AN EFFICIENT APPROACH FOR VISION INSPECTION OF IC CHIPS

LIEW KOK WAH

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SUPERVISOR'S DECLARATION

I hereby declare that I have checked this project and in my opinion, this project is adequate in terms of scope and quality for the award of the degree of Bachelor of Computer Systems and Software Engineering (Graphics & Multimedia Technology) with honors.

Signature
Name of Supervisor:
Position:
Date:

STUDENT'S DECLARATION

I hereby declare that the work in this project is my own except for quotations and summaries which have been duly acknowledged. The project has not been accepted for any degree and is not concurrently submitted for award of other degree.

Signature
Name:
ID Number:
Data:

Dedicated to my parents

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ABSTRACT

The research aims to develop an automated vision inspection system of IC chips that used to detect the defects of marking and design shape of IC chips. As a result of higher failure probability of manual inspection system, this automated system is developed. The automated vision system will consists of five main phases which are image acquisition, image enhancement, image, segmentation, comparison on features and decision making. The features will be extracted from the target image using projection profile method. The decision will be made using the trained neural network to identify the four common defects of IC chips which are illegible marking, upside down marking and missing character on chip. The results of the automated system are to determine whether to accept or reject the chip. The results are computed within 10 seconds and have a high percentage of defects detection which is about 95 %. Through the results obtained, the automated vision inspection system of IC chips can be utilized in the manufacturing field to replace the manual inspection system. It can replace about five to eight inspection experts to reduce the cost of hiring and resources in about 70%. Other than that, the rate of accuracy and efficiency of detecting the defects are improved by 95% because the consistency of inspecting the chips is maintained from having variations of judgments by the experts.

ABSTRAK

The research aims to develop an automated vision inspection system of IC chips that used to detect the defects of marking and design shape of IC chips. As a result of higher failure probability of manual inspection system, this automated system is developed. The automated vision system will consists of five main phases which are image acquisition, image enhancement, image, segmentation, comparison on features and decision making. The features will be extracted from the target image using projection profile method. The decision will be made using the trained neural network to identify the four common defects of IC chips which are illegible marking, upside down marking and missing character on chip. The results should be able to decide whether to accept or reject the chip. The results are expected to be computed within 10 seconds and have a high percentage of defects detection which is about 95 %.

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LIST OF ABBREVIATIONS

OPENCV	Open source Computer Vision
AI	Artificial Intelligence
Micro SD	Micro Secure Digital

CHAPTER 1

INTRODUCTION

1.1 INTRODUCTION

This project is generally about developing a computerized system to inspect Integrated Circuit chips. Integrated Circuit chips are the electronic circuits that are used in all electronic equipment such as the mobile phones, televisions, computers and other electronic appliances. The laser markings on the chips are found having the printing problem such as illegal markings which defines as unreadable words but the chips are still in the market sale. So, the project is introduced to overcome this main problem. This chapter provides background information about the project which includes background of the study, problem statements, research objectives, expected outcomes, significance of the study and scopes of the study.

1.2 BACKGROUND OF THE STUDY

Inspection of the Integrated Circuit (IC) chips is the method that arranges the chips according to the quality assurance standards. The chips that meet the standards will be delivered to the market. The chips that do not meet the required standards are blocked and may be for further detailed examination. The quality is ensured on the basis of the design architecture and the printed markings. The IC chips undergo many inspections and verifications to ensure a guaranteed quality.[1] Quality control of IC is performed by inspecting the design and the printed markings.[1]

At present, the inspection method is done manually in some electronic industries such as EISAI Machinery USA. Inc.[2] and Microtronic Inc.[3]. Such inspection is done off-line and frequently on sample basis by human operators. In addition to being expensive and time consuming, the results of such testing are also somewhat subjective due to factors such as fatigue and limitations of human visual consistency.[4] The manual inspection system does produce more accurate results but it is time-consuming job. The industries have to employ a large number of the experts to inspect the IC chips during the electronic productions. The employment method is applicable but it may affect economic condition of the industries and the definite availability of the experts cannot be ensured all the time. Even if there are enough experts, the efficiency may decrease proportionally with the growing age which eventually increases the inspection time.

Moreover, the experts have to inspect each product with their naked eyes and could cause lots of problems such as missed checking fail products, eyes problem and so on. In IC marking inspection, incorrect direction or marking will lead to incorrect placement of an IC on a printed circuit board (PCB).[5] Manual inspection of this kind is not only labor intensive and slow but also mistakes such as misjudgment and misobservation are easy to make. This situation results in unstable quality and high cost for the IC industry.[5]

In addition, quality control of the IC chips is very important and needs to emphasize the standardization of the design architecture and printed marking styles. Nevertheless, it does happen when there is a large group of inspecting experts working together and they may have different points of view on inspecting the same IC chips. It may cause variation among the experts. In manual inspecting markings on IC chips, an incorrect decision on marking may result in inappropriate placement of chip on printed circuit board during assembly process.[6]

In order to make the inspection system standardized, the automated inspection system is a better method to inspect the IC chips because the automated inspection system can be conducted within the defined parameters of standardizations, time, productivity and cost. The automated system can be set to fulfill the quality assurance standards. The automated inspection system is likely to reduce the inspection time. Besides that, the system is expected to bring economic relief for the industry because it would replace the experts. One obvious advantage is the elimination of human labor, which is increasingly expensive.[7] Human inspectors are slow compared to modern production rates, and they make many errors.[7] Other advantages of automatic operation are speed and diagnostic capabilities. Several practical reasons for automated inspection include:

(i) freeing humans from the dull and routine;
(ii) saving human labor costs;
(iii) performing inspection in unfavorable environments;
(iv) reducing demand for highly skilled human inspectors;
(v) analyzing statistics on test information;
(vi) matching high-speed production with high-speed inspection.[7]

In this research, a computerized inspection system will be developed and integrated into the inspection machine so that higher performance can be achieved.

1.3 PROBLEM STATEMENTS

The manual inspection system is likely to be costly and have probability of delaying the electronic productions. Besides that, different experts may produce variation in the results and on top of it, this requires larger inspection time. The consequence may lead to the economic burden on the electronic industries. Manual inspection may be unrealistic due to the high escape rate and lack of consistency from operator to operator [8]. Therefore, the computerized inspection system is proposed to be developed to overcome the problems.

1.4 RESEARCH OBJECTIVES

The objectives of the research are:-

(i) To develop a computerized inspection system to replace the manual inspection system
(ii) To reduce the failure rate of determining the defected chips
(iii) To enhance the system reliability to increase the productivity of the IC chips
(iv) To reduce the resources usage and cost of hiring inspection experts.

1.5 SCOPES OF THE STUDY

Due to the difficulty of getting IC chips, the system will only inspect micro SD memory cards images which are already captured by camera. However, the performance requirements such as high speed, accuracy, and reliability are often stringent [9]. The system can still be able to detect the IC chips because of inspecting the same element with micro SD which is the printed markings.

There are around two things involved in the implementation of the automated inspection system which are software and hardware. For developing software, the research uses OPENCV [10] which provides C programming library. The hardware needed for this research is a personal laptop with 4GB RAM and 320GB HDD and 2.53GHz processor. The system loads the image and the image is processed by the inspection system programmed in OPENCV throughout some main procedures of image processing.

1.6 CONCLUSION

Obviously, the manual inspection system causes problems on cost, productivity and performance. Therefore, an automated inspection system which will be developed in OPENCV is proposed to encounter the problems. The system should be composed with a suitable algorithm to perform as fast and accurate as possible. The system should have the faster speed, higher accuracy and lesser cost in the benefits for the industries.

1.7 THESIS ORGANIZATION

This thesis consists of six chapters and each chapter is to discuss the different issues in the project. Below that is the summary of the content for each chapter.

(i) Chapter 1 – Introduction
This chapter provides background information about the project which includes problem statement, objectives and scope.

(ii) Chapter 2 – Literature Review
Some literature and research which related to this project will be reviewed and discussed in this chapter.

(iii) Chapter 3 – Methodology
Data analysis, method and the procedure of this project development will be discussed.

(iv) Chapter 4 – Implementation
The implementation of the system using OPENCV will be explained in this chapter.

(v) Chapter 5 – Results and Discussion
This chapter will present the testing result of the system and result on the discussion.

(vi) Chapter 6 – Conclusion
A complete summary of the project will be presented in this chapter.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

This chapter briefly discusses about the literature reviews for the current research on vision inspection of Integrated Circuit (IC) chips. The reviews basically focus on the types of techniques used in the existing systems. There are four major sections discussed in this chapter as listed below to have some reference materials on implementing the automated inspection system of this project.

(i) Existing Systems Reviews
(ii) Vision Inspection Techniques
(iii) Feature Extraction Techniques
(iv) Artificial Neural Networks

2.2 EXISTING SYSTEMS REVIEWS

This section is to review four existing systems that are similar to the current research. Section 2.1.5 will discuss the relationships between the existing systems and give a preview for the vision inspection techniques. The four existing systems are listed as below:

(i) Real Time Marking Inspection Scheme for Semiconductor Industries
(ii) An Automated IC Chip Marking Inspection for Surface Mounted Device
(iii) An Intelligent Vision System for Inspection of Packaged ICs
(iv) Automated Vision System for Inspection of IC Pads and Bonds

2.2.1 Real Time Marking Inspection Scheme for Semiconductor Industries

The real time vision inspection system was able to inspect the laser-printed marking on the IC chips and classify into accepting or rejecting region. The system could generally identify the laser printing errors such as illegible characters, missing characters and upside down printing. The vision inspection technique used was the feature extraction method. The feature extraction method was the projection profile method which extracted the pattern of row-sum and column-sum of white pixels and then defined the feature of each character. The Artificial Intelligence (AI) technique used was the forward neural network which was trained with varied input sizes and back propagation training algorithm [1].The processing time for the projection profile method was in the range of 0.19 to 0.21 seconds for each methodology. Besides that, the number of inputs to the neural network had been optimized for fast processing and it was determined to be 75 neurons for a momentum factor of 0.87 and a learning rate of 0.25. The neural network had been trained to indicate whether the IC marking is acceptable or classify the marking errors if not acceptable.

2.2.2 An Automated IC Chip Marking Inspection for Surface Mounted Device

The automated inspection marking on surface mounted device was prior to the IC packaging. The overall inspection scheme consisted of loading/unloading mechanism, image acquisition system and marking inspection system. The marking inspection system included the process of image filtering, character segregation and automatic character recognition with neural network which was trained by linear vector quantization scheme. The automated inspection system was built to replace the manual inspection system which always resulted in incorrect decision making of classifying the quality of IC packaging. It was used to ensure the high rate and speed of recognition as well as the real time inspection capability. Before the image filtering, the target image was found using template matching with normalized cross-correction algorithm and multi-resolution pyramid image processing technique. By this approach, this inspection system was able to inspect each IC marking in less of one seconds and three IC chips at the same time. The recognition rate was 99.14% which showed that the contour profile method is also a preferable method to extract the features from the IC chips.

2.2.3 An Intelligent Vision System for Inspection of Packaged ICs

The vision inspection system aimed for IC packaging which were IC leads and IC surface quality. Due to the subtle changes in illumination angles could cause a good IC lead to be classified as defective one, the system was claimed to be the solution while provides the short real-time processing time. The defects of the IC packaging were recognized by comparing the image data with a predefined threshold value. The lead inspection uses the cross-mark edge detector and the moments analysis approach while the solder quality inspection applies the profile data collection method with gray level pixels. Besides, the surface fault inspection uses the profile method and the corner classification method [11]. By the approach, the result was desired in which the accuracy in detecting the defects on the IC packages was 95 %. However, the whole inspection process took about 11 seconds which was not ideal for computational speed. The correct threshold value during the preprocessing phase was important in providing reliable results.

2.2.4 Automated Vision System for Inspection of IC Pads and Bonds

The automated vision system inspected the bond pads and bonds of IC wafer. The inspection system included pre-bonding and post-bonding inspection. It was used to replace the off-line inspection which was expensive and time-consuming. It was a matter of fact too that the packing density of IC chips increased continually [12]. This system used feature extraction technique to obtain the needed information easily. Instead of using projection profile method, the system used moments method which was also a type of feature extraction techniques. For pre-bonding inspection, the processing time took about 0.007 seconds per image while for the post-bonding inspection, it took about 0.125 seconds to complete all the stages of computation. The results were satisfied in overall performance but the use of run-length encoding did make the program complex and lengthy and it might make the maintenance duration longer to enhance the algorithm in it.

2.2.5 Discussions on existing systems

By going through the existing systems, there are some common features can be the reference of the current research which are the overall process for the inspection schemes and the vision inspection technique used in the existing systems. The overall process for the inspection scheme is listed in sequence:

(i) Image Capturing/ Acquisition
(ii) Image Preprocessing (Image filter, Image Transformation, Thresholding, Contour Search)
(iii) Image Segmentation(Select the region of cropping and for the use of feature extraction)
(iv) Feature Extraction
(v) Artificial Intelligence Recognition (Neural Network Algorithm)
(vi) Decision Making/ Output from Recognition

The processes above are followed by the existing systems in Section 2.1.1, 2.1.2 and 2.1.3 while for Section 2.1.4, the system followed the process similarly because the target inspecting object is not same with the other systems. Each system used different type of vision inspection techniques. There are types of vision inspection techniques will be discussed in the Section 2.2 to know the difference and determine the better technique to be used in current research.

2.3 VISION INSPECTION TECHNIQUES

This section will discuss about comparison on several inspection techniques which are as follow:

(i) Comparison Based on Pixels
(ii) Comparison Based on Features
(iii) Comparison Based on Generic Property
(iv) Comparison Based on Gray Relationship

2.3.1 Comparison Based on Pixels

Pixel-by-pixel comparison is one of vision inspection techniques. The concept of pixel-by-pixel comparison method is a traditional but simple and straight forward way to be used in inspection system [8]. Almost all commercial machines for vision inspection utilize this comparison method because of its simplicity and the built-in cost.

There are three major sequential process included in the comparison method. At first, an image is captured from a good product which is free from error of printed marking and design architecture. The defect-free image is then used as a reference image for the inspection scheme. The reference image is a gray scale image because the gray level value of each pixel is needed to be compared with the target gray scale image of the inspecting product.

Secondly, the product to be inspected is placed under the camera to be captured as an image. After the image is generated, it needs image preprocessing certainly to enhance the quality of the image besides avoiding the blurry and noisy image from disturbing the inspection system by making wrong decision on good product. Third, the enhanced image is properly aligned to the reference image which is stored in computer memory. Then, the gray values are compared pixel by pixel from the same coordination of the reference image and the target image. Both images have to be in same dimension.

A subtraction process is applied when comparing in order to evaluate the subtracted value either exceeds a preset threshold or is zero. If it is zero, then the target pixel is perfectly matched with the reference pixel. If it exceeds the threshold value, the target pixel is bad.

There is also a situation that compares pixel by pixel in color where Ito [13] had developed such method. The reference product is illuminated by red light while the target product is illuminated by green light. The two images are projected onto a screen to get a composite image where black or yellow pixels are error-free but red or green pixels will indicate that the target pixel has defect.

2.3.2 Comparison Based on Features

Feature extraction method is also the vision inspection technique and is commonly used in the existing system with better storage utilization compared to pixel-by-pixel comparison method because the storage of the reference image is not needed [8]. Instead, features which are a set of characteristic identification are extracted from the reference image. The extracted features are stored as the reference feature vector. Then, the image of the target product is also taken but feature extraction still applies on it. Subtracting reference feature vector from target feature vector will product the feature difference vector which is then examined according to the inspection scheme criteria.

Jarvis [14] has designed an inspection system for the Western Electric Series 700 connector, a slotted U-shaped contact preassembled in a two-piece sealant-filled plastic housing. Connection is made by compressing the housing to make the contact cut through the wire's insulation, and the connector is inspected by viewing it from the side using transmitted light. Nine features in terms of gray-level intensities in the contact and sealant areas characterize a connection, and an inspection algorithm involving these features and their predetermined thresholds separates the good from the bad parts.

In the feature inspection method, a set of specific and various features always characterize a satisfied product. However, features are not always found easily and clearly defined when dealing with complex products. In the regards, different techniques in feature extraction method are capable of dealing with different inspection situation.

2.3.3 Comparison Based on Generic Property

Generic property verification is one of the vision inspection techniques too. Instead of comparison between reference image and target image, generic property verification is commonly regarded as the non-reference method which does not compare any images. The generic property verification depends totally on a set of general rules which is transformed from the knowledge of localized generic properties [8]. Then, a small window is moved over the whole target image to investigate the particular window area only by detecting the defect with the set of general rules.

Other than investigation with a set of general rules, the localized generic properties can also be represented through a set of structural or grammar rules. The input pattern is first extracted and processed and then represented by a string. After that, the local defects are determined by applying the grammar rules to the string. Jarvis [15] had designed a grammar that characterizes a few defects of printed wiring boards. A string is generated from preprocessing of the conductor boundary pattern of the board under inspection.

2.3.4 Comparison Based on Gray Relationship

The gray relational analysis method which is also the vision inspection technique expresses the relationships between a system and its subsystems and the relationships among the subsystems. The overall system and subsystems generally contain the "gray" information. The fundamental concept of the method is a ranking scheme that ranks the order of the gray relationships among several subsystems. Take the curves in Figure 2.2.1 (a variable is changing to the time) as an example of relation of different curves; curves (1) and (2) are intuitively more similar than curves (1) and (3). Curves (1) and (4) have the most difference. Therefore, the ranking of their relations are [curves (1) and (2)] [curves (1) and (3)] [curves (1) and (4)]. [16]

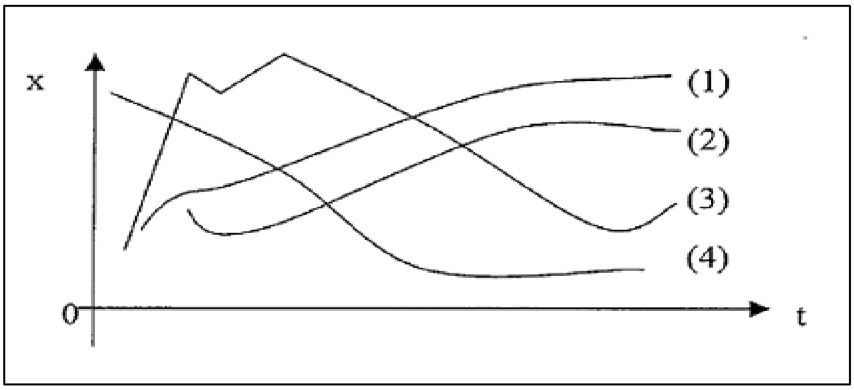

Figure 2.3.1: Gray Relationship Curves [16]

There are measures called localizes or globalized gray relation measure which differ from the availability of sets as reference set to express the gray relationship between two sets.

2.3.5 Discussion on Vision Inspection Techniques

The common vision inspection technique used in the existing systems is the feature extraction technique as it can give better storage utilization in which the storage of the reference image is not needed. It is an easier technique that can extract useful information from the region of interest of an image. Pixel-by-pixel comparison would require storage of the reference image and much comparing time. The generic property verification needs set of general rules to be compared at which it is a long procedure to determine the rules while gray relational analysis method emphasizes on the gray values for comparison which is not so suitable for the IC chips inspection.

From the discussion above, it is clear that feature extraction techniques are better than the other vision inspection techniques due to its better storage utilization and only process related information that can reduce the computational cost. The types of feature extraction techniques will be discussed in the Section 2.3 to know the difference and determine the better technique to be used in current research.

2.4 FEATURE EXTRACTION TECHNIQUES

This section will explain about comparison between few types of feature extraction techniques which are commonly used in the existing systems. This section will also provide a clear and understandable way to present how the types of the feature extraction techniques work. There are three types to be presented in following sub-section:

(i) Projection Profile
(ii) Moments
(iii) Contour Profile

2.4.1 Projection Profile

The projection profile method was the feature extraction that involved the row sum and column sum of white pixels [17]. The feature of each character on printed marking was defined from the pattern of the row-sum (P_h) and column-sum (P_v) of white pixels.

Let S (n, m) represents a binary image of n rows and m columns. Then, the sum of white pixels of each column perpendicular to the x-axis is defined from the vertical profile so that it is represented by the vector P_v of size m as defined by

$$P_{v[j]} = \sum_{i=1}^{n} s[i,j] \quad j = 1,2,3,\ldots,m \tag{2.4.1}$$

The horizontal profile is the sum of white pixels of each row perpendicular to the y-axis so that it is represented by the vector P_h size n, where

$$P_{h[i]} = \sum_{j=1}^{m} s[i,j] \quad i = 1,2,3,\ldots,n \tag{2.4.2}$$

Then the projection profile is defined as $P=\{P_v, P_h\}$ [1].

2.4.2 Moments

The moments method was also a feature extraction technique used in recognizing printed and handwritten characters and also pattern recognition [18]. Central moments was a faster type of moments used for recognition of characters compared to Zernike moments and moments invariants [1]. Central moments of the binary image for each column of the image orders which started from order 1 could be obtained. In the order 1, moment values were zero. If the orders were more than 3, it produced smaller and smaller moment values.

2.4.3 Contour Profile

Contour profile is one of the basic and important feature extraction techniques used for object identification in the field of pattern recognition [19]. Besides from pattern recognition field, contour profile method can also be used in IC chip marking. A cropped binary image of character ‘2’ is shown in Figure 2.4.1. The outer vertical and horizontal profiles of white pixels in black background are computed. The contour projection is shown in Figure 2.4.2.

Figure 2.4.1: Cropped binary character[19]

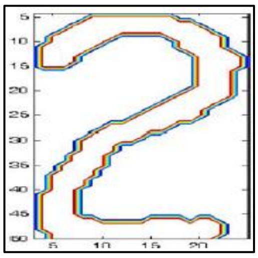

Figure 2.4.2: Outer profiles of white pixels and black background [19]

The features which were concerned in the contour profile are the character width, ratio, location of extrema (minima/maxima) and discontinuities. The contour profile technique uses few properties therefore the system is likely to be computed slowly.

2.4.4 Discussion on Feature Extraction Techniques

The systems in Section 2.1.1 and Section 2.1.3 used the projection profile method. The system in Section 2.1.2 used the contour profile method while in Section 2.1.4, the system used the moments method. From the results obtained in every system, the projection profile method was the fastest and most efficient among the other feature extraction methods. Going through the reviews on the feature extraction techniques in this section, projection profile method was suitable also for the current research because it was easy to implement for both IC chip design and marking. Unlike the contour profile and moments, both techniques were not easy to implement for both IC chip design and marking.

2.5 ARTIFICIAL NEURAL NETWORK

There are many AI techniques around the world such as neural network, fuzzy logic and expert systems. This section will only explain about comparison between feedforward and recurrent neural network to be determined for the use of current research because neural network can solve more complicated problems easily once it is trained well.

(i) Feedforward Neural Network
(ii) Recurrent Neural Network

2.5.1 Feedforward Neural Network

Feedforward neural network was the artificial neural network where there was no cycle in the network. All information would only be transmitted straight from the input nodes to the output nodes through the hidden nodes in only one forward direction. There were two basic types of feedforward neural network which are single layer and multilayer. Single layer was the simplest type so it was not discussed. Multilayer was the feedforward neural network where it consisted multiple layers including interconnecting nodes such as input, hidden and output nodes. Hidden nodes were grouped into few layers to compute such values from predefined functions such as the sigmoid and linear function.

Neural network should learn wisely so that it could encounter any inputs without errors. There were few types of learning patterns which are supervised learning [21], unsupervised learning [21] and reinforcement learning [21]. Supervised learning was about the training process with providing the input and output patterns to the network. It would let the network self-supervise to match the computed output with the given output so that the network would repeat the whole process again until the outputs were matched. Unsupervised learning required self-organization where there are no categories of the patterns to be classified. So the network needed to classify the output itself within the input. The reinforcement learning also could be self-organizing in which the outputs were generated with the parameters adjusted based on the environmental response.

Supervised learning was the suitable learning pattern for the current research because it required the input and output patterns to learn while the current research could train the network with the reference images as the output patterns. In common, backpropagation is the supervised learning algorithm which is very easy to be implemented. Backpropagation required weight adjustment when there is error signal occurs. The weight adjustment would depend on the activation function used. If the activation function was the sigmoid function, then the weight adjustment would be:

The weight was adjusted by an amount proportional to the product of an error signal δ, on the unit k receiving the input and the output of the unit j sending the signal [21]:

$$\Delta_p w_{jk} = \gamma \delta_k^p y_j^p. \tag{2.5.1}$$

If the unit was an output, then the error signal was given by

$$\delta_o^p = (d_o^p - y_o^p)\,\mathcal{F}'(s_o^p) \tag{2.5.2}$$

Where

$$y^p = \mathcal{F}(s^p) = \frac{1}{1+e^{-s^p}}. \tag{2.5.3}$$

For F’ (s^p) , it could be derived from

$$\begin{aligned}
\mathcal{F}'(s^p) &= \frac{\partial}{\partial s^p}\frac{1}{1+e^{-s^p}} \\
&= \frac{1}{(1+e^{-s^p})^2}(-e^{-s^p}) \\
&= \frac{1}{(1+e^{-s^p})}\frac{e^{-s^p}}{(1+e^{-s^p})} \\
&= y^p(1-y^p).
\end{aligned} \tag{2.5.4}$$

Finally, the error signal for an output unit can be written as

$$\delta_o^p = (d_o^p - y_o^p)\, y_o^p(1 - y_o^p) \tag{2.5.5}$$

The weight and the error signal are very important as both of them are used to determine the output generated by the neurons in each layer. Every neuron outputs continue adjusted until the output layer gives a precise and accurate results.

2.5.2 Recurrent Neural Network

Recurrent neural network was the artificial neural network where there were one or more cycles in the network. The cycles are the connection between the nodes where they form a directed cycle which the network will continuously compute the output in certain node until it is satisfied. The recurrent neural network will need to have a short-term memory to store the previous state output to be used as inputs and reprocess until the desired output is generated.

Hopfield neural network [22] was the one of the earliest recurrent neural networks in literature. It had a group of neurons with connections between each node I and j where i = j. For this particular neural network, all the nodes were both inputs and outputs. The interconnected nodes will keep updating their values independently of other nodes from the activation function. The activation values are only binary.

A simple threshold function is applied to the net input to obtain the new activation value y_k (t+1) at time t+1.

$$y_k(t+1) = \begin{cases} +1 & \text{if } s_k(t+1) > U_k \\ -1 & \text{if } s_k(t+1) < U_k \\ y_k(t) & \text{otherwise,} \end{cases} \tag{2.5.6}$$

As such, the state of the Hopfield neural network is given by the activation values y = (y_k). The net input s_k(t+1) of a node, k at cycle t+1 is a weighted sum

$$s_k(t+1) = \sum_{j \neq k} y_j(t)\, w_{jk} + \theta_k. \tag{2.5.7}$$

By using Hopfield neural network, it is likely to be not cost-effective due to its recurrent characteristic which requires continuously computation of the output in certain node until it is satisfied

2.5.3 Discussion on Artificial Neural Network

After reviewed on both feedforward and recurrent neural network, feedforward neural network with backpropagation learning algorithm could help the current research in determining the target IC chip defected or not because it was easy to implement and was applicable with the research as it required the input and output patterns during the learning process.

In another point of view, taking concern of the cost, reliability, productivity and efficiency, feedforward neural network is better than recurrent neural network. In technical point, feedforward neural network requires lesser storage utilization and performs faster than recurrent neural network because it does not need store previous output state until desired output is generated.

2.6 CONCLUSION

In this chapter, four systems had been reviewed and the overall inspection processes were obtained. There were four types of vision inspection techniques investigated and it came to a decision that feature extraction technique is the better solution as it is an easier technique that can extract useful information from the region of interest of an image. After that, the types of feature extraction techniques were also analyzed to determine a good method which is projection profile method as it is easy to implement for IC chip marking. Finally, the neural network chosen is feedforward neural network with backpropagation learning algorithm because it fits with the current project. The application of the projection profile method and feedforward neural network will be discussed in the next chapter.

CHAPTER 3

METHODOLOGY

3.1 INTRODUCTION

This chapter describes about the system development processes and also the methods of collecting and analyzing image data.

The research needs a steady and efficient software development model to be followed so that the research will be completed without problems. Waterfall model is meant to be the ideal model to be followed where it flows steadily downwards through Requirements, Design, Implementation, Verification and Maintenance [23]. The five phases are the main stages out of eight stages in the waterfall model. From the main phases listed, the research can be done accordingly and well-planned in order to develop a good system. Time spent early in the phases can lead to much available time to conduct the processes at later phases.

3.2 PROJECT PLANNING

In the research, the development flow should be planned well and completely from background study until the final system release. The development should not be delayed because the research must be ended around a year. The research will be conducted under the waterfall model which provides a strict environment where each phase must be finished before proceeds to the next one. If there is a change in a phase, it will delay the whole development. In this regards, the revision of any phase is not encouraged once the phase is complete unless there is a need to make a deep change in the phase. The desired development flow regards to the waterfall model is shown in Figure 3.2.1.

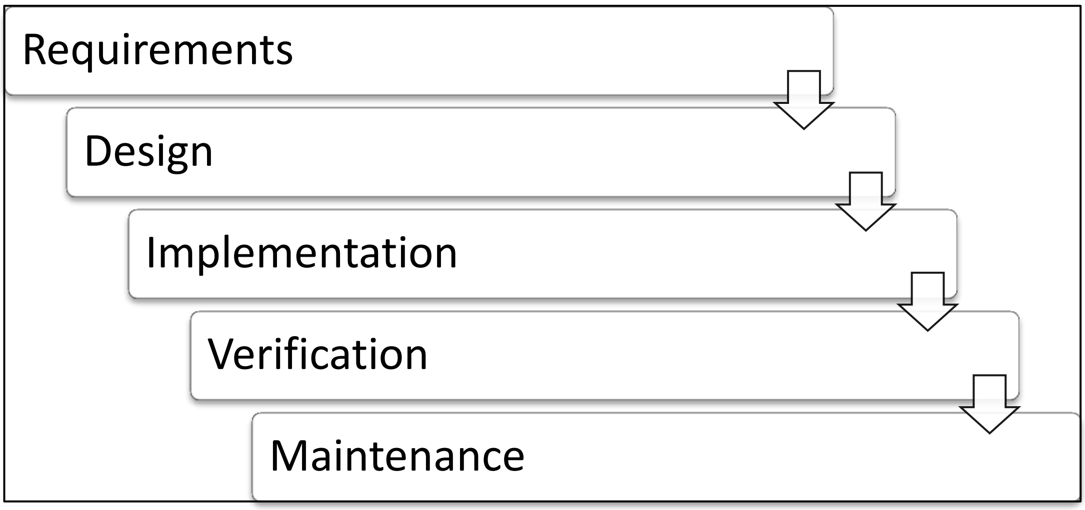

Figure 3.2.1: Waterfall Model

The first phase, requirements phase explains about the planning for preparing the tangible and intangible materials such as the required hardware and software, the knowledge about the research and so on. The hardware and software are the laptop, OPENCV, Microsoft Word 2010 and so on. Literature survey is conducted to get more information about the available vision inspection techniques and the performance of every technique. The second phase, design phase describes about the overall system operations flow to be completed which starts from image acquisition until decision making of choosing IC chips. The implementation phase mostly describes about the implementing the image processing techniques found in the system operations flow with OPENCV. The verification phase has the testing conducted on the system implemented with OPENCV during the implementation phase before. During the last phase, maintenance phase will explain on the maintenance flow after the system release.

3.3 WATERFALL MODEL

Waterfall model is typically an old type but sequential methodology for software development processes. The waterfall model requires a completion of the phase before proceeding to the next phase. The research needs to conduct various processes to develop the system step-by-step. In this regards, the waterfall model is chosen to be the development model of the current research.

3.3.1 Requirements

During the requirements phase, lots of information is collected regarding to the vision inspection system problems background, vision inspection techniques and implementation of OPENCV on vision inspection techniques. The hardware and software required for the research will be acquired after complete the information collection and analysis. In this phase, the knowledge of image processing, vision inspection techniques and OPENCV are necessary to be explored because the knowledge is needed much in the following phases.

3.3.2 Design

The design phase will mainly emphasize on the flow of the system operations. It should be the system architecture that is needed to be followed sequentially by the system. Figure 3.2 shows the whole vision inspection scheme. Figure 3.3 shows the architectural view of the system which consists of five main processes:

(i) Image Acquisition
  a. The system first loads an image with micro SD memory cards.
  b. The loaded image will then be processed in the preprocessing process.

(ii) Image Enhancement/ Restoration
  a. The image is then processed using morphology which is dilation and erode as well as threshold process so that the required information can be greatly visible and extracted well.

(iii) Image Segmentation
  a. It mainly zones the image to only the laser markings.

(iv) Comparison on Features
  a. Projection profile method will be used to extract the features for the segmented part.
  b. While extracting the features from the inspecting image, the neural network is trained to generate results according to the input later.
  c. The result is generated using feedforward neural network with backpropagation algorithm.

(v) Decision Making

a. After result is determined, the system will determine whether the IC chip should be accepted or rejected.

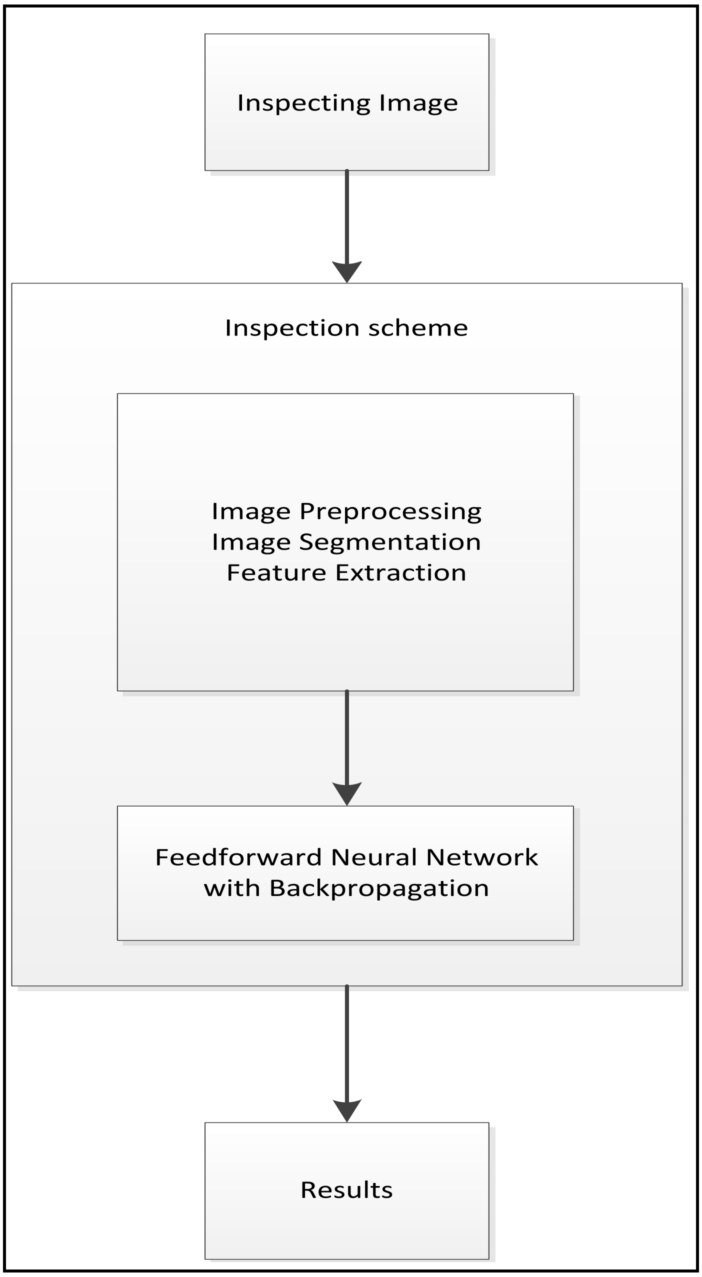

Figure 3.3.1: Vision Inspection System Scheme

The similarity percentages should be more than 95 percent to make accurate decision in either accepting or rejecting the IC chips. The overall system processes should not be more than 10 seconds per chip.

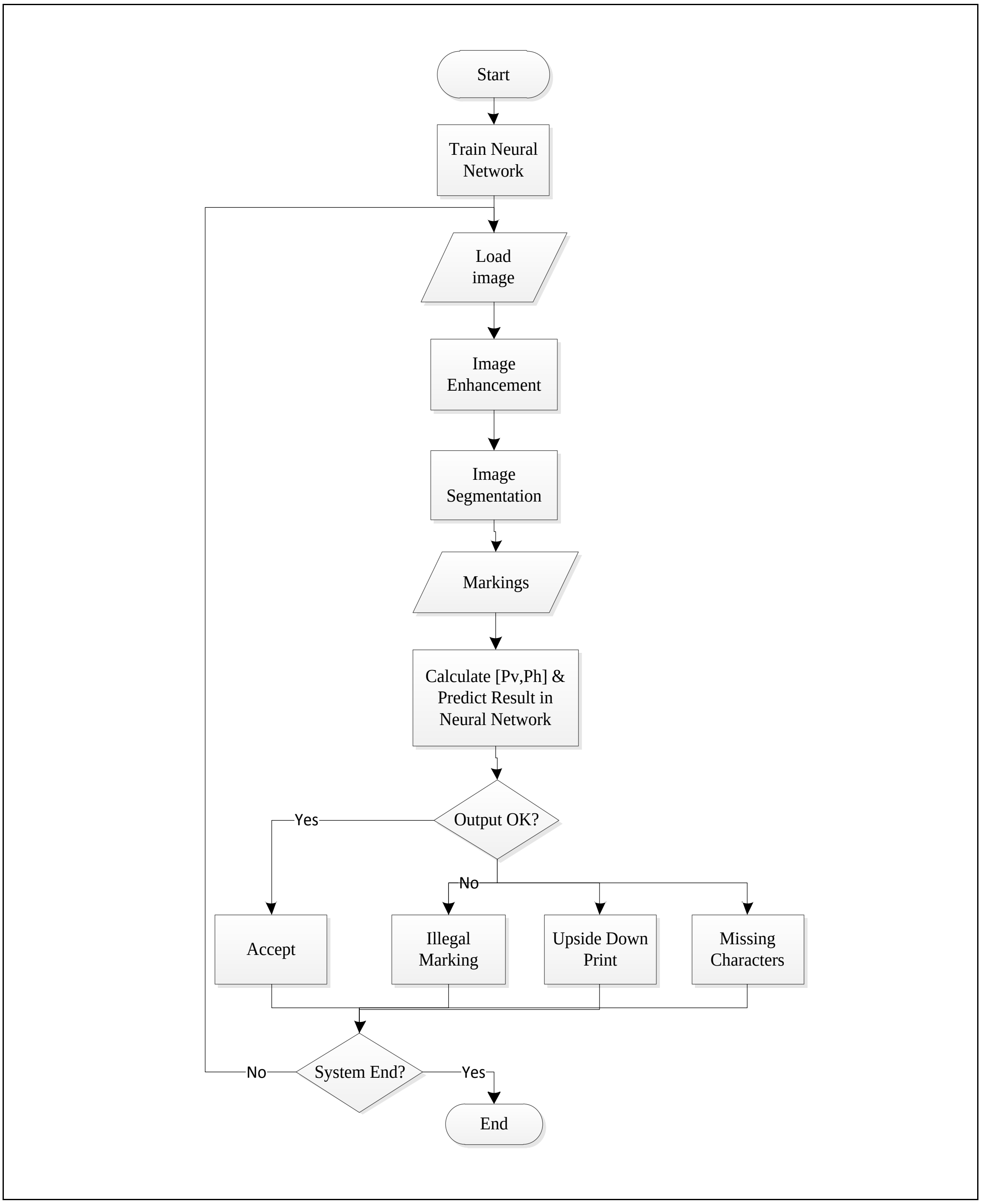

Figure 3.3.2: Vision Inspection System Flowchart

3.3.3 Implementation

The implementation phase mostly describe about the implementing the image processing techniques found in the system operations flow with OPENCV. OPENCV can be implemented in Microsoft Visual Studio 2010 because it supports C++ programming. OPENCV library provides lots of built-in functions to ease the users in processing image. The data types and call functions are all created in the library so that the users can focus on the algorithm programming part to develop the system. Table 3.3.1 lists the examples of data types and functions found in the library [10].

Feature extraction technique is the vision inspection technique to be used in the system and the algorithm used in the technique is the projection profile because it can produce better results in faster computation time. The artificial intelligence technique used in the system will be neural network technique. The input will be the projection profile data produced from the feature extraction process. Figure 3.4 shows the example of neural network for projection profile [1].

Table 3.3.1: Examples of Data Types and Functions

Data Types	Functions
IplImage	cvLoadImage
CvCapture	cvShowImage
CvSize	cvReleaseImage
CvRect	cvGetCaptureProperty

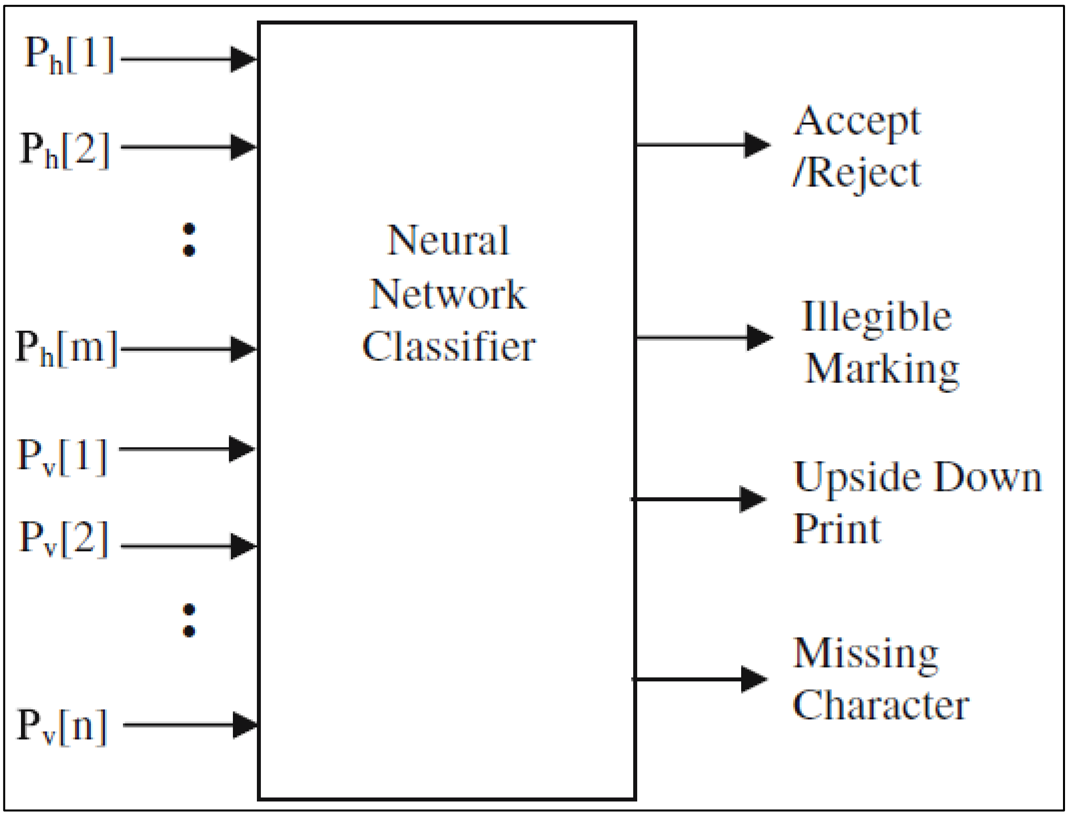

Figure 3.3.3: Example of Neural Network for Projection Profile [1]

3.3.4 Verification

After implementing the algorithms and inspection technique into the system with OPENCV, the system needs to be verified before it can be released finally. The verification is essential in order to ensure the system quality and system performance is in expectation. The testing parameters will be according to the performance, computation time, error handling responses and system bugs finding. If there is issue to be changed, the system will have either minor or major modification depending on the severity of the issue.

3.3.5 Maintenance

When the verification is complete, the system should be in a final release with good performance and error handling response as well as bug-free. After the final release, the maintenance may still be needed in case there is unknown problem occurred. If it is, the system will be verified again to be modified and tested until it is solved.

3.4 PROJECT REQUIREMENTS

The research requirement such as hardware and software are listed in Table 3.4.1 and 3.4.2

Table 3.4.1: Software Required

Software	Acquisition	Purpose
OPENCV 2.2	Open Source	To provide image processing library in C++
Microsoft Visual Studio 2010	From University Malaysia Pahang	To develop the system in C++ platform
Microsoft Word 2010	From University Malaysia Pahang	To do documentation

Table 3.4.2: Hardware Required

Hardware	Specification	Purpose
Laptop	Intel Core2Duo P8700 2.53GHz , 4GB DD2 RAM, 500GB HDD, Windows 7 Ultimate 64bit	To provide the environment for documentation and system development

3.5 CONCLUSION

The current research is conducted according to traditional waterfall model which consisted of planning, design, implementation, testing and maintenance phases. There are five main processes which are image acquisition, image preprocessing, image segmentation, comparing on features and decision making in the system. The system run through few tests to be verified and released so that there is no maintenance needed in the future.

CHAPTER 4

IMPLEMENTATION

4.1 INTRODUCTION

This chapter explains about the processes that involve in the development of the designed vision inspection system including the related C coding for certain process. The processes are basically the image processing steps that are discussed in Section 2.2.5.

(i) Image Acquisition
(ii) Image Preprocessing
(iii) Image Segmentation
(iv) Feature Extraction
(v) Artificial Intelligence Recognition
(vi) Decision Making/ Output from Recognition

4.2 PROJECT DEVELOPMENT

The project development mainly depends on the system implementation processes which can be divided into two parts. The main part of system implementation focuses on OPENCV library which provides handful functions to process the images. The used functions are discussed in Section 4.2.1: OPENCV in Visual C++. The secondary part of system implementation is about the graphical user interfaces that provide the system users to interact with the inspection system. The user interfaces are simple but effective enough to show the details of the inspection process.

4.2.1 OPENCV in Visual C++

The functionality of OPENCV is explained in different image processing steps throughout the inspection system.

4.2.1.1 Image Acquisition

During this step, image is loaded into the system to be processed and identified as either accept or reject in the form of illegal marking, missing characters and upside down print.

Load image from folder	IplImage* image = cvLoadImage("First_Pass7_1.tif", CV_LOAD_IMAGE_GRAYSCALE);

Figure 4.2.1: Image Acquisition Coding

4.2.1.2 Image Enhancement/ Image Restoration

In this step, restoration is a must because the image captured has some distortion around the markings on the chip. Therefore, morphology is used in this step. Enhancement is not needed because the image has already been processed under threshold function and the marking is clear to be extracted.

```
cvErode(image,image);
cvThreshold(image, image, 100, 255, CV_THRESH_BINARY|
CV_THRESH_OTSU);
cvDilate(image,image);
```

Figure 4.2.2: Image Restoration Coding

4.2.1.3 Image Segmentation

During this segmentation step, the range of interest is determined to be able to focus on the markings only.

```
ROIImage=cvCreateImage(cvGetSize(image), image->depth, image->nChannels);
cvCopyImage(image, ROIImage);
cvSetImageROI(ROIImage, cvRect(x, y, width, height));
```

Figure 4.2.3: Image Segmentation Coding

4.2.1.4 Feature Extraction

In this step, the projection profile method is being implemented after the pixel values become only 0 and 255 which represent black and white respectively. The pixel values are then stored in a double array variable. After that, the values are total up based on column or row.

```
uchar pixel[HEIGHT+1][WIDTH+1];
for (int row=0;row<HEIGHT;row++)
{
	for (int col=0;col<WIDTH;col++)
	{
		pixel[row][col]=((uchar *)(image->imageData + row*image->widthStep))[col];
	}
}
for (int row=0;row<HEIGHT;row++){
	totalNumInRow[row]=0;
	for (int col=0;col<WIDTH;col++){
		if(pixel[row][col]==1){
			totalNumInRow[row]+=1;
		}
	}
}
for (int col=0;col<WIDTH;col++){
	totalNumInCol[col]=0;
	for (int row=0;row<HEIGHT;row++){
```

```
                if(pixel[row][col]==1){
                        totalNumInCol[col]+=1;
                }
        }
}
```

Figure 4.2.4: Feature Extraction Coding

4.2.1.5 Artificial Intelligence Recognition & Decision Making

In this step, neural network is being created and trained with learning rate of 0.02 and momentum factor of 0.05. After the training process of the neural network, it can be functional to identify whether the image should be accepted or rejected. Creation and training are the hardest part in this step but still able to proceed with the neural network. Below is the code for creation and training part of the neural network.

```
int train_sample_count, ind_train_sample_count, ind_train_sample;
/** Create matrices for mlp **/
//input data samples
CvMat* trainData=cvCreateMat(train_sample_count,ind_train_sample-
1,CV_32FC1);
//output data samples
CvMat* trainClasses=cvCreateMat(train_sample_count,1,CV_32FC1);
//weight of each training data sample
CvMat* sampleWeights=cvCreateMat(train_sample_count,1,CV_32FC1);
/** mlp representation **/
//five layers
CvMat* neuralLayers = cvCreateMat(5,1,CV_32SC1);
CvMat _trainData, _trainClasses, _neuralLayers, _sampleWeights;
cvGetRows(trainData,&_trainData,0,train_sample_count);
cvGetRows(trainClasses,&_trainClasses,0,train_sample_count);
cvGetRows(trainClasses,&_trainClasses,0,train_sample_count);
cvGetRows(sampleWeights,&_sampleWeights,0,train_sample_count);
cvGetRows(neuralLayers,&_neuralLayers,0,5);
//set the number of neurons on each layer
cvSet1D(&_neuralLayers,0,cvScalar(ind_train_sample-1));
cvSet1D(&_neuralLayers,1,cvScalar(ind_train_sample-100));//hidden
cvSet1D(&_neuralLayers,2,cvScalar(ind_train_sample-200));//hidden
cvSet1D(&_neuralLayers,3,cvScalar(ind_train_sample-300));//hidden
cvSet1D(&_neuralLayers,4,cvScalar(1));// 1 output
```

```
//Assemble the mlp training data
for (int i=0; i<train_sample_count;i++){
      //input
      for(int k=1;k<ind_train_sample;k++){
            cvSetReal2D(&_trainData,i,k-1,td[i][k]);
      }
      //output
      cvSet1D(&_trainClasses,i,cvScalar(td[i][0]));
      cvSet1D(&_sampleWeights,i,cvScalar(1));
}
CvTermCriteria criteria;
criteria.max_iter=200;
criteria.epsilon=0.000001f;//stop when error is below 0.00001
criteria.type=CV_TERMCRIT_ITER; //set termination condition
//set the training parameters
CvANN_MLP_TrainParams params;
//training method with backpropagation
params.train_method= CvANN_MLP_TrainParams::BACKPROP;
params.bp_dw_scale= 0.02f;//learning rate
params.bp_moment_scale=0.05f;//momentum factor
params.term_crit = criteria;
CvANN_MLP mlp; //initialize neural network
mlp.create(neuralLayers); //create neural network with defined layers
printf("MLP created!\n");
mlp.train(trainData,trainClasses,sampleWeights,0,params);
printf("Train Succesfully!");
```

Figure 4.2.5: Creation and Training of Neural Networks Coding

After train the neural network, the data, totalNumInCol and totalNumInRow, from feature extraction step can be used as input to generate the result from neural network classifier.

```
CvMat input = cvMat(1,590,CV_32FC1,_input);
CvMat output = cvMat(1,1,CV_32FC1,_output);
mlp.predict(&sample,&output);
```

Figure 4.2.6: Decision Making by Neural Networks Coding

4.2.2 MFC User Interface

This is the first interface that loads image in certain folder by user. After that, the user can click the “Process” button to get the result of neural network classifier.

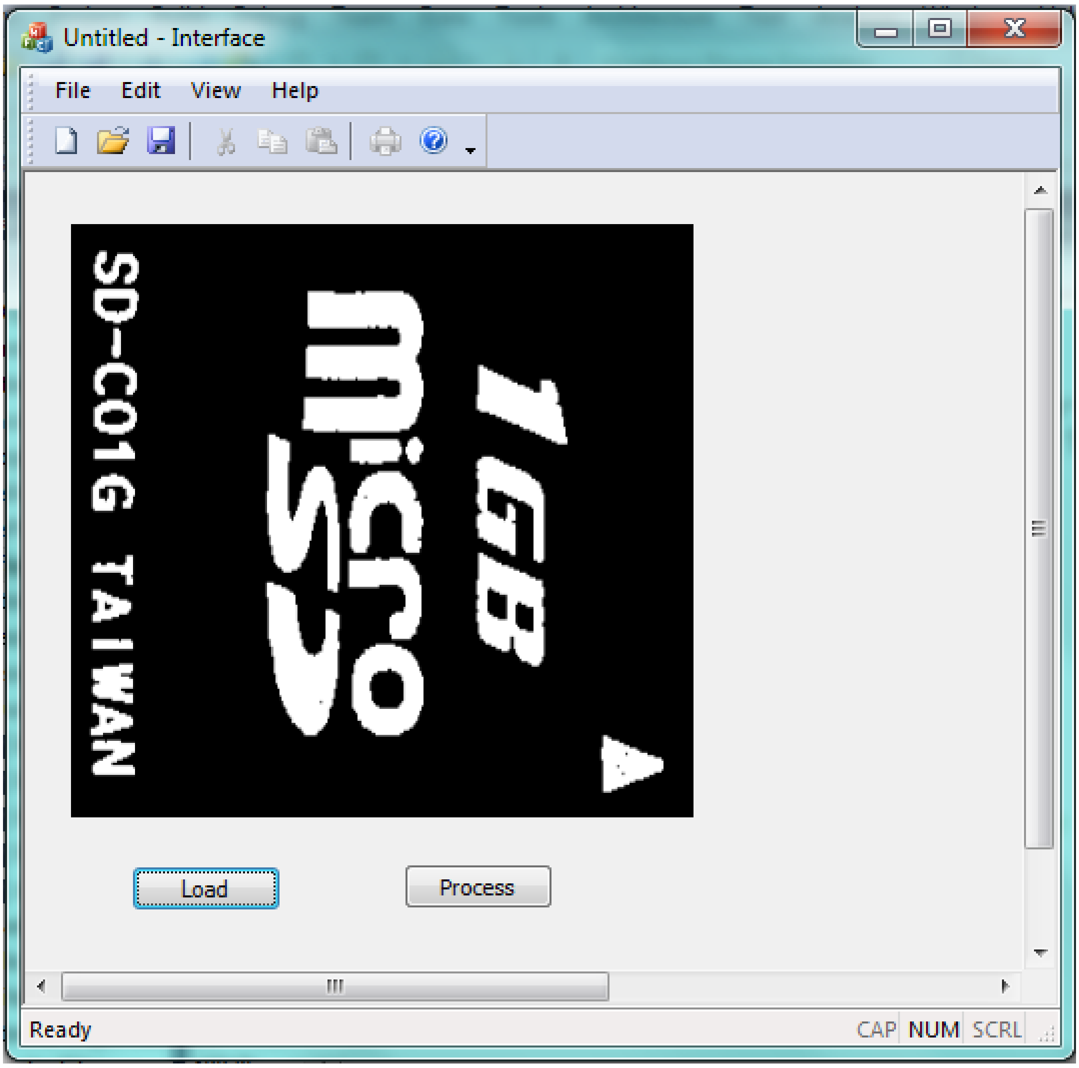

Figure 4.2.7: MFC User Interface

CHAPTER 5

RESULTS & DISCUSSION

5.1 INTRODUCTION

This chapter discusses about the results of the neural network classifier, the project limitation in development and system and suggestions to enhance the project in further study. There are three sections in which results analysis discusses the results findings from the neural network, project limitation explains the development constraints and system constraints and suggestions provides some opinions on enhancing the project in future.

5.2 RESULTS ANALYSIS

After the system implementation, results are collected according to four classes which are Accept, Illegal Marking, Upside Down Print and lastly Missing Character. From the collected results, it is clear that the systems runs in a short period and be able to process and identify the micro SD memory card in less than 10 seconds. The first objective is achieved to be the computerized inspection system that can replace the manual inspection system. Figure 5.2.1 is the results generated by the neural network classifier. It actually loads 22 images at once to process and the results are correct in 100%.

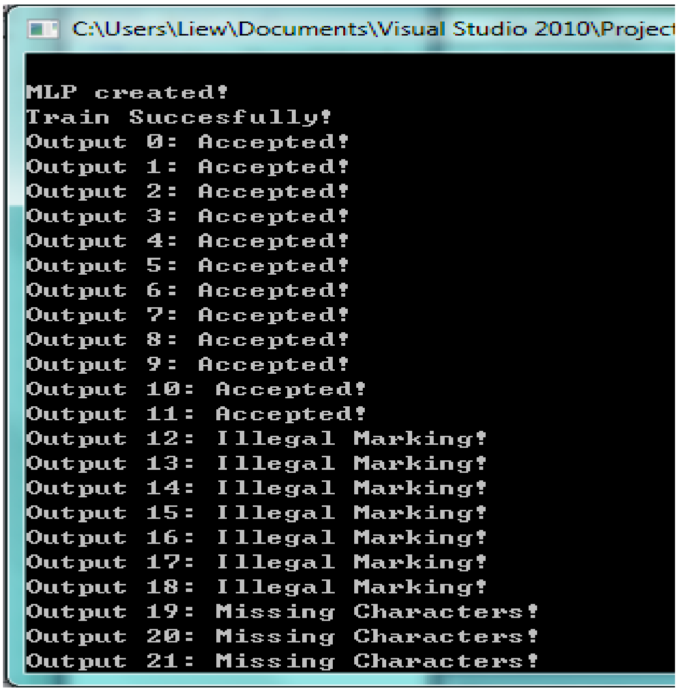

Figure 5.2.1: Results generated

5.3 PROJECT LIMITATION

In this section, the limitations are briefly described into two sub-sections which are development constraints and system constraints. The development constraints describe about the constraints on developing the project and the system constraints describe about the constraints on implementing the system.

5.3.1 Development Constraints

During the project development, there are some difficulties to apply the actual project idea. The first constraint is about the IC chips which are very hard to find lots of chips in the market and the chips are very expensive. Therefore, the project has scoped to replace the IC chips with the micro SD memory card. The second constraint is about the camera usage. Initially, the camera is the first choice image source in the image acquisition step but eventually it has to be cancelled due to the difficulty in linking the camera with the system. The linkage problem is further described in the next sub-section.

5.3.2 System Constraints

The system has some constraints that the users may find the system not convinced. The first constraint is about the camera linking problem. The system currently does not support camera function because the frame buffer from the camera needs to be captured with certain software supported by the camera manufacturer. The next constraint is about the design of the user interface which is not interactive enough for the users to navigate upon the interfaces. The other constraint is that the system does not show the steps of getting through the inspection steps and the time for processing an image.

5.4 SUGGESTIONS & PROJECT ENHANCEMENTS

Nevertheless, this project is still available to be enhanced in certain criteria which are the user interface design, the camera usage and display of processing time. The system can be improved by showing the inspection steps from image acquisition to decision making. Therefore, the users can navigate around the system and understand the system implementation. Apart from that, the processing time can also be shown for every step to allow the users know the processing speed of the system. Lastly, the camera is still the main part of the system because it is the first step of inspecting the IC chips in the manufacturing factory.

5.5 CONCLUSION

In conclusion of this chapter, the results are generated as expected and in fast processing speed. The system can be the ideal solution of the inspection system of IC chips according to the results findings. However, in order to become a real solution of the inspection system of IC chips, the camera is a must to really fit into the system.

CHAPTER 6

CONCLUSION

6.1 CONCLUSION

The research presented about a feedforward neural network based vision inspection system for detecting the defects of marking of the micro SD memory cards. The system used feature extraction technique as the vision inspection methods which was discussed in Chapter 2 and the feature extraction technique to be used is projection profile method. In the proposed system, the micro SD memory cards will be captured from camera and enhanced by removing noise and de-blurring. Then the micro SD memory cards get segmented and extracted the laser markings and design outline using Projection Profile method. The target image is matched with the reference images using the trained neural network. The results are produced and stored as reference in the future.

The system is able to inspect within 10 seconds per chip and achieve 95 percents of detection rate. The automated inspection system is built to improve the inspection system which is manually conducted. It can provide an ideal solution for automated inspection of IC chips in commercial IC chips production system. By making use of the automated inspection system, the percentage of accuracy and efficiency to reject the defected chips can be increased to 98%. Other than that, the cost and resources usage can be reduced to certain amount lower than 40% due to the unnecessary of many inspection experts.

Further research on this title is not limited because different approaches of combination of inspection techniques and artificial intelligence techniques may produce better results than this research. The researchers could try other combinations to get the results compared in order to investigate better approach of vision inspection technique.

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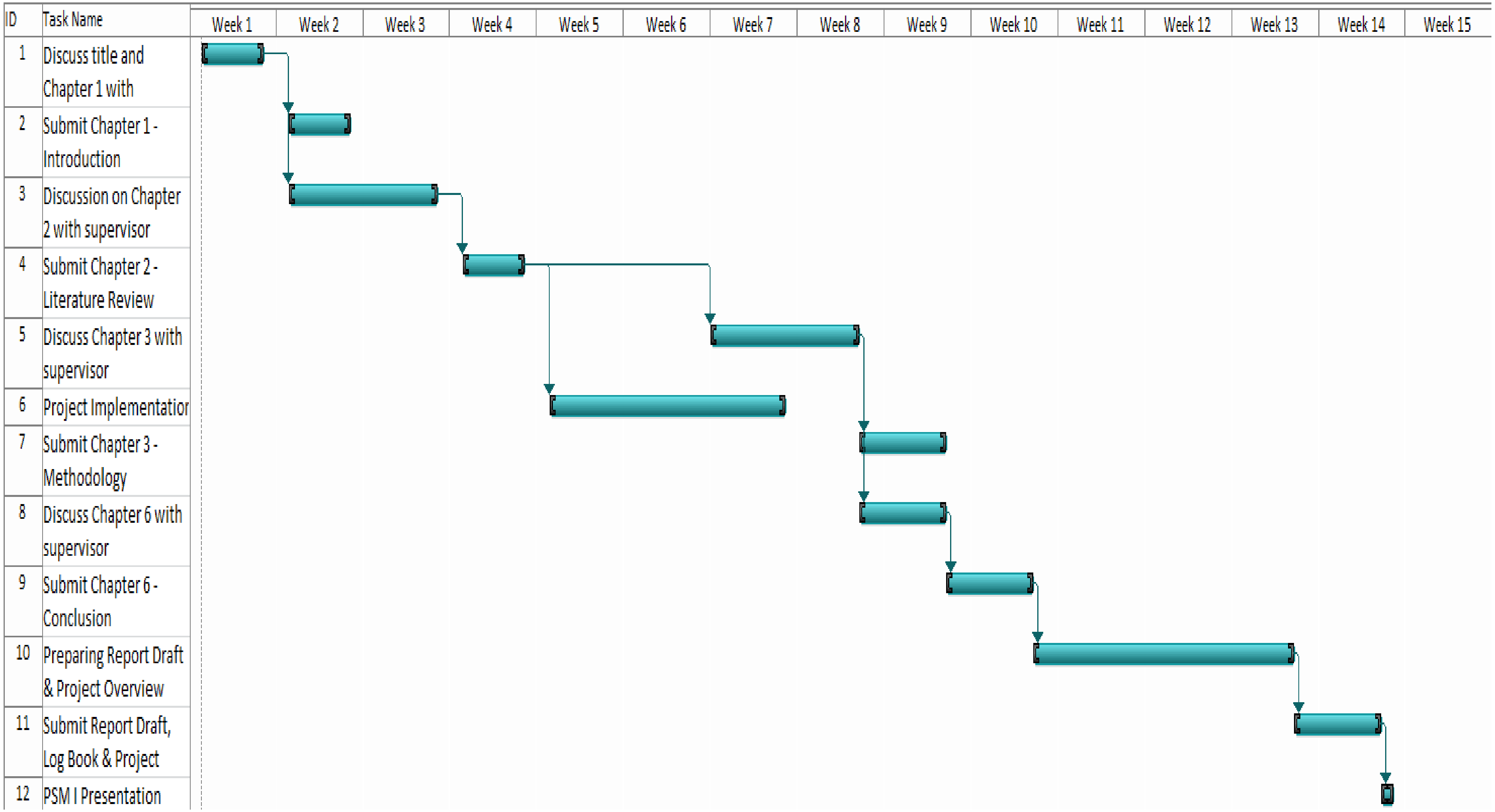
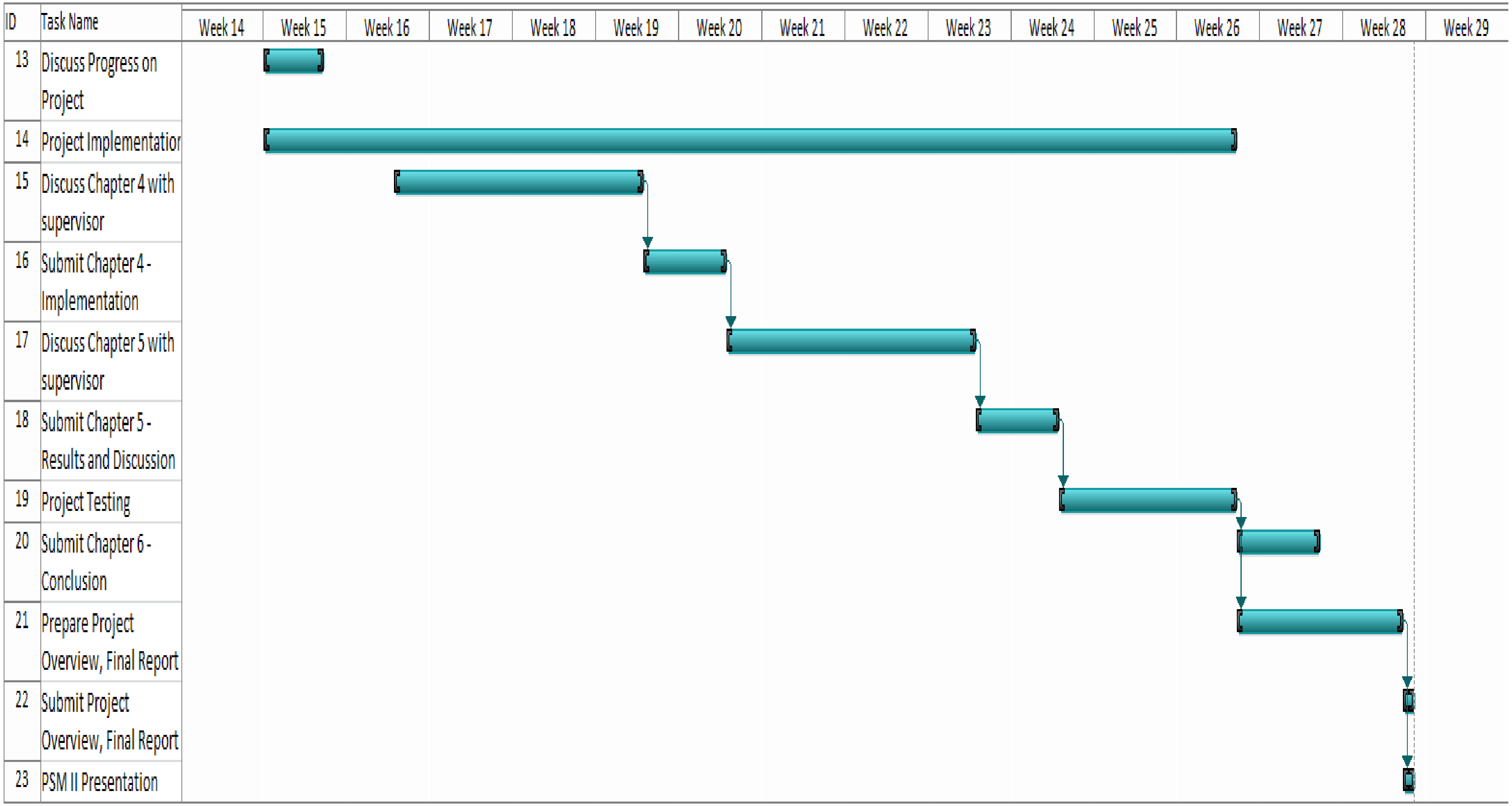
APPENDIX A – Gantt Chart




ID
Task Name
Week 14
Week 15
Week 16
Week 17
Week 18
Week 19
Week 20
Week 21
Week 22
Week 23
Week 24
Week 25
Week 26
Week 27
Week 28
Week 29
13
Discuss Progress on Project
14
Project Implementation
15
Discuss Chapter 4 with supervisor
16
Submit Chapter 4 - Implementation
17
Discuss Chapter 5 with supervisor
18
Submit Chapter 5 - Results and Discussion
19
Project Testing
20
Submit Chapter 6 - Conclusion
21
Prepare Project Overview, Final Report
22
Submit Project Overview, Final Report
23
PSM II Presentation