STROKE PREDICTION FROM HYPERTENSIVE RETINOPATHY

by

NANDINI A/P RAVINDRAN

16311

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Universiti Teknologi PETRONAS,
32610, Bandar Seri Iskandar,
Perak

CERTIFICATION OF APPROVAL

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A project dissertation submitted to the
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Approved by,

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(DR.LILA IZNITA)

UNIVERSITI TEKNOLOGI PETRONAS
BANDAR SERI ISKANDAR, PERAK
January 2016

CERTIFICATION 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 acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

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(NANDINI A/P RAVINDRAN)

ABSTRACT

Hypertensive Retinopathy (HR) is known as the damage to the eye which occurs due to high blood pressure. This HR may lead to permanent vision lost hence timely diagnosis and treatment of this disease is very important. Fundus image analysis is used to diagnose HR and stroke prediction. There are four steps in the proposed systems which are the Image Enhancement, Fourier Fractal Dimension, Logistic Regression Classifier and Stroke Prediction Model. The proposed system consists of method used to analyse retina blood vessels using Fourier Fractal Dimension to extract the complexity of the retina blood vessels enhanced in different scales. Logistic regression was used to model the classifier for stroke prediction. The probability from 0 to 0.5 was classified as control case and the probability from 0.5 to 1 was classified as stroke case. From 20 images used in this project only 14 images was classified as the stroke case. The estimated percentage increase in the odds of incident of stroke is calculated and categorised according to the Hypertensive Retinopathy stages.

ACKNOWLEDGEMENTS

All praises go the Almighty, the gracious, for granting me the greatest health in order for me to complete this project without any hiccups. Not forgetting to mention, the women who has been guiding since day 1 of this project, none other than my supervisor, Dr. Lila Iznita. Besides that, my eternal gratefulness goes to my family, who has been my backbone, supporting me in completing my degree in anyways possible, be it in terms of morale or financial. In addition, I would like to express my gratitude to my fellow friends, classmates and seniors who have been a great help for me to complete this project with a success. I would like to once again thank everyone who is involved in completing this project, whether directly or indirectly. Your kind cooperation is forever appreciated.

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CHAPTER 1

INTRODUCTION

1.1 Background Study

High blood pressure is a disease in which blood flows through vessels are higher and cause malfunction to the organ. High blood pressure is also known as hypertension. There are approximately 1.56 billion people are estimated to be affected with hypertension worldwide by 2025. In England, 32% men and 30% women are affected by hypertension [1]. Normally, blood pressure will increases according to age and body size. Adults will have higher blood pressure compared to new-born babies.

The blood pressure is measured by the systolic pressure number above the diastolic pressure number. Systolic pressure is the blood pressure when the heart beats while pumping blood and diastolic pressure is blood pressure when the heart is at rest between beats. The main cause for hypertension are overweight, consume to much of salt, not enough of exercise, relative with high blood pressure, consume too much of alcohol and coffee and also smoking. Normal blood pressure for adults is systolic pressure below 120mmHg and diastolic pressure below 80mmHg. Abnormal blood pressure is having blood pressure higher than 120mmHg/80mmHg[2]. The Table 1.1 below shows the hypertension stages with the value of the systolic and diastolic pressure.

TABLE 1.1 Hypertension stages Reproduced from [2]

Blood pressure Category	**Systolic mm Hg (upper)**	**Diastolic mm Hg (lower)**
Normal	Less than 120	Less than 80
Prehypertension	120 - 139	80 - 89
High blood pressure Hypertension Stage 1	140 - 159	90 – 99
High blood Pressure Hypertension Stage 2	160 or higher	100 or higher
Hypertensive Crisis (Emergency care needed)	Higher than 180	Higher than 110

Hypertension is the single most important modifiable risk for stroke. Stroke is the uncontrolled high blood pressure which can cause problems by damaging and narrowing the blood vessels in the brain. Over time, this damage and narrow of blood vessels in the brain raises the risk of a blood vessel becoming blocked or bursting. Stroke is the most common cause of adult disability and emotional problems. The most common signs and symptoms of having a stroke are severe headache, feeling unsteady, vision loses or blurred vision and being paralysed on one side of the body [3].

Every year, an estimated 150,000 people in the U.K and 800, 000 people in the U.S suffer from stroke. Stroke, also called brain attack, is a loss of brain function due to an interruption of blood supply to the brain. Lack of adequate blood supply or ischemia (87% of registered stroke), starves the affected region of the brain of nutrients and can cause it to stop functioning. The severity of a stroke is determined by its location, the size of an affected area and the duration of the tissue being deprived of blood [4].

Cerebral and retinal vasculature share embryological and anatomical characteristics thus they may show similar patterns of damage from diseases such as hypertension that could lead to stroke. The ocular effect of hypertension such as narrowing of retinal arteriolar, arteriovenous nicking, increased vascular tortuosity, vessel thickening, extravascular lesions (microaneurysms, cotton wool spot), shunt vessels etc. has been reported to associate with cerebral diseases and thus fundus imaging can become a potential tool in prediction of stroke [4].

1.2 Problem Statement

In current practice, the prediction of stroke for a hypertensive patients is been done by medical observation. Doctors will collect some details of the patients such as age, body weight and height and also their medical history such as hypertension, diabetic, and family history. By all these details, doctors will observe the situation of the patients and predict the risk of having stroke in future. However, this method is reported to have some concerns in reproducibility, relevancy of the system to clinical practice and poor correlation with the severity level. An objective way is needed to predict the stroke from a hypertension patient.

1.3 Objectives

The objective of this project is to measure risk of mild stroke based on evaluation of fundus image of hypertension patients. A new system is needed in order to find out how much percentage of hypertension patients in the risk stage to get stroke in the future. To achieve this objective, a few steps will be done to create a new and potential system which can provide the accurate and reliable output.

1.4 Scope of study

This research will involve in the understanding of hypertensive retinopathy changes for mild stroke predictions. The study of this project can be broken down into two parts. The first part will be collecting fundus image of hypertension patients. In this part, few images from the selected databases will be used and the image will be categorised according the hypertension stages. The second part will be prediction of stroke model. The image was enhanced to remove the background noise and filter the un-necessary pixels. The retinal vasculature was analysed and the dimension will be calculated. A classifier will be used to classify between control case and stroke case. Some calculation will be done to find out the percentage of having stroke in the future.

CHAPTER 2

LITERATURE REVIEW

For the study of hypertensive retinopathy changes for stroke prediction, there are several research papers that were reviewed and studied in order to understand the scope of the topic. The research done was divided into three categories which are the images database and enhancement techniques, techniques used to diagnose hypertensive retinopathy and the stroke prediction model.

2.1 Image Database and Enhancement

There are few retinal databases such as DRIVE (Digital Retinal Images for Vessel Extraction), STARE (Structures Analysis of Retina) databases and VICARV databases. There are 40 colour fundus photographs in DRIVE database, 20 images in STARE database and 58 images in VICARV which can be used for the grading of hypertensive retinopathy[5]. The images from the databases can be used for different function. The images from DRIVE database are suitable to be used for vessel segmentation, the images from STARE database are suitable for Diabetic retinopathy grading and the images for the VICARV are suitable for artery and vein computational and Hypertensive Retinopathy.

The retinal images often have low grey level contrast and dynamic range. The objective of this enhancement is to remove the unnecessary background noise from the images to provide a better quality image. Several techniques have been used to improve the image quality such as Histogram Equalization, unsharp masking and local normalization, Gabor 2D wavelet, retinex, contourlet and many others [6]. Each technique has its own advantages and disadvantages depending on how it is being used. Table 2.1 below shows the advantages and disadvantages of each technique.

TABLE 2.1 Image Enhancement Techniques

Technique	Advantages	Disadvantages
Histogram Equalization	-Enhance the vessels very clearer.	-Absence of some grey levels and non-uniform background distribution. -Strongly amplifies the noise also[7].
Retinex	-Sharpen a blur image by image formation process -Improve consistency of output as illumination changes -Dynamic range compression.	- Not suitable to use coloured images for multiscale - Difficulty in fixing the constant needed to different pixels of images[8].
Local Normalization	- Normalized each pixel of image to enhance the images -Edges are being enhanced together and sharpen the images.	-Amplifies noise strongly -Background grey distribution is not uniform and more noise in the background[6].
Contourlet	-Higher contrast between vessels and background	-Thin vessel and nerves almost invisible. -Artifacts due to shift-variance [6].

2.2 Hypertensive Retinopathy

Hypertensive retinopathy is known as the abnormality of the retina due to high blood pressure. The retinal changes which occur due to HR such as damage in the choroidal circulation, optic and cranical neuropathies. There are five stages for hypertensive changes where at first stage there are no visible retinal vascular abnormalities, second stage the arteriolar narrowing where the vessels will be smaller, third stage the arteriolar narrowing is more bigger and focal is formed, fourth stage the focal and diffuse arteriolar narrowing is very obvious and retinal haemorrhages is present and at last stage all the previously listed abnormalities is present together with retinal oedema, hard exudates and optic disc oedema[9]. The Table 2.2 below demonstrates the adjustments according to hypertensive patients and the Figure 2.1 show the changes occur due to HR.

TABLE 2.2 Hypertensive changes [9]

Stage	Description
Hypertensive changes	
0	Patient has diagnosed hypertension There are no visible retinal vascular abnormalities
I	Diffuse arteriolar narrowing is seen, especially in the smaller vessels. Arteriolar calibre is uniform, with no focal constriction
II	Arteriolar narrowing is more pronounced, and there can be focal areas of arteriolar constriction
III	Focal and diffuse arteriolar narrowing is more obvious and severe Retinal haemorrhages may be present
IV	All of the previously listed abnormalities may be present, along with retinal oedema, hard exudates, and optic disc oedema

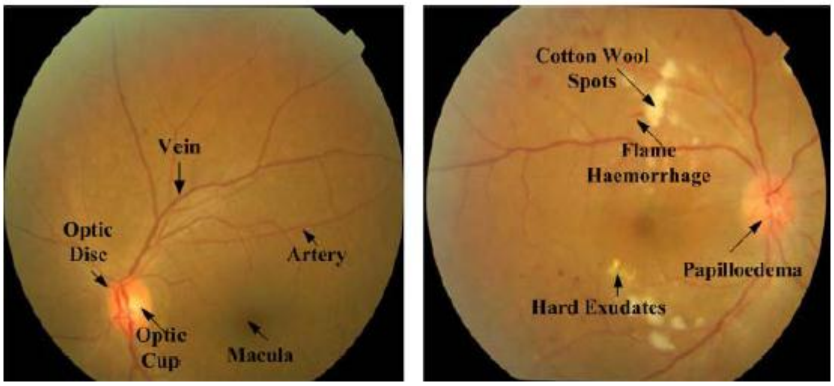


FIGURE 2.1 The changes between normal retina and hypertensive retina [9]

There are many state of the art techniques used for automated detection of HR such as blood vessels segmentation using Radon Transform, Hough Transform to detect the optic disk, measure vessel diameter in order to compute the ratio of average diameter of arteries to veins (AVR) using Gabor Wavelet and morphological operations, multiscale filtering and region based identification used to estimate the vessels width, segmentation of vessels using moment based and grey level feature and support vector machine (SVM), and top hat transformation and double ring filter used to detect retinal blood vessels [10].

The method use for grading of hypertensive retinopathy consist of four stages which are preprocessing, retinal vessel segmentation, artery and vein classification and finally artery to vein ratio computation. The images will first go through the preprocessing phase to remove the background and noise. The vessels are extracted and classified as arteries and veins using many methods such as Naïve Bayes Classifier, Support Vector Machine and Hybrid Classifier. Figure below shows the example of vessel classification where the red colour is classified as arteries and the blue colour is veins [10].The advantages and disadvantages of each method are described in Table 2.3 . Finally the AVR is calculated by Parr-Hubbar formulas and graded by the hypertension stages [10].

TABLE 2.3 Comparison of classifier used for classification of artery and vein

Methods	Advantages	Disadvantages
Support Vector Machine (Separates with maximum margin by using separating hyperplane) [10]	-Flexible -Provides good out-of-sample generalization -Deliver unique solution	-Lack of transparency of results -Speed and size limitation -High algorithmic complexity and extensive memory requirements
Naïve Bayes Classifier (The presence or absence of particular features is unrelated to the presence and absence of any other feature) [11]	-Fast and speed efficient -Not sensitive to irrelevant features -Easy to implement -Good results obtained	-Loss of accuracy -Dependencies exist among variables
Hybrid Classifier (Combination of Naïve Bayes and SVM classifier) [12]	-Better performance than using one classifier -Reduce individual limitations of basic models	-Complex using many methods -Need to be more accurate and careful -Longer time taken

2.3 Stroke Prediction Model

Stroke prediction model is the model which will be used to predict the risk of stroke. There are a few models which have been used to predict stroke in medical way such as Korean Stroke Risk Prediction (KSRP) model, Bayesian List Machine, Multivariate Cox Proportional Hazard Model and etc. The KSRP model has used the cox proportional hazard model as the base model. It is proven that the KSRP model could make good predictions when KSRP function was applied to the Korean cohort participants [13]. This model is similarly to the Framingham's model. The Bayesian List Machine model used the decision list such as if, else, then and etc. This model is a interpretable predictive models using massive observational medical data which used the FP-Growth algorithm to find all item sets that satisfy constraints on minimum support and maximum cardinality [14].

Multivariate Cox Proportional Hazard model is used to access the importance of various covariates in the survival times of individuals or objects through the hazard function [15]. This model includes seven significant predictors which are age, gender, systolic and diastolic blood pressure, family history of stroke, diagnosis of atrial fibrillation and diabetes mellitus. This model not include smoking, alcohol intake or BMI because their no significance in the multivariate model.

The stroke prediction can also been done using a formulated model such as using logistic-based fusion of multiscale fractal analysis. These multiscale analyses on retinal have been limited to vessel segmentation. Fractal dimension (FD) is a measure of structural complexity of the retinal vasculature. Fourier fractal dimension (FFD) is used to computes the fractal dimension of the grey scale image and reduce the vessel segmentation method. This model also uses logistic function to fuse the outcomes at different scales to model the classifier for 5-year stroke prediction [16].

CHAPTER 3

METHODOLOGY

3.1 Project Work

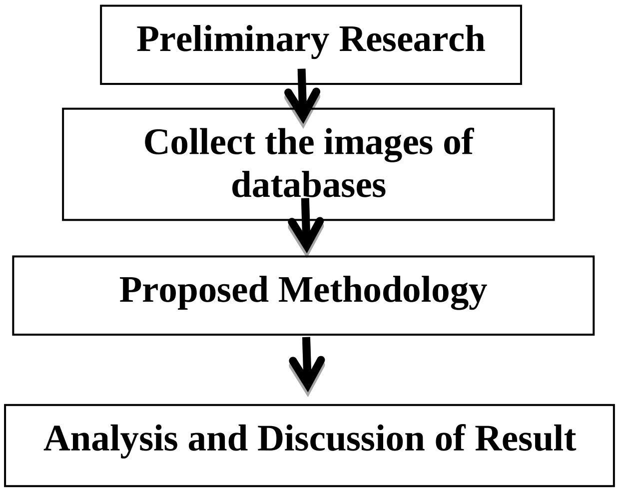


FIGURE 3.1 Project Activities Flow Chart

3.1.1 Preliminary Research

The study on the hypertensive retinopathy changes for stroke prediction will be done based on several studies and analysis. There are few methods which will be done in order to complete this project work. The first method will be the preliminary research where research will be done on the stages of HR, techniques used to diagnose, stroke prediction model and the image database and preprocessing.

3.1.2 Collection of images from the databases

The second method will be the collection of images from databases. There are few image databases such as DRIVE, STARE and VICARV. The images from all the databases will gathered for references and filter the suitable images for HR and collect more details of the images.

3.1.3 Proposed methodology

In this method, there are six steps which are image enhancement, Fourier Fractal dimension (FFD), Logistic Regression Classifier and Stroke Prediction Model. Below will be the explanations of each step used to this project:

3.1.3.1 Image Enhancement

This preprocessing will be done to filter unnecessary pixels from background and noise from the images. This will provide a better quality images which will be used for the coming steps. Retinex image enhancement was used to enhance the vessel surface in the retinal image. Retinex is a method bridging the gap between images and the human observation of scenes. This technique can sharpen a blur image by image formation process, improve consistency of output as illumination changes and dynamic range compression. There are 3 type of techniques which are single scale retinex(SSR), multiscale retinex(MSR) and multiscale retinex with colour restoration(MSRCR) [8]. For this project, single scale retinex is used because the images need to decompose in different scales to produce better and accurate results.

The SSR of the image, R(x,y) is calculated as

$$R(x,y) = log\, I(x,y) - log[F(x,y) * I(x,y)] \quad (1)$$

where F(x,y) is known as Gaussion function and calculated as

$$F(x,y)=Ke^{-(x^2+y^2)/c^2} \quad (2)$$

The value K is determines by $\iint F(x,y)dxdy = 1$ and the C is known as Gaussian surround space constant. Gaussian surround function with a space constant of 80 pixels is a reasonable compromise between range and rendition but it also depends on the size of images. A small value of C gives out a good dynamic range compression and a larger scale provides better colour rendition [8].

3.1.3.2 Fourier Fractal dimension (FFD)

For the computational of fractal dimension, the Fourier Fractal dimension (FFD) is used. Fourier Fractal dimension is one of the fractal dimension method. Fractal dimension is known as ratio providing a statistical index of complexity comparing how details in a pattern changes with the scale at which it is measured. FFD will compute the fractal dimension of image and eliminates the need for image segmentation. FFD has also found to be relatively insensitive to noise and believed to work effectively [17].

The Fourier transform of the image f(x,y) with size of MxN is calculated using the below equations

$$F(k,l)= \frac{1}{N^2}\Sigma\Sigma f(x,y)e^{-i2\pi(\frac{ka}{M}+\frac{lb}{N})} \qquad (3)$$

and the magnitude of the Fourier transform is given by

$$M(k,l)=log\ (|F(k,l)|^2 + 10^{-}6) \qquad (4)$$

Graph of M *vs* log(frequency) was plotted to determine the FFD. The slope of the plotted graph,β is substitute in the following equation to find out the FFD value.

$$FFD=\frac{(6+\beta)}{2} \qquad (5)$$

3.1.3.3 Logistic Regression Classifier

Logistic regression was used as an example of classification tool to classify between stroke and control case. It is defined as

$$f(z)= \frac{1}{1+e^{-z}} \qquad (6)$$

the variable z is defined as

$$z=\alpha^o+\alpha^1FFD^1+\alpha^2FFD^2+\alpha^3FFD^3 \qquad (7)$$

where α^o is a constant and α^1,α^2 and α^3 are the regression coefficients of FFD at different Gaussian constant[17].

3.1.3.4 Stroke Prediction Model

After the classifier had classify the stroke case, odd ratio is calculates. An odds ratio is measure of association between an exposure and an outcome. The odd ratio represents the odds that an outcome will occur given a particular exposure, compared to the odds of the outcome occurring in the absence of that exposure [17]. The formula for odd ratio is given as

$$Odd\ Ratio = \frac{p}{1-p} \qquad (8)$$

where the value of p defined as the probability of success. The logistic regression equation can be written in terms of an odds ratio.

$$\frac{p}{1-p} = e^{(\beta^{o}+\beta^{1}FFD^{1})} \qquad (9)$$

Since the logistic regression classifier is used in this project, the formula used to calculate odds ratio is

$$Odds\ Ratio = e^{(\beta^{o}+\beta^{1}FFD^{1})} \qquad (10)$$

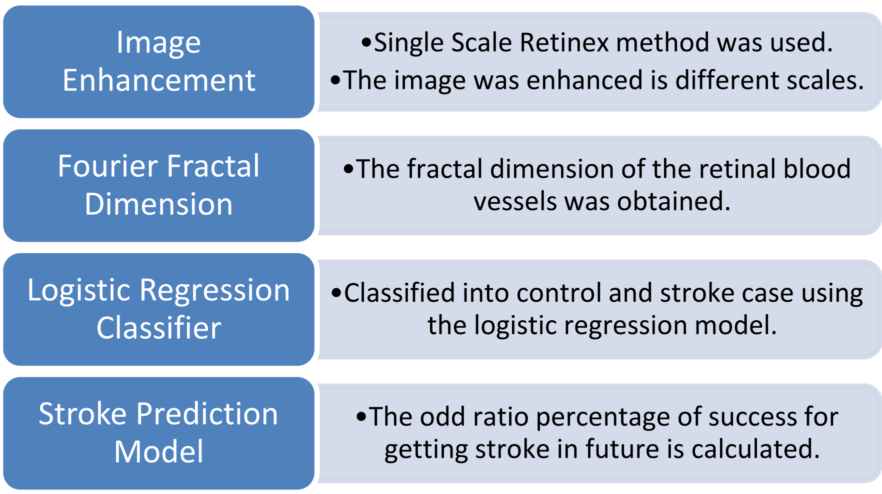


FIGURE 3.2 Flowchart of Methodology

3.1.4 Analysis and discussion of results.

The fourth method will be analysis and discussion on the results. The results will be analysed and the procedure was repeated few times to obtain averaged results. The findings from the results obtained will be discussed and make a conclusion out of the study and determine if the objective has met. The last method will be the report writing. All the research findings, literature reviews, experimental works and outcomes are compiled into a final report.

3.2 Gantt Chart

TABLE 3.1 Gantt Chart of Project Planning

	FYP 1													
	WEEK													
Activites	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Selection of Project Topic														
Study on hypertensive retinopathy and its changes														
Study on image database and enhancement														
Analyse the image databases and its used														
Study on the techniques used to diagnose the HR														
Image Collection and categorized by the HR stages														

	FYP 2													
	WEEK													
Activites	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Image Enhancement														
Fourier Fractal Dimension														
Logistic Regression Classifier														
Stroke Prediction Model														
Analysis and discussion of results														
Technical Report														

CHAPTER 5

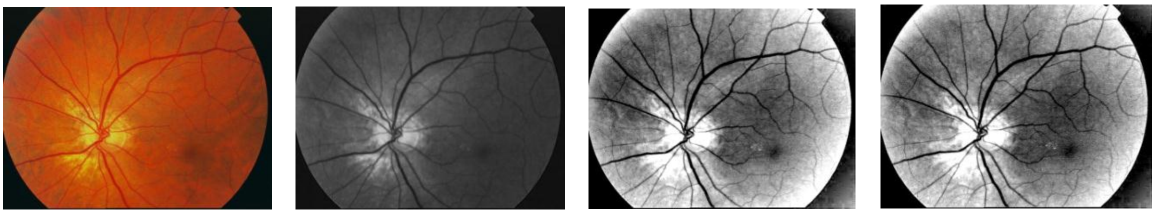
RESULTS AND DISCUSSIONS

For this project, MATLAB software is used throughout the grading of hypertensive retinopathy. The first two steps which are the image enhancement and fourier fractal dimension was done and the results is attached below.

4.1 Image Enhancement

As mentioned in the methodology part, single scale retinex method was used to enhance the vessel surface in the pictures. Around 20 images from the VICARV database were used because these images are the retinal images for hypertension patients. The green channel of the image is extracted first before it is enhanced. The images was decomposed at 2 different Gaussian constant, C= 800 and 1000. These are the suitable constant which enhanced the image clearly.

The Gaussian constant of 100 and 1200 was also tested. The C=100 image output does not give the desired output where the image was not fully enhanced whereby the C=1200 image output is the same as 1000. The maximum Gaussian constant needed to enhance these retinal images is 1000 and it is suitable for all the images in the VICARV database as it was tested. The output of each image is shown in the **Appendix I**.



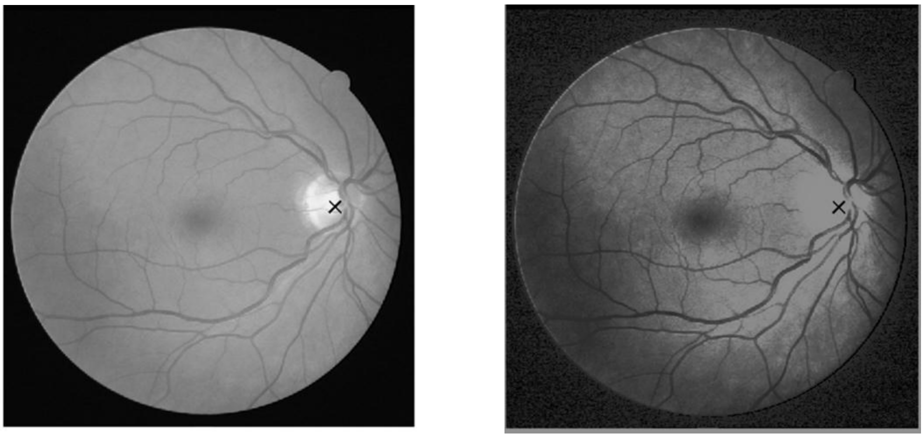
(a) (b) (c) (d)

FIGURE 4.1 Single Scale Retinex technique ; (a) Original picture (b) Green Channel Image (c) SSR at C=800 (d) SSR at C=1000

Before this single scale retinex technique was selected, few different techniques was also tested such as image adjustment, histogram equalization, and few others. These techniques can enhance the retinal images but the ouput was not as the desired one. For the image adjustment technique, the background noise was removed but the vessel surfaces was not enhanced whereby the histogram equalization enhance the vessel surfaces but it enhance the background noise together.By comparing the output of each techniques, single scale retinex technique produced the best results. The output of the other techniques is shown below.

(a) (b) (c)

Figure 4.2 Image adjustment technique; (a) Original Image (b) Green Channel Image (c)Image adjustment

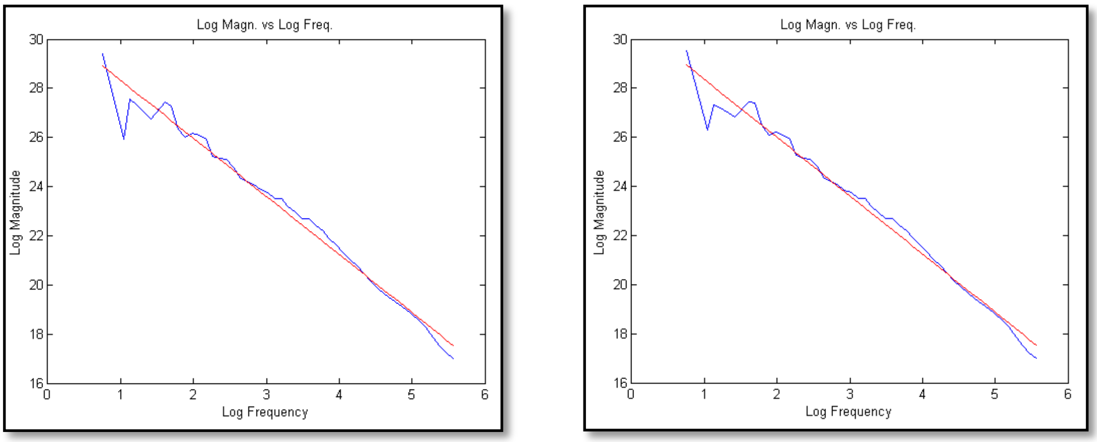


(a) (b)

FIGURE 4.3 Histogram Equalization Technique; (a) Green Channel Image (b) Equalized Image

4.2 Fourier Fractal Dimension

The image was transformed using the fast fourier transform algorithm. The fractal dimension is calculated from the power spectrum as a function of the frequency in the Fourier transform of the image. Graph is plotted in a bi-log scale, the curve is approximately similar to a straight line and the dimension was provided by the slope of such line.



(a) (b)

FIGURE 4.4 Graph of log magnitude vs log frequency; (a) Graph for C=800 (b) Graph for C=1000

The slope of the plot were calculated and substituted in the fourier fractal dimension formula to obtain the FFD value. The more complex the retinal vasculature, the higher the FFD value obtained. This means that the bigger Gaussian constant will produce the higher FFD value because the clearer the blood vessel was enhanced. The Table 4.1 below shows the slope value and the FFD value of each graph.

TABLE 4.1 The Fourier Fractal Dimension Values

Image	SSR 800		SSR 1000	
	Slope	FFD	Slope	FFD
Image 30	-2.2883	1.86	-2.2170	1.89
Image 31	-2.5716	1.71	-2.4236	1.79
Image 32	-2.7311	1.63	-2.6232	1.69
Image 33	-2.4657	1.77	2.3536	1.82
Image 34	-2.4303	1.78	-2.3761	1.81
Image 35	-2.4239	1.79	-2.3898	1.80
Image 36	-2.3457	1.83	-2.3181	1.84
Image 37	-2.6121	1.70	-2.6086	1.71
Image 38	-2.7221	1.64	-2.7050	1.65
Image 39	-2.5616	1.72	-2.5597	1.73
Image 40	-2.6949	1.65	-2.6570	1.67
Image 41	-2.8547	1.57	-2.8286	1.59
Image 42	-2.5809	1.70	-2.5252	1.74
Image 43	-2.4888	1.76	-2.4439	1.78
Image 44	-2.7478	1.62	-2.7350	1.63
Image 45	-2.6210	1.69	-2.6060	1.70
Image 46	-2.5885	1.71	-2.5600	1.72
Image 47	-2.9098	1.54	-2.8729	1.56
Image 48	-2.5287	1.73	-2.4375	1.78
Image 49	-2.6486	1.67	-2.6323	1.68
Image 50	-2.9208	1.54	-2.9082	1.56

These are the selected 20 images which were used for the testing and it is taken from the VICARV databases. The graph of the other images is shown in the **Appendix II.**

4.3 Logistic Regression Classification

Logistic regression is used widely in many fields, including the medical and social sciences. This classifier will classify the outcome into two possible outcomes which are success and failure based on their symptoms. Logistic regression can be binomial, ordinal or multinomial. In this project, the binomial logistic regression is used. Binomial or binary logistic regression deals with situation in which the observe outcome for an event can have only two possible type which is success and failure.

The outcome is normally coded as 0 or 1 as its leads to the most straightforward interpretation. The glmfit function is used to obtain the coefficients which are needed to calculate the probability of the hypertension patients getting stroke. This glmfit function fits a generalized linear model that allows for linking functions such as the logistic function. The regression coefficients are usually estimated using maximum likelihood estimation. The regression coefficient obtained is a^o= -0.2647, a^1=0.1933 and a^2=0.3192. These coefficients are inserted in the following formula (7).

In this part, the fusion of multiscale FFD is also calculated. Multiscale FFD is the combination of the both single scale FFD. This is to show that the fusion of multiscale FFD provides better performance than single scale FFD and much informative data and information obtained from the image. The logistic function f(z) is obtained from the algorithm (6) which will separate the control case and stroke case. If the value of f(z) is in between 0 to 0.5, it is classify as control case and if the value of f(z) is in between 0.5 to 1, it is classify as stroke case. From 20 fundus images used, 14 images are classified as the stroke case. This is how the image will be classified and only the stroke case will be used to calculate the odd ratio. The Table 4.2 below shows the value of z, f(z) and odd ratio of the images used.

TABLE 4.2 The logistic function and the odds ratio

	HR diagnosis	z	F (z)	Odds Ratio
Image 32 800	Grade 4	0.095	0.524	1.0996
1000		0.339	0.584	1.4035
800_1000		0.689	0.668	1.9917
Image 34 800	Grade 4	0.079	0.520	1.0822
1000		0.313	0.578	1.3675
800_1000		0.657	0.588	1.9289
Image 35 800	Grade 4	0.081	0.520	1.0843
1000		0.309	0.577	1.3602
800_1000		0.655	0.658	1.9251
Image 36 800	Grade 4	0.089	0.522	1.0930
1000		0.323	0.580	1.3771
800_1000		0.676	0.663	1.9656
Image 37 800	Grade 3	0.064	0.516	1.0660
1000		0.281	0.569	1.3244
800_1000		0.610	0.648	1.8404
Image 38 800	Grade 2	0.052	0.513	1.0533
1000		0.262	0.565	1.2995
800_1000		0.579	0.641	1.7842
Image 39 800	Grade 3	0.068	0.517	1.0703
1000		0.288	0.572	1.3337
800_1000		0.620	0.650	1.8589
Image 41 800	Grade 2	0.054	0.514	1.0554
1000		0.268	0.567	1.3073
800_1000		0.587	0.643	1.7985
Image 43 800	Grade 3	0.064	0.516	1.0660
1000		0.291	0.572	1.3377
800_1000		0.619	0.650	1.8570
Image 45 800	Grade 4	0.076	0.520	1.0789
1000		0.303	0.575	1.3539
800_1000		0.644	0.656	1.9040
Image 46 800	Grade 2	0.048	0.512	1.0491
1000		0.256	0.564	1.2917
800_1000		0.568	0.638	1.7647
Image 47 800	Grade 3	0.062	0.515	1.0639
1000		0.278	0.569	1.3204
800_1000		0.605	0.647	1.8312
Image 48 800	Grade 3	0.065	0.519	1.0671
1000		0.284	0.570	1.3284
800_1000		0.615	0.649	1.8496
Image 49 800	Grade 3	0.069	0.517	1.0714
1000		0.303	0.575	1.3539
800_1000		0.637	0.654	1.8907

4.4 Stroke Prediction Model

The odds ratio was also includes in the table above to provide a clearer estimate of the percentage increase in the odds of incident of stroke. For example, the value of 1.3675 is interpreted as, for every change in standard deviation, there is an estimate of 36.75% increase in the odds of incident stroke. Statistical significance is assumed as the 1 is not included.

Since the fundus image from the VICARV database provide the stages of the hypertension, the risk of getting stroke can be classified by the stages. As the image had been classified between the control and stroke case, it is observed that the stroke case start for the grade 2 of the hypertensive retinopathy stage. The Table 4.3 below shows the percentage of the hypertension patients getting stroke by the stages.

TABLE 4.3 The estimated percentage of getting stroke according to HR stages

Stages of HR	Symptoms	Estimated Percentage,%
Grade 2	Compression of elevation of venules	70 – 80
Grade 3	Right angled crossing of vessels	80 - 90
Grade 4	All above symptoms along with papilledema	90- 100

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 CONCLUSION

By following the proposed method, the percentage of hypertension patients to get stroke can be identified. The fundus images from the VICARV databases are used overall for this project. The green channel of the image is extracted first and followed by enhancing the image in two different scales.

The Fourier Fractal Dimension is used to measure the dimension of the retinal blood vessels. This method also eliminates the needs for image segmentation and relatively insensitive to noise which provides a better results.

The logistic regression classifier plays a main role here where it will classify into control and stroke case. The odds ratio was calculate which will give the estimate percentage increase in the odds of incident stroke. The results have shown this proposed system has the potential to be used to measure the risk of hypertension patients of getting stroke. From the study and research done, the objectives set have been achieved.

5.2 RECOMMENDATIONS

This project can be improved to the next level of research that is to study on different changes in the retina due to hypertension rather than the blood vessels. For examples, finding the different changes occur to the retina in the stages of hypertensive retinopathy such as retinal oedema, cotton wool patches and optic disc swelling. The changes in the dimension of retinal vasculature are one method of diagnosis the hypertensive retinopathy.

Apart from using retinex, there is also other method of image enhancement which can be used to enhance the fundus image which may influence the dimension of the retinal blood vessels. Different image enhancement has different function which can produce better output. These factors can be taken in consideration to enhance the output of this research.

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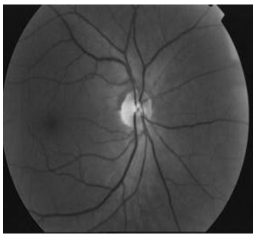
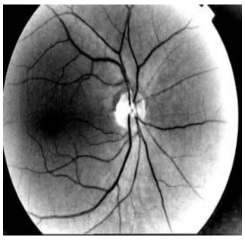
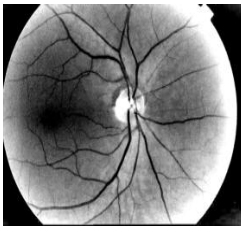
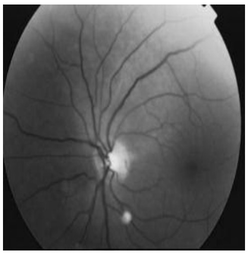
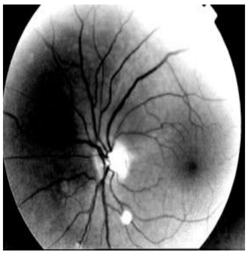
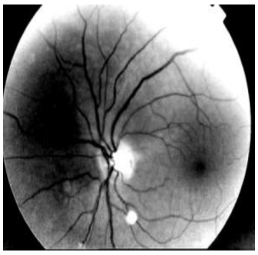
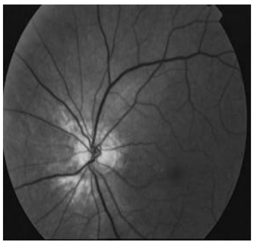
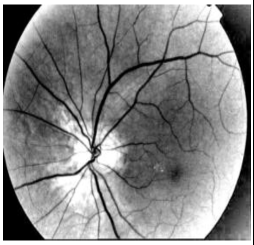
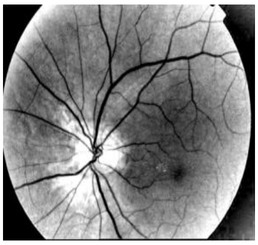
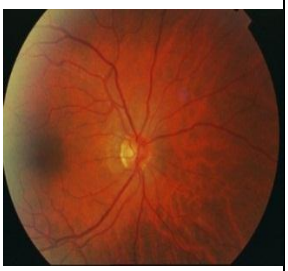
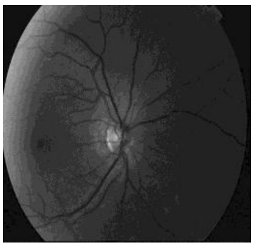
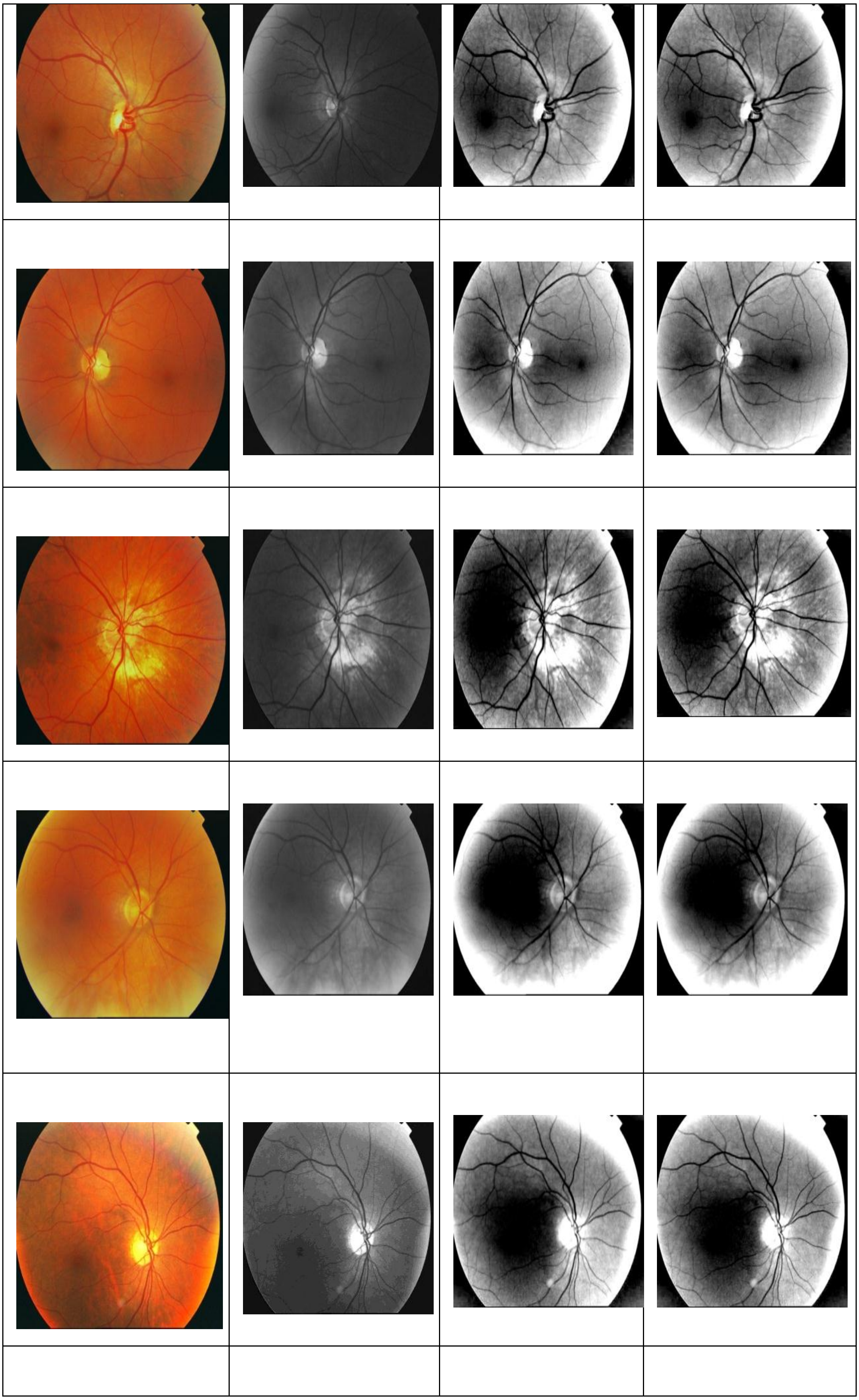
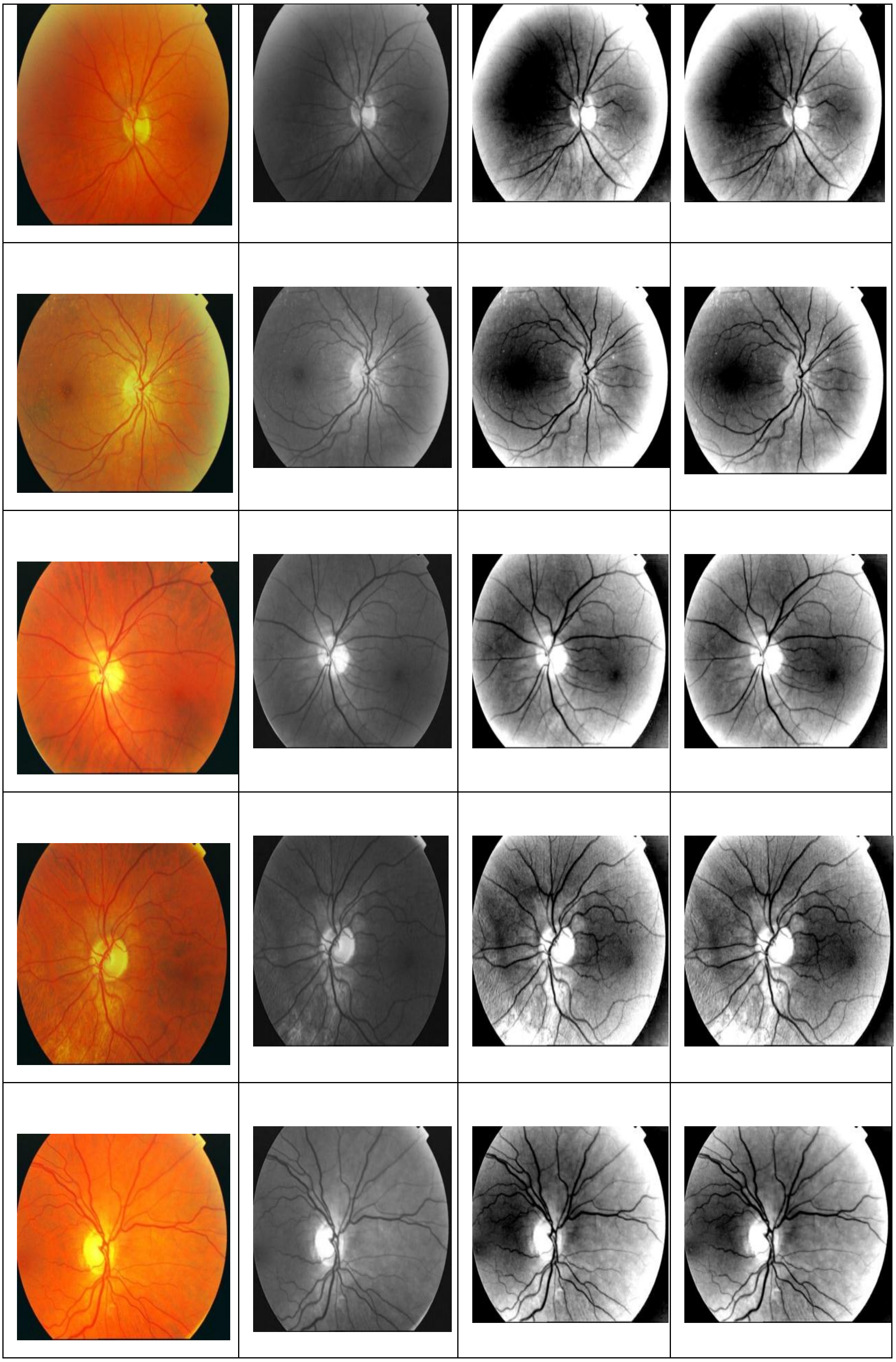
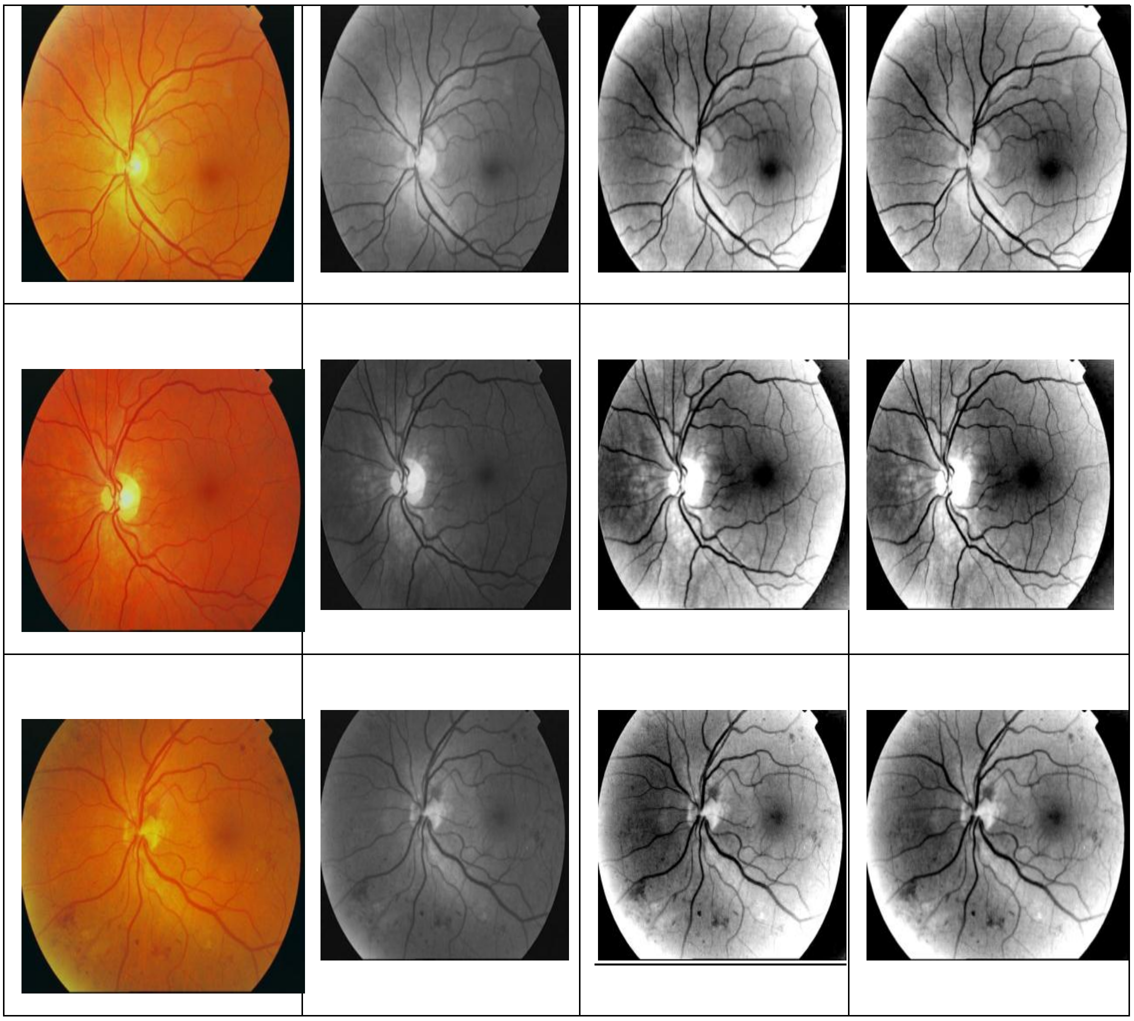
APPENDICES

<u>Appendix I</u>

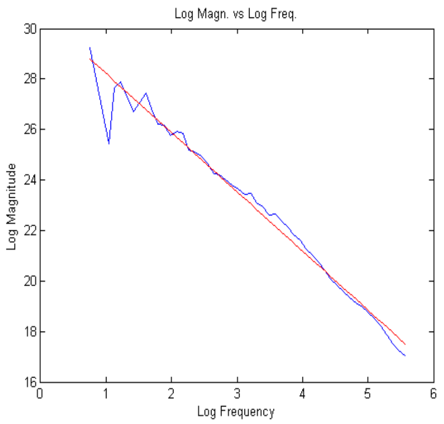
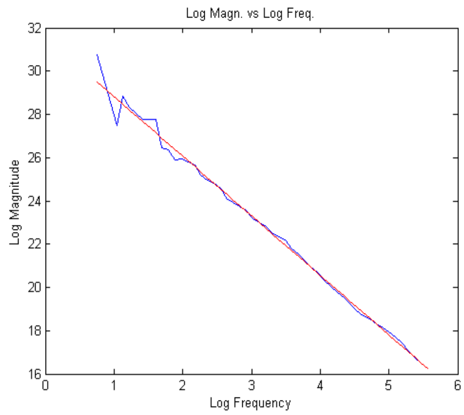
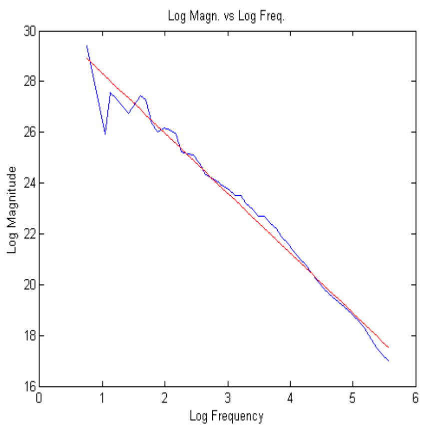
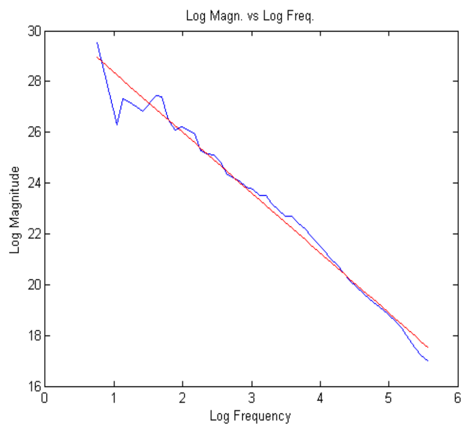
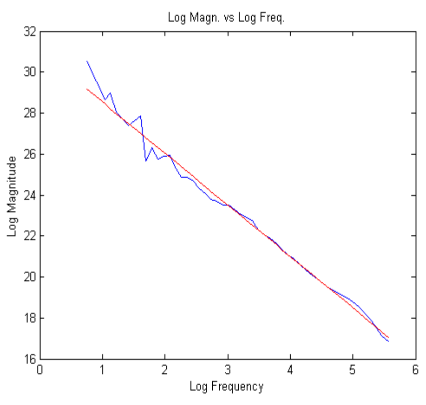
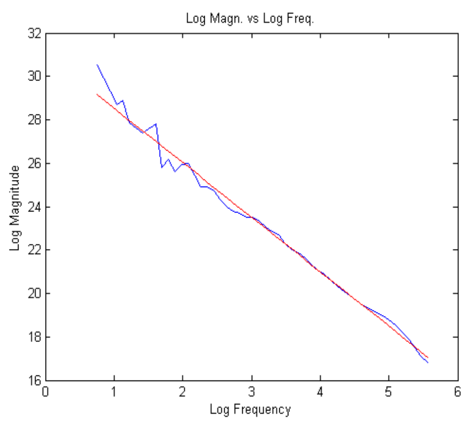
Original Picture	Green Channel	SSR 800	SSR 1000
			
			
			
			

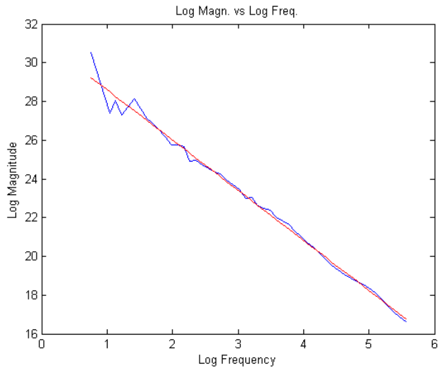






Appendix II

Graph of SSR 800	Graph of SSR 1000
	
	
	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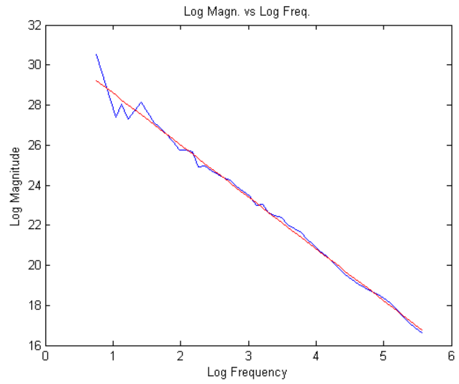
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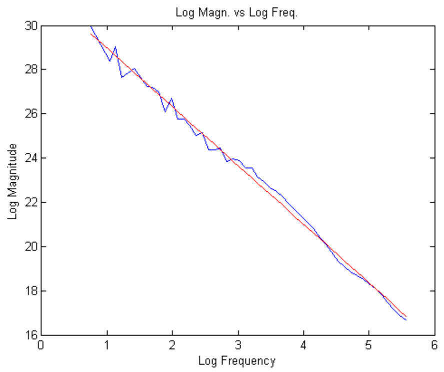
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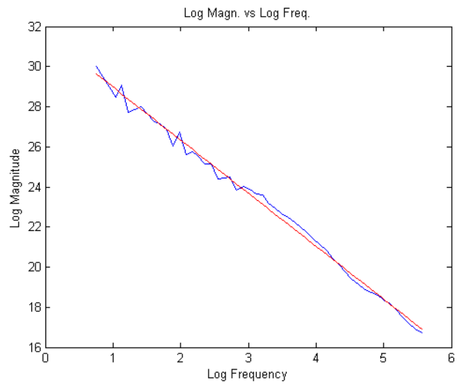
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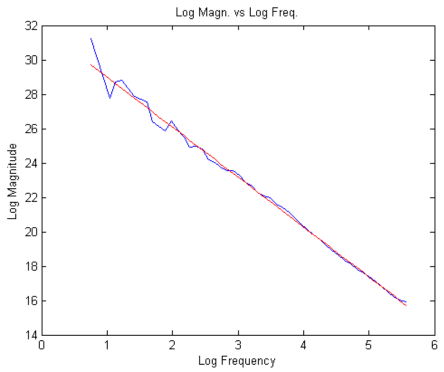
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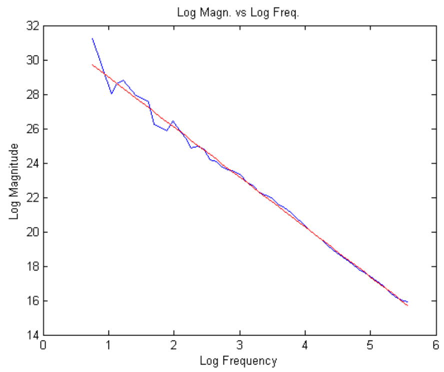
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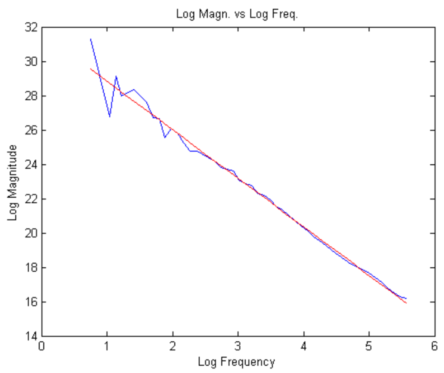
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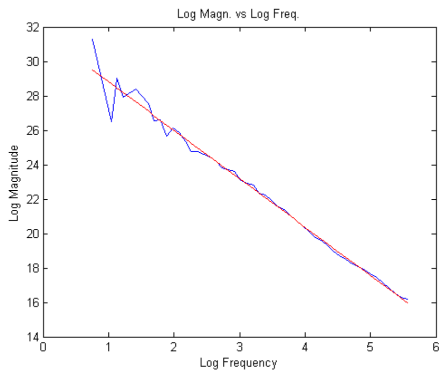
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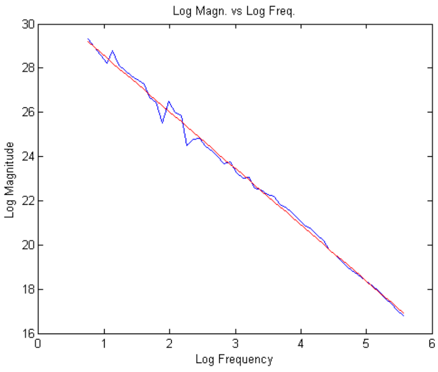
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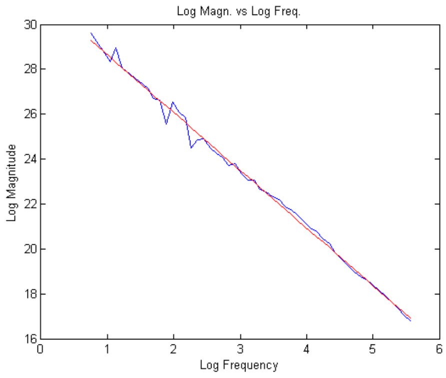
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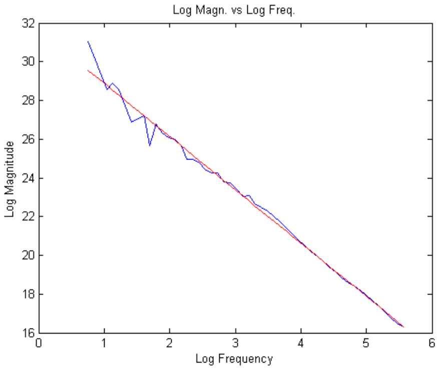
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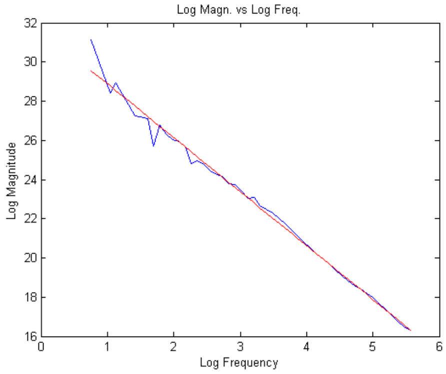
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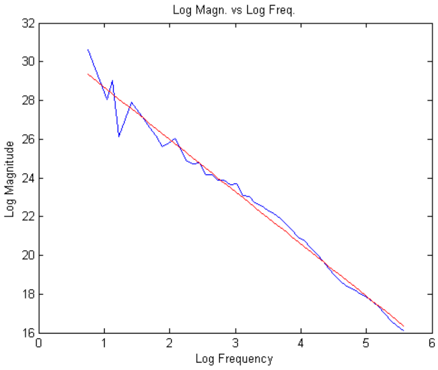
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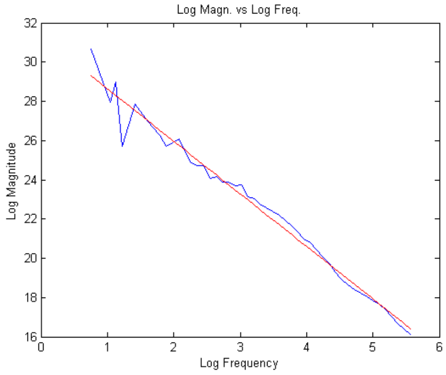
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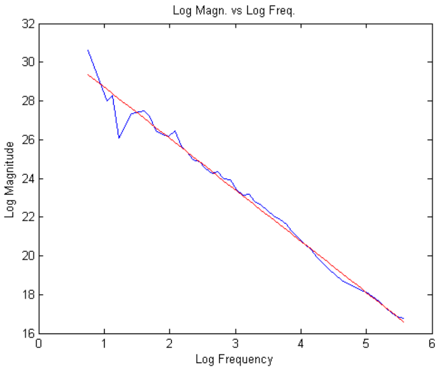
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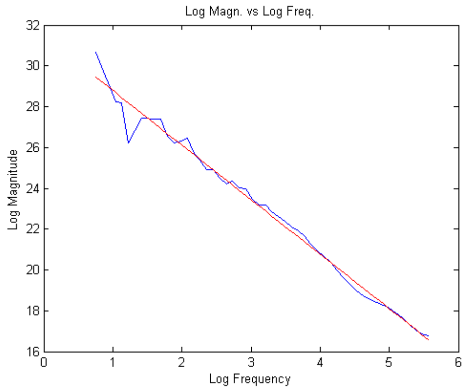
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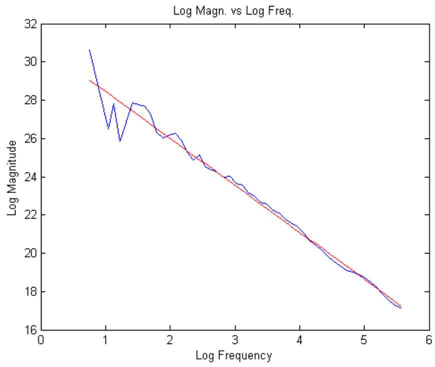
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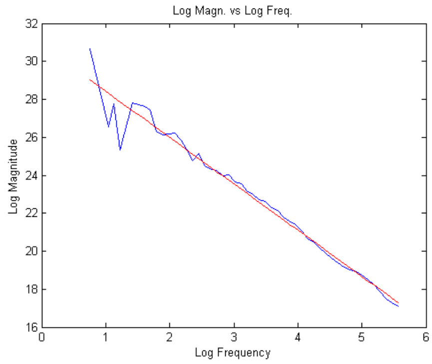
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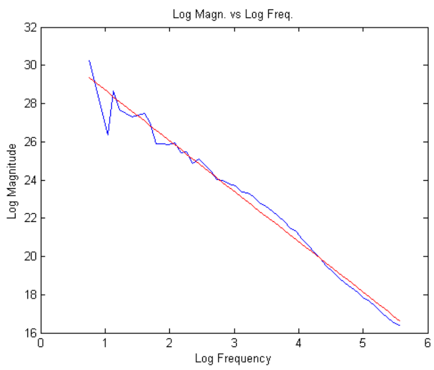
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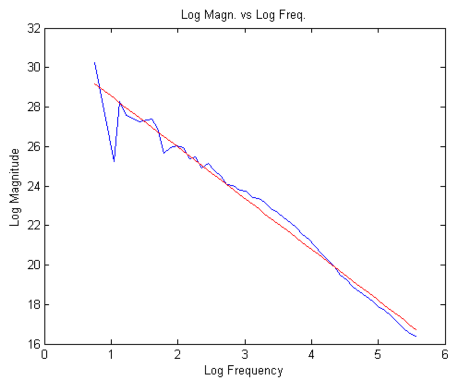
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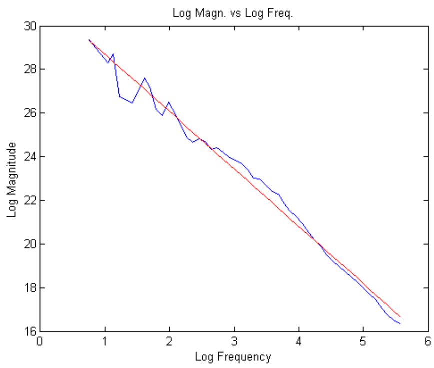
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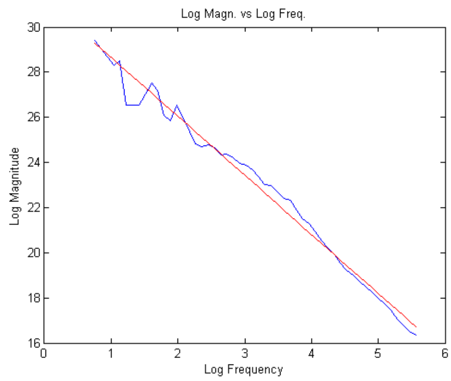
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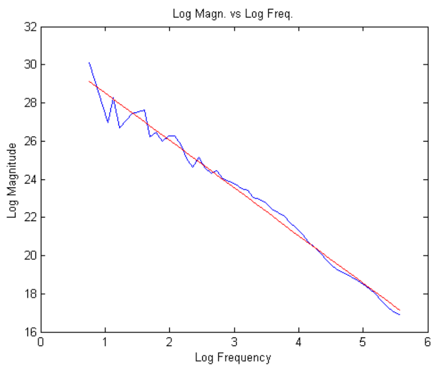
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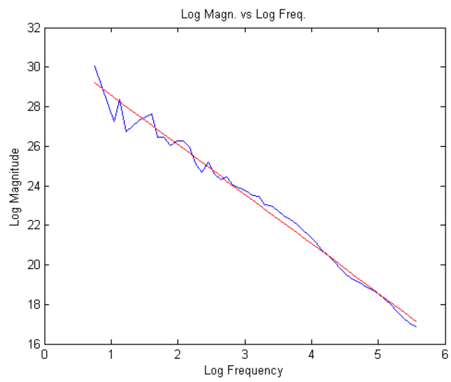
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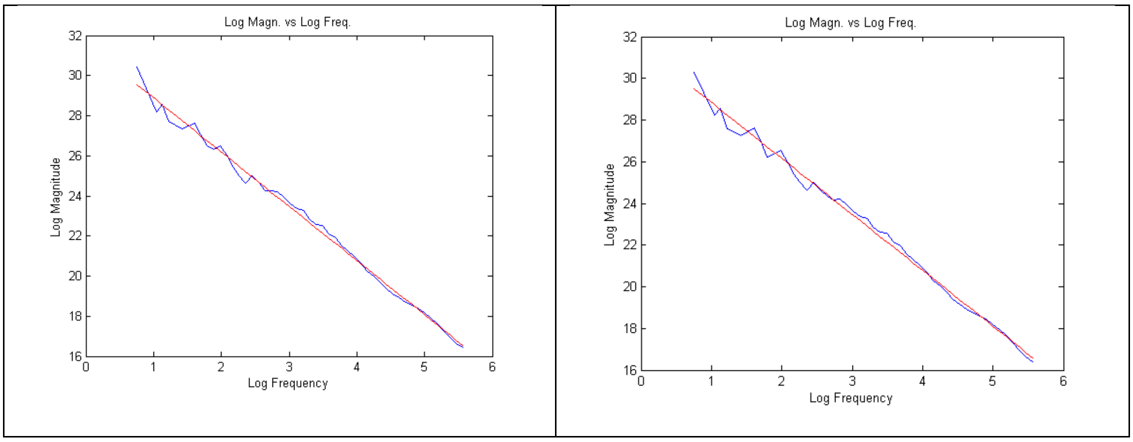
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