other word a small value of the PSNR implies high numerical differences between images.

3.1.2 Noise Variance (NV)

The noise is characterized by its variance, which is an important parameter for the majority of image de-noising algorithms- how noisy a given image is [4]- because it controls the strength of the altering, it enables propagation channel estimation improvement, it can be needed for signal detection and it is a key decision parameter in adaptive processes, the noise variance is often unknown and should be estimated.

Noise variance estimation is required in many image de-noising, compression, and segmentation applications.

How will we estimate the noise variance?

Note that Noise variance = Variance of the image

This simple example of a simple steps how to estimate noise variance:

1. Constant intensity regions separated by edges.
2. Compute variance of patches in the image.
3. Patches that contain edges will have higher variance than patches without edges.
4. Variance of patches without edges = noise variance.
5. Discard top K patches with highest variance – use the rest for estimating noise variance.

3.1.3 Correlation:

Correlation is one of the standard methods to extract information and features from image. The analyze and understand the correlation can be very well because this operation is one of the simple operations can be applied on images [11].

Correlation can be computed by putting the correlation filter on the image, then multiply overlapping values, after that add all the result values of multiplying. The final result is one value and this is a result of correlation at the center value of given pixel of image.

This approach is for pixels that have neighbors, but what about boundaries? What about pixels that not have neighbors?

There are four common approaches to deal with this issue:

1. The original image is padded with zeros. In this case, each boundary pixel has a neighbor equals zero.
2. The original image is padded with the last or first values. In this case, each pixel boundary has a neighbor equals to the value of itself.
3. The original image is repeated cyclically. In this case, the boundary pixel in the left side of the image has a neighbor equals to the value of boundary pixel in the right side of image, and the boundary pixel in the right side of the image has a neighbor equals to the value of boundary pixel in the left side of image.
4. Consider the image is undefined when the given values are one of the boundaries. In this case, we can't compute the correlation that uses undefined values.

The Correlation was defined as the following equation:

$$F \circ I(x,y) = \sum_{j=-N}^{N} \sum_{i=-N}^{N} F(i,j)\, I(x+i, y+j) \qquad (3.2)$$

Where F: is a Correlation Filter. I: image.

And i, j are denote to the position in image and in correlation filter.

3.3 :Methodology and samples :

In this work we demonstrate qualitative and through simulations that the performance of the proposed method substantially surpasses that of well-known methods, both visually and in terms of statistical measures. The validation of the proposed filter employs simulated PET data of a slice of the thorax, which allows generating multiple realizations of the noisy data. The used methods for comparing the filters results are: Peak Signal to Noise Ratio (PSNR), Noise Variance (NV), and Correlation**.**

We have a sample of 50 simulated PET data that represents the parameters for each filter function , after applied each filter we take the average of the all 50 image to compute the value of PSNR , NV,and Correlation then compare the results with the the value of PSNR , NV,and Correlation for the noisy image.

In both of Perona and Malik and curvature filters , the de-noising process applied 30 iteration , to obtain the best de-noising image, we choose the number of iteration according to the best scale that make the best filtered image.

Chapter Four

Results and Conclusion

Contents:

4.1 Experiments and results

The goal of this search is to measure the performance of the filters on PET image. Anisotropic, Curvature, Gaussian and Wavelet Transform are the proposed filters that apply on PET images with size 256 × 256 pixels.

De-noising Quality: we follow the following measures to verify the quality of de-noised PET image:

In this work, we are interested in comparing the proposed filters: Perona and Malik, Gaussian, Wavelet, Curvature, so we calculated the de-noising quality measure defined in chapter (3) for each filtering schemes.

Figure (3.1) illustrates the optimal enhancement scale of the PET image for all considered filtering methods. As shown in (e)The filter PET by curvature show better enhancement results, and this mention in the result table()which show that curvature motion filter has the best de-noising measures ,for example it has the largest PSNR value ,and the lowest NV value .

Table 3.1: De-noising quality measure.

	Noise fbp	Perona & Malik	Gussian	Wavelet	Curvature
PSNR	12.1155	21.9530	16.9102	18.6044	**22.9178**
Correleion	0.6922	**0.9681**	0.9323	0.9591	0.9673
NV	0.0696	**0.0236**	0.0971	0.0850	0.0238

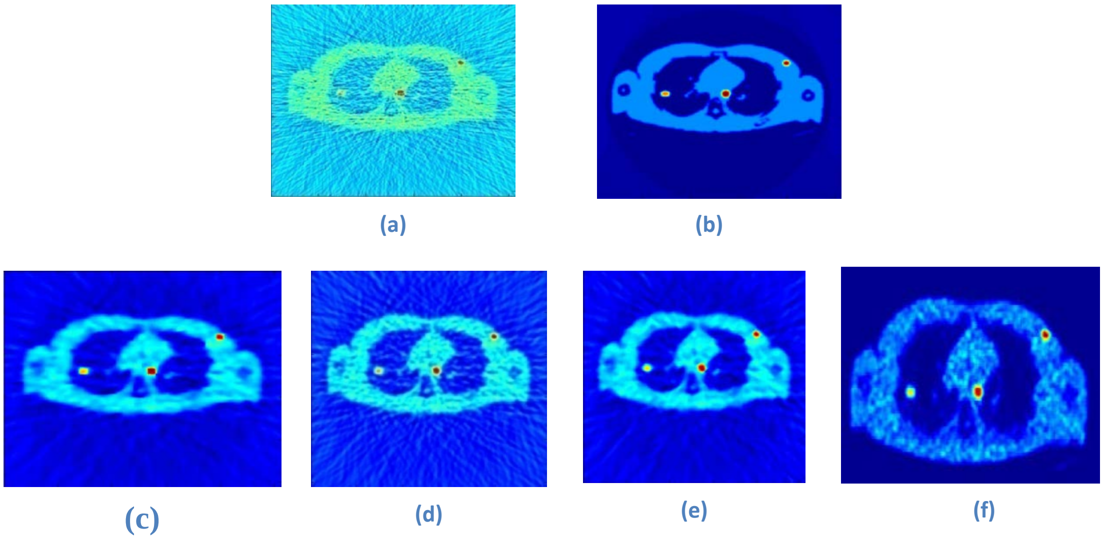


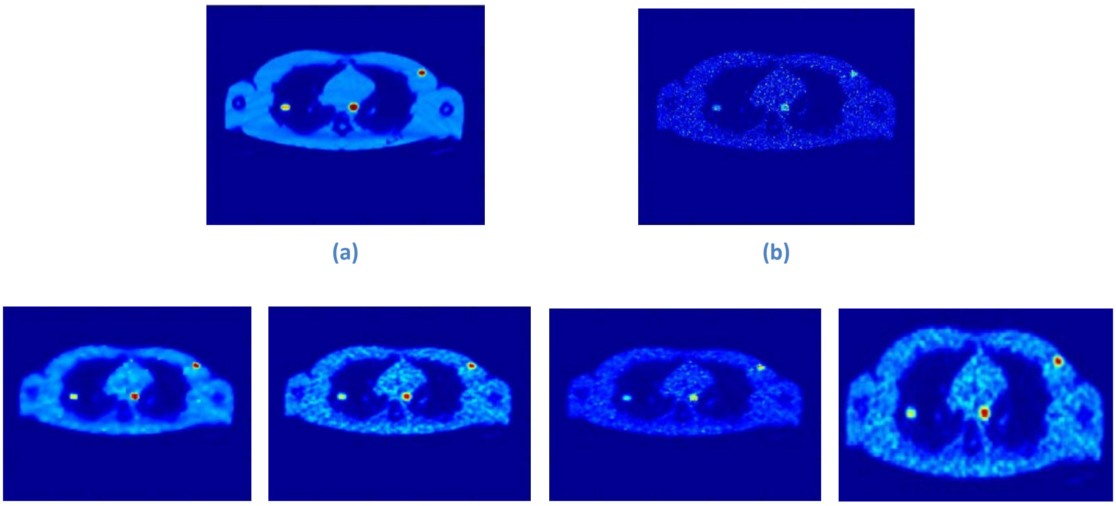
Figure (3.1): (a) Noise image, (b) Original image, (c) after applied Perona filter, (d) after applied Gaussian, (e) after applied curvature ,(f) after wavlet

Figure (3.2) illustrates the reconstruction PET image OSEM and the images after applying each filter to the noisy OSEM image. We notice that the optimal enhancement scale of the PET image for all considered filtering methods is the filtering PET by Perona and Malik which shown in (c).

The figure (e) shows better enhancement results, and this mention in the result table (3.2) which shows that Perona and Malik filter has the best de-noising measures, it has the largest PSNR, correlation values, and smallest NV value. Also in this case Perona and Malik filter is the best de-noising filter, The best performing filtering method per measure is displayed in bold .

Table 3.2: De-noising quality measure.

	Noise osem	Perona& Malik	Gussian	Wavelet	Curvature
PSNR	22.9196	**32.5611**	21.5641	21.7255	27.4822
Correlation	0.7948	**0.9805**	0.9777	0.9786	0.9701
NV	0.0652	**0.0216**	0.0758	0.0743	0.0367



(a) (b)

(c) (d) (e) (f)

Figure 3.2: (a) Noise image, (b) Original image, (c) After applied Perona, (d) After applied Gaussian, (e) After applied curvature, (f) After applied Wavelet.

The PDEs methods (Perona and Malik ,curvature motion) smooth data in the image in a nonlinear way ,so preserving the important features of the image, the capability of the PDE-based approaches depends highly on the neighboring structure this technique depends on edges, PDEs filtering techniques improve both accuracy and stability ,because of this properties the PDEs filters show in our project result best than other filtering.

PDEs filters remove noise from digital images without blurring edges. With a constant diffusion coefficient, and reduce to the heat equation which is equivalent to Gaussian blurring [7] .

4.2 Conclusion

In this work, we compared four filtering approaches for enhancing PET image that reconstructed by FBP and OSEM. The comparison is achieved by measuring the quality of the filtered PET images and visually. The experiment results showed that the PDE-based filters (Perona & Malik and CCM) are better enhancing PET images and keep the important features.

4.3 Recommendations

The research team recommend the people who interested in this filed, expand the scope of comparison, in another words increase the number of filters in the comparison process to get the better de-noising of the PET as possible.

Appendix: Filters matlab run code

Introduction

This code implemented to compute the value of PSNR, correlation , and NV using each of the interested filters:

1) Perona & malik run code.

2) Gaussian filter run code.

3) Wavelet filter run code.

4) Curvature motion run code.

1) Perona & malik run code :

```
temp = zeros(2,3);
%oris =rec2(orifbp);
for i=1:50
A =rec1(:,:,i);
%out2 = A;
out2 = myperonaandmalik(A,30,0.15);
[ss,mes] = scaleselction(out2,A,orifbp);
temp(i,:)= mes([1 3 5])
```

```
sino2(i,:) = mes;
scale2(i)=ss;
end
%mean (temp(i,:))
sum(temp)/50
```

2) Gaussian filter run code:

```
ori=orifbp;
for i=1:50
   A = rec2(:,:,i);
G = fspecial('gaussian',[5 5],2);
Im2 = imfilter(A,G);
psnr(i) = abs( 10*log10((1/mean(abs((ori(:)-abs(Im2(:)))).^2))))
cor(i) = corr(ori(:),Im2(:))
NR(i) =  std(abs(ori(:) - Im2(:)))
% temp(i,:)= psnr([1 3 5])
% temp(i,:)= cor([1 3 5])
%temp(i,:)= NR([1 3 5])
end
mean(psnr(:))
mean(cor(:))
mean(NR(:))
% imagesc(Im2(:,:,30));
%sum(temp)/50
```

3) Wavelet filter run code:

```
ori = orifbp;
%temp = zeros(2,3);
for i=1:50
    A = rec2(:,:,i);
    [C,S] = wavedec2(A,2,'db4');
ng = waverec2(C,S,'db4');
psnr(i) = abs(10*log10(1/mean(abs((ori(:)-Im2(:)).^2))))
cor(i) = corr(oris(:),Im2(:))
```

```
NR(i) =  std(abs(oris(:) - Im2(:)))
%temp(i,:)= psnr([1 3 5])
%temp(i,:)= cor([1 3 5])
%temp(i,:)= NR([1 3 5])
end
%sum(temp)/50
mean(psnr(:))
mean(cor(:))
mean(NR(:))
```

4) Curvature motion run code :

```
temp = zeros(2,3);
for i=1:50
A =rec2(:,:,i);
Im2 = mymcmgray(A,25,0.15);
mes = measure(Im2, orifbp);
temp(i,:)= mes([1 3 5])
%sino2(i,:) = mes;
%scale2(i)=ss;
end
%mean (temp(i,:))
sum(temp)/50
```

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