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FINAL REPORT

RETINAL MICROVASCULATURE EXTRACTION USING GABOR WAVELET

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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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ABSTRACT

This project discusses diabetic retinopathy which contributes to adult major vision loss. It is caused by abnormal changes in blood vessels on retina.[1] Therefore, a system is developed to enable early inspection. Using 2-D Gabor wavelet vascular pattern is enhanced and further classified by comparing the result from a set of database available on DRIVE. [2]

ACKNOWLEDGEMENT

Final year project 1 is the first phase for the whole project. By submission of this interim report, it means final year project 1 officially completed. With that, one would like to thank respected supervisor for this project AP Dr Tang Tong Boon for his endless patience and guidance throughout the project. It is hoped that, one will be able to accomplish the project while contributing the knowledge gained throughout the experience for others.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLE

1.0 INTRODUCTION

1.1 BACKGROUND OF STUDY

As an introduction, the title of the project is “Retinal Microvasculature Extraction Using Gabor Wavelet”. Let’s define vasculature. According to Merriam Webster dictionary, vasculature through medical definition is the disposition or arrangement of blood vessel in an organ part. [10] Any change in the blood vessel structure and distribution obviously can cause damage to organs in human body. This paper will focus on one organ which is the eye as abnormalities in vasculature of the eye affect human vision to a great extent.

Let’s first begin by understanding the eye structure and how it works. Figure below shows a cross-sectional diagram of an eye which consists of several main elements such as cornea, pupil, lens and retina. Briefly, light rays from external surrounding pass through the clear cornea, pupil and lens and directed straight onto the retina and transmitted to the brain. The brain interpreted the signal sent by retina as images. [4]

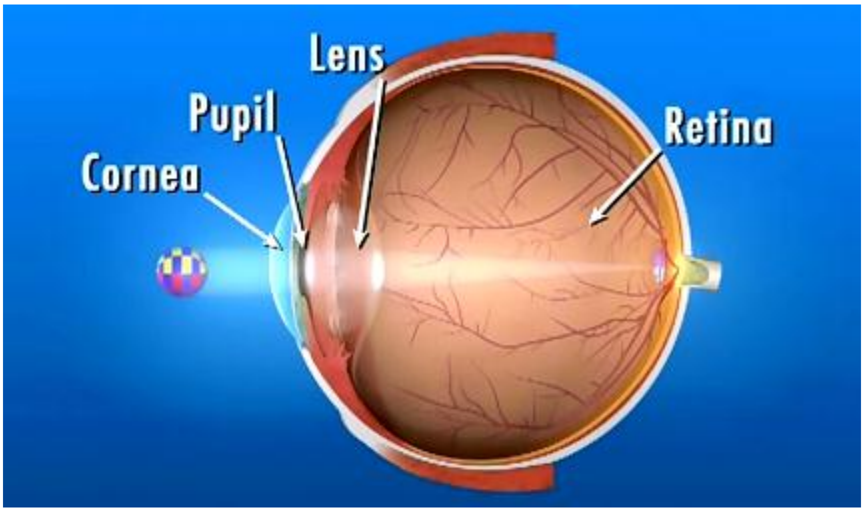

Figure 1.1: Cross-sectional diagram of an eye.

In depth, retina is defined as a thin layer at the back of the eye. It is sensitive to light and it consists of several other components namely neuronal component, glial component and vascular component. Light is converted into electrical signal by neuronal component while glial components support the column in the retina. The most important component that the paper will thoroughly discuss is vascular components in the retina. As defined earlier, vascular is the arrangement of blood vessel that constitutes branches of central retinal artery. [3]Abnormal changes in the vascular component can cause danger in term of vision loss to the human eye. This complication is likely to be experienced by diabetic patients. The term referred to this disease is diabetic retinopathy (DR).

Diabetic retinopathy (DR) is known to be a major cause of adult blindness nowadays. There are two types of diabetic retinopathy; nonpoliferative (NPDR) which is the earlier stage of DR and poliferative (PDR) which is the final stage as it causes severe vision loss. The disease progresses slowly stage by stage. Often, in the earlier stage which is NPDR there are small amounts of fluid and blood leak into the eye as the blood vessels damage. At this stage, patients don't notice changes in their vision yet, but as it progresses towards PDR, the defect cannot be reversed once the blood vessels in the retina close and create another abnormal growth. PDR is dangerous to the patient since it can cause a complete blindness. Figure below shows an example of fundus image for normal eyes and patient with diabetic retinopathy. Notice the difference between the two images in term of retinal vascular distribution pattern. [11]

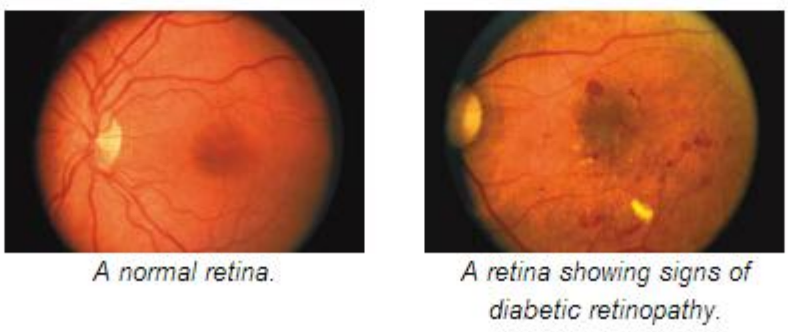

Figure1. 2: Fundus image for normal retina and diabetic retinopathy retina.

Therefore in order to avoid the problem, early prevention measures must be taken. This can be accomplished through diagnosing and analysing retinal images at regular intervals which is every six months to one year so that changes in blood vessel can be recognized earlier. Retinal images are also known as fundus or orcular images can be acquired by making photographs at the back of the eye using color cameras or through angirograms that use fluorescein as a tracer. These set of images will be further inspect by a specialist. Unfortunately, the process requires a lot of hard work and time due to the limited and outdated technology. Furthermore, the whole process demands thorough assessment from a qualified specialist. [1]

Hence, a simple computerized and automated blood vessel extraction and segmentation should be developed since retinal images provide information on severity of the disease which is diabetic retinopathy. The characteristic is that it has measureable changes in term of diameter, branching angles and length. By using computerized and automated method, it helps regular health workers to utilize it as it becomes simpler. Furthermore, lot of time can be reduced due to its simplicity. There are many methods of blood vessel extraction and segmentation that have been done before. Nevertheless, in this paper one is interested in using Gabor wavelet as to enhance blood vessel pattern of fundus image. [2]

Gabor wavelet is chosen based on its characteristic and efficiency that it imitates behaviour of human vision closely. It is widely used to detect changes on images that have regular or periodic texture and successfully installed in many vision applications mainly for texture detection purpose. By definition Gabor wavelets are a filter with each wavelet within the group captures energy at certain frequency, orientation and direction. Thus, enable it to decompose image into numerous orientations and scales. More explanation on Gabor wavelet will be in later section of the paper. [4]

1.2 PROBLEM STATEMENT

Detection of abnormal changes in blood vessel requires laborious work from a specialist. Thus the process takes a long time to be completed which make early detection of diabetic retinopathy becomes difficult.

1.3 OBJECTIVES

The objective of the project is to provide a simple and quick computer based analysis for initial inspection of diabetic retinopathy in order to enable prevention of major vision loss. [1]

1.4 SCOPE OF STUDY

The project aims to produce a computerized and automated system for vessel segmentation. The scope of study for the project is classified into two which is theoretical work and technical work. For this project to be completed one has divided the timeline for two parts according to the scope of study. Semester one will be devoted mainly for theoretical work as in study and research progress. Theoretical work is also an important part in the project for one to gather adequate information and knowledge regarding the subject. On the other hand, technical work will be carried out starting semester two. Technical work particularly for this project involves only software which is Matlab. This software will be used to develop a program for blood vessel segmentation.

2.0 LITERATURE REVIEW

Various methods have been developed in order to extract blood vessel segmentation from fundus image. According to a research paper entitled "[5]"; the paper reports that there are seven categories of different approach for retinal vessel segmentation. The seven methodologies are (1) pattern recognition techniques, (2) matched filtering, (3) vessel tracking/tracing, (4) mathematical morphology, (5) multiscale approaches, (6) model based approaches and (7) parallel or hardware based approaches. [5]

Figure below shows tabulation of data for number of articles produced according to each type of approach since 1982 until September 2011. [5]

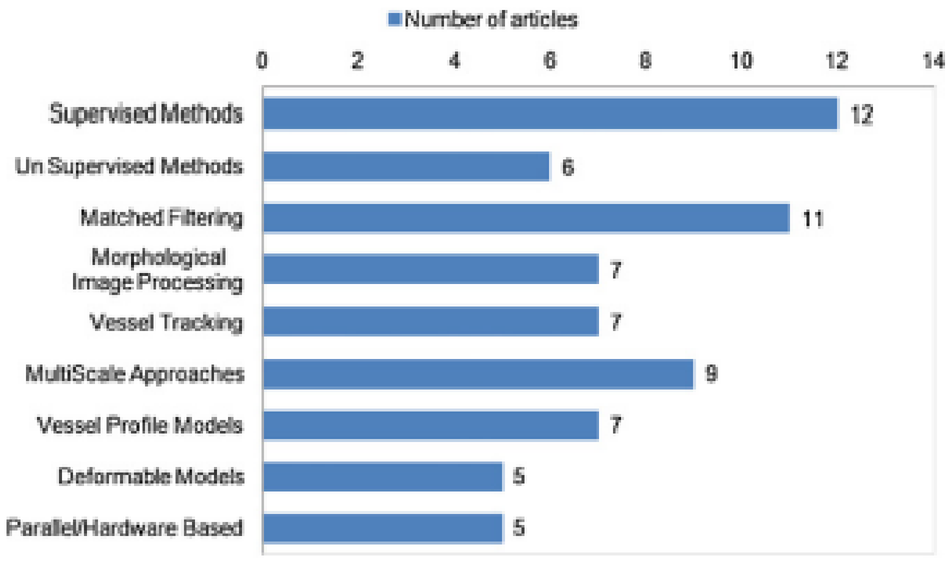

Figure 2.1: Article distribution frequencies on different approach. .

For this literature review section, one will use the data presented in the article as a guide to choose three approach to be reviewed from three most frequent articles produced. Based on the diagram, supervised methods indicate the highest frequency of article distribution which is 17%. The second highest frequency is matched filtering which is 16% followed by multiscale approach that dominates 13% of the frequency. [5] Therefore, three different approaches for blood vessel segmentation are set to be reviewed.

Based on each approach selected above, one article is to be reviewed in order to study methodology used for better understanding. The aim is to look for performance of each method. Table below shows the list of articles chosen for each approach.

Table 2.1: List of articles reviewed based on each approach.

Num.	Method	Article
1	Supervised Methods	A New Supervised Method for Blood Vessel Segmentation in Retinal Images by Using Gray-Level and Moment Invariants-Based Features
2	Matched Filtering	Detection of Blood Vessels in Retinal Images Using Two-Dimensional Matched Filters
3	Multiscale Approach	Real-Time Diabetic Retinopathy Patient Screening Using Multiscale AM-FM Methods

Based on the article "A New Supervised Method for Blood Vessel Segmentation in Retinal Images by Using Gray - Level and Moment Invariants - Based Features"; one found that supervised method are based on pixel classification that classified the image into vessel or non-vessel using neural network (NN) scheme. Pixel is represented using 7-D vector consists of gray-level and moment invariants. This is done by a trained person through supervised learning with data from manually labelled images. The performance is evaluated using DRIVE and STARE online databases that contain retinal images marked by professional. [6]

From the article "Detection of Blood Vessels in Retinal Images Using Two-Dimensional Matched Filters" a method of feature extraction for object to be recognized is introduced. The concept use is based on optical and spatial properties. Gaussian shaped curve is used to estimate the gray-level profile of the vascular pattern. Twelve different templates are developed in order to detect all possible vessel segments. Matched filters concept is applied for piecewise linear segments of vascular to be detected. [7]

The article "Real-Time Diabetic Retinopathy Patient Screening Using Multiscale AM-FM Methods" stated that multiscale approach is implemented using regions of interest concept. The procedure starts with a set of digital images taken from patients and it is normalized to ensure all images have consistent mean intensity. By using AM-FM texture features are computed using 13 combinations of scales. K-means cluster is applied in order to determine region of interest. The high dimensionality of the data is reduced using partial least squares and it is combine to produce final image grade.[8]

In conclusion, there are many ways to do vessel segmentation. Most popular methods are as reviewed above namely supervised method, matched filtering and multiscale approach. Based on the article, all methods work even though the concept used are totally different. However, the steps used are complicated to be implemented. Furthermore, some methods still require a trained person to handle the process. Besides, some of them are unfamiliar and rarely used in applications involving image processing and pattern recognition which make the result inefficient and unreliable.

3.0 METHODOLOGY

Based on literature review done on three different approaches of blood vessel segmentation in the previous section, one found that there is still room of improvement that could be made in order to develop a better system. However, before one comes to any conclusion, the challenge in segmenting vascular pattern should be addressed and well understood first. Fundus image includes wide range of vascular pattern in term of vessel widths, variety structures such as optic disc, retinal boundary and other pathologies. Besides, fundus image appear to be with low in contrast compared to the background. [2] Therefore, this situation should be addressed properly as it adds to more difficulties in handling vascular extraction later.

As stated in the background study earlier; Gabor wavelet seems to be the best approach to be implemented for this project. Gabor wavelet has the best characteristics for vascular extraction purpose in which it imitates the behaviour of human vision closely. Therefore, the result of vascular extraction by Gabor wavelet is more efficient that other approach. Besides, the ability to decompose image to different scale and orientation is very useful for this purpose. On top of that, Gabor wavelet has been widely implemented before in numerous vision machines and it is suitable for texture detection purpose.

Technically, Gabor wavelet means an elementary function that is developed to overcome limitation of Fouries analysis representation. Phase and magnitude can be obtained by analyzing a signal of Gabor wavelet. As a matter of fact, Gabor filters is recognized to be an important method in multiple applications involving image processing and pattern recognition. [9]Therefore, it strengthens one justification to implement Gabor wavelet in the project.

For better understanding, the basic process of vascular extraction is presented by a block diagram below.

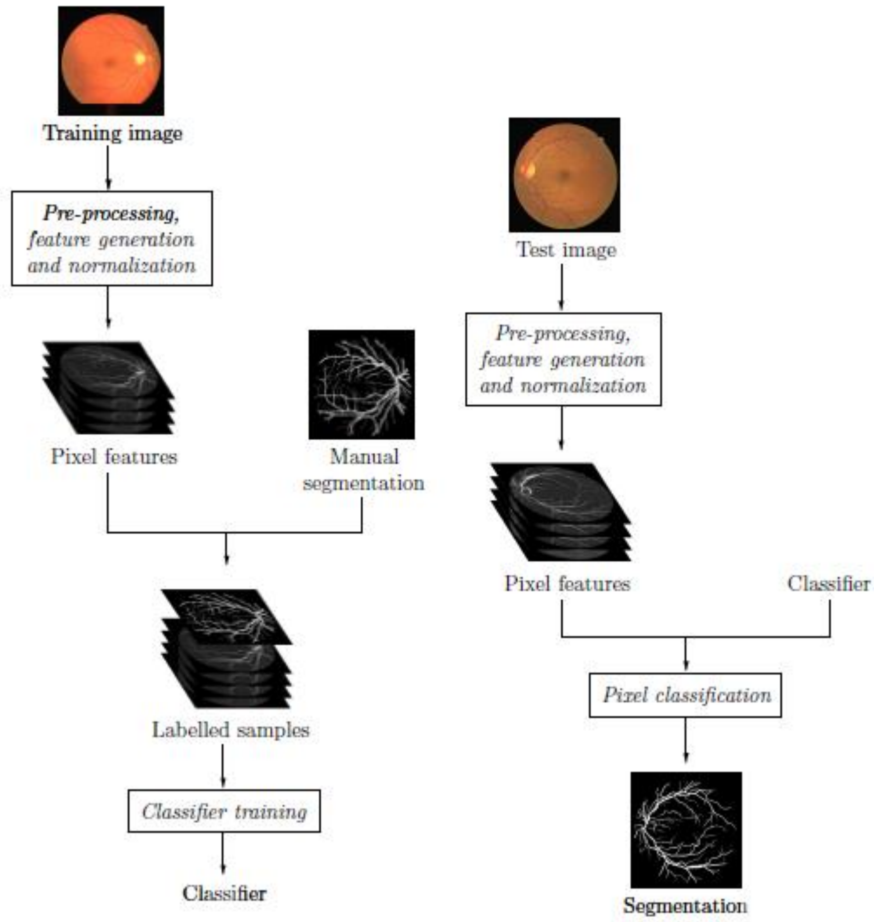

Figure 3.1: Flow diagram for vessel segmentation system using supervised pixel classification approach.

Referring to the flow diagram above there are two major process illustrated in which the left diagram shows supervised training of a classifier and on the right diagram shows the segmentation of test images. This is a standard procedure for any image processing method. In order to have a better understanding of the methodology used one shall explain the whole process step by step.

In any image processing system, the procedure starts with the process of training the classifier which is illustrated by the left flow diagram above. The training image will pass through pre-processing step for feature generation and normalization using green channel of RGB components. Green channel is used due to its high contrast against background image. Before applying any wavelet transform to it, the green channel is inverted to enhance vessel image against the background.

Pixel feature will be generated from the pre-processing step. When combine with manually segmented image will produce labeled samples. In order to get a complete classifier the labeled samples will go through classifier training. Once the process is complete the classifier is ready to be used. This supervised classification step is important as it serves as foundation for next classification process.

After classifier is obtained from the first process image are ready to be tested and segmented. Referring to the right diagram, segmentation process starts with pre-processing step of test image. Then, classifier is used to produce pixel classification. Pixel is classified into two classes which is vessel and non-vessel pixel. Therefore, retinal image is segmented. During this project one uses training and test image from DRIVE database which is online database which consists of retinal images for test purpose. There are also image which already manually segmented by professionals for training purpose.

4.0 RESULT & DISCUSSION

As proposed in methodology section, Gabor Wavelet is chosen to be the most suitable method for blood vessel segmentation. The idea is to classify vessel and nonvessel retinal image pixels by looking at pixel's feature vector composed of 2D Gabor wavelet transform at various scales. Due to its ability to tune to a specific frequency level; thus Gabor wavelet helps eliminate noise for image enhancement. [12]

Technically speaking, the project is based on implementation of Gabor wavelet and pixel classification using Matlab. There are sets of coding available in the network. One of the reliable sources for this particular project is from SourceForge.net which discusses Human-Machine Integration for Vessel Segmentation. [12]

As for the time being, the source code is still under integration and amendments. The challenge is the compatibility among devices and operation system of device. The code and sources are kept in different format which is unfamiliar from the typical software available inside a normal computer. The extraction and implementation of codes into Matlab become time consuming since one need to do a lot conversion, extraction and downloading new software that are compatible to the sources. [12]

On top of that, the Matlab implementation of blood vessel segmentation will be presented in the form of graphical user interface GUI as the final result. Referring to the diagram below, the figure shows a graphical user interface of blood vessel segmentation which is the final output of the project. There are several windows and dialogs illustrating the segmentation process which consists of main window, image window, classifier window, image segmentation dialog and segmentation result window.

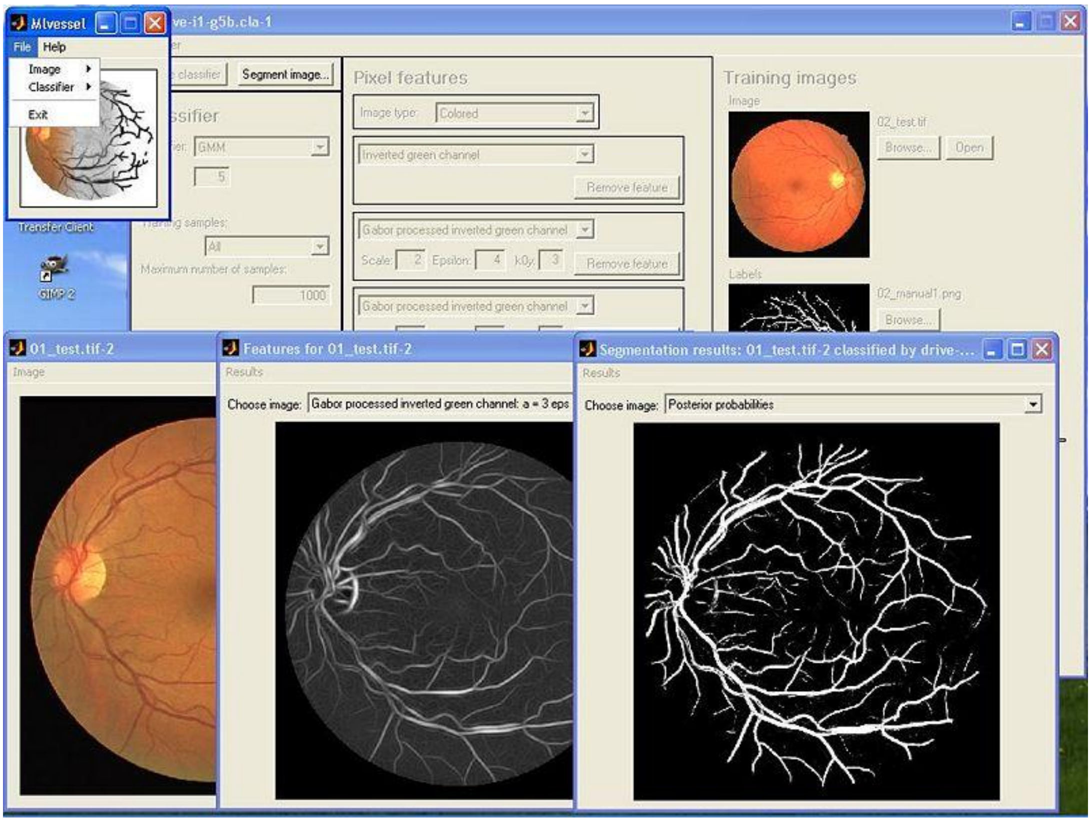

Figure 4.1: Windows and dialogs illustrating the segmentation process.

5.0 CONCLUSION & RECOMMENDATIONS

In conclusion, Gabor wavelet satisfies the needs of the project as it solves the problem regarding blood vessel segmentation extensively compared to other approaches presented in the previous literature review section. It wavelet is an ideal choice of method due to its characteristics and behaviour that follow human vision closely. Thus, the result will be more reliable and efficient. The final product of the project which is computerized and automated program using Gabor wavelet for vascular extraction is simple and practical for even regular health workers to use. On top of that, early inspection for diabetic patient can be done regularly due to the simplicity of the system. This helps save a lot of time and man power in health organisation too.

Even so technology is something dynamic that changes over time as people acquire more knowledge regarding the subject. Hence, further improvement research should be continued in order to develop better technology. As a matter of fact, information from blood vessel segmentation can be used to define various other health problems such as hypertension, diabetes, arteriosclerosis, cardiovascular disease and stroke. [1]The same principle of Gabor wavelet can be implemented to reveal these diseases as well. Thus the single software can be developed to carry multiple other purposes. The study should not stop here as the technology has a lot of potential.

As for now, the project shows a great progress in term accumulation of sources and references. Available research that is publicly published all over the network provides a lot of helpful information for the progress and improvement of the project. The single challenge for the project is the technical part which is to integrate every piece of information collected into one project for example to integrate all pieces of Matlab script and coding into one functional automated system. In addition, there is another technical challenge in term of software used for the project. Most of them are unfamiliar software which requires time for one to understand and familiarize with. However, it’s a great opportunity to learn and develop new skills.

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<http://sourceforge.net/projects/retinal/?source=dlp>

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http://www.parl.clemson.edu/~ahoover/stare/index.html

14 DRIVE:Digital Retinal Images for Vessel Extraction
http://www.isi.uu.nl/Research/Databases/DRIVE/

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APPENDICES

MILESTONES & GANTTCHART

Timelines for FYP 1

No.	Detail/ Week	1	2	3	4	5	6	7		8	9	10	11	12	13	14
1	Selection of Project Topic	■	■						Mid-semester break							
2	Preliminary Research Work		■	■	■	■										
3	Submission of Extended Proposal Defence						●									
4	Proposal Defence									■	■ ●					
5	Project work continues											■	■	■		
6	Submission of Interim Draft Report														●	
10	Submission of Interim Report															●

● Suggested milestone

■ Process

Timelines for FYP 2

No.	Detail/ Week	1	2	3	4	5	6	7		8	9	10	11	12	13	14	15
1	Project Work Continues	■	■	■	■	■	■	■	Mid-Semester Break								
2	Submission of Progress Report									●							
3	Project Work Continues									■	■	■	■	■			
4	Pre-SEDEX												●				
5	Submission of Draft Report													●			
6	Submission of Dissertation (soft bound)														●		
7	Submission of Technical Paper														●		
8	Oral Presentation															●	
9	Submission of Project Dissertation (Hard Bound)																●

● Suggested milestone

■ Process