PENUKARAN FAIL-FAIL CAD, PENUKARAN FAIL GERBER DAN PENGOPTIMUMAN BINGKAI-BINGKAI PANDANGAN BAGI SISTEM PEMERIKSAAN OPTIKAL AUTOMASI

Oleh

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ABSTRAK

Projek ini adalah berkenaan dengan penukaran fail-fail bagi sistem pemeriksaan optikal automasi. Sistem pemeriksaan optikal automasi yang terlibat dalam projek ini adalah sistem pemeriksaan optikal automasi bagi pemeriksaan *solder paste* dan sistem pemeriksaan optikal automasi bagi pemeriksaan *pre-reflow*. Antara penukaran fail-fail yang akan dilaksanakan dalam projek ini adalah penukaran fail Gerber, penukaran fail-fail CAD dan pengoptimuman bigkai-bingkai pandangan. Penukaran fail Gerber hanya diaplikasikan ke atas sistem pemeriksaan optikal automasi bagi *pemeriksaan solder paste* manakala penukaran fail-fail CAD dilaksanakan pada sistem pemeriksaan optikal automasi bagi pemeriksaan *pre-reflow*. Fail Gerber dan fail-fail CAD ditukarkan kepada fail pemeriksaan masing-masing menerusi penukaran fail Gerber dan penukaran fail-fail CAD. Pengoptimuman bingkai-bingkai pandangan juga dikenali sebagai penukaran fail pemeriksaan. Fail pemeriksaan ditukarkan kepada fail pengoptimuman gambaran dan diaplikasikan ke atas sistem-sistem pemeriksaan optikal automasi tersebut. Pengoptimuman bingkai-bingkai pandangan adalah penting bagi menigkatkan perlaksanaan sistem pemeriksaan optikal automasi. Projek ini diusahakan dengan menggunakan *Microsoft Visual C# 2005 Express Edition*. C# merupakan bahasa aturcara terkini dan diaplikasikan atas *.NET Framework*. C# berlaksana dengan baik dalam pengaturcaraan penukaran fail-fail bagi sistem pemeriksaan optikal automasi dalam projek ini.

ABSTRACT

This project is about files conversion of automated optical inspection (AOI) system. The AOI for solder paste inspection and the AOI for pre-reflow inspection are the designated AOI systems where the files conversion of the project take place. The AOI files conversion involved in this project are Gerber file conversion, CAD files conversion and view frames optimization. Gerber file conversion is applied specifically on AOI for solder paste inspection while CAD files conversion is applied on AOI for pre-reflow inspection. Gerber file and CAD files are input files of AOI systems. The files are converted to inspection file through the Gerber file conversion and CAD files conversion. The file conversion of view frames optimization also known as inspection file conversion. It converts the inspection file to image optimization file and it is applied on both the AOI systems mentioned above. View frames optimization is important in improving the performance of the AOI system. The project is developed using the software development tool of Microsoft Visual C# 2005 Express Edition. It is a new programming language that is applied on the .NET Framework and performs well in the AOI files conversion of the project.

ACKNOWLEDGEMENT

I might be inarticulate, yet my heartfelt gratitude would never fade.

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Last but not least, I reserve my appreciation for my family. They have always been my support and perked me from depression. To my father and mother, I appreciate your sacrifice for me.

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AOI	Automated Optical Inspection
CAD	Computer Aided Design
CLR	Common Language Runtime
ECMA	European Computer Manufacturers Association
FCL	Framework class library
FOV	Field of View
GDI+	Graphics Device Interface
GUI	Graphic User Interface
IC	Integrated Circuit
IDE	Integrated Development Environment
ISO	International Organization for Standardization
JIT	Just-In-Time
JVM	Java Virtual Machine
MSDN	Microsoft Developer Network
MSIL	Microsoft Intermediate Language
MVI	Manual Visual Inspection
PCB	Printed Circuit Board
ROI	Return-On-Investment
SMD	Surface Mount Device
SMT	Surface Mount Technology

CHAPTER 1

INTRODUCTION

1.1 Project Background

This is a project organized by TT Vision Technologies Sdn. Bhd., a local electronic company. The participation of university in such a company project provides a good chance for students to learn about the real situation of the industry. The students gain the opportunity to work in a team with the engineers and benefit from their experience. At the same time, the students are revealed to the latest technologies in industry while acquiring the practical experience on the technologies.

Even though the automated optical inspection (AOI) system is not a novelty nowadays, the technology is only developed in foreign countries. The industries in Malaysia rely on the overseas AOI producers to get the machines and technical supports. Obviously, this is not an effective solution because it consumes a lot of time and increases the cost. As a result, TT Vision Technologies Sdn. Bhd. takes the initiative to learn the technology of the AOI system by carrying out the AOI system design project.

1.2 Introduction on TT Vision Technologies Sdn. Bhd.

With the motto *Tomorrow's Technology Today*, TT Vision Technologies Sdn.Bhd. is aiming to reach the front line of technology. Figure 1.1 is the logo of the company. As a solution provider for the vision applications, it supports the vision applications for local industries as well as overseas industries. It had been recognized as a MSC-status company. TT Vision Technologies Sdn. Bhd. produces systems with vision application such as inspection systems. It is currently develops on the AOI system design project.

Figure 1.1: Logo of TT Vision Technologies Sdn. Bhd.

1.3 Introduction on the AOI System Design Project

AOI system can be applied to the industries that perform inspection. For example, it can be applied to the manufacturing industry that requires quality assurance. The AOI system design project is targeting the surface mount technology (SMT) manufacturing sector. It is more effective and more productive to utilize AOI technology in the SMT production line inspection. Manual inspection on the surface mount devices (SMDs) is less efficient due to the limitation of the human’s sight ability (Todd O’Neil and Marc Peallet, 2000). AOI saves time and reduces cost in the production line while increasing the productivity and the efficiency of the SMT production line (Todd O’Neil and Marc Peallet, 2000).

The AOI system has different inspection target for each station in the SMT production line. The AOI systems developed are the AOI for solder paste inspection and AOI for pre-reflow inspection. AOI for solder paste inspection is located after the solder paste printer. It inspects on the solder paste printed on the printed circuit boards (PCBs). On the other hand, the AOI for pre-reflow inspection is located before the reflow oven and it inspects the components placements on the PCBs.

Both the AOI systems play a significant role in improving the productivity of the production line. Therefore, they are chose to be developed in the project.

1.4 Scopes of the Project

The design of AOI system requires technologies on vision system, mechanical system and software system (personal conversation: P.K. Choong, 2005). Therefore, the project is divided into three main portions based on the vision application, mechanical application and software application, as illustrated in Figure 1.2.

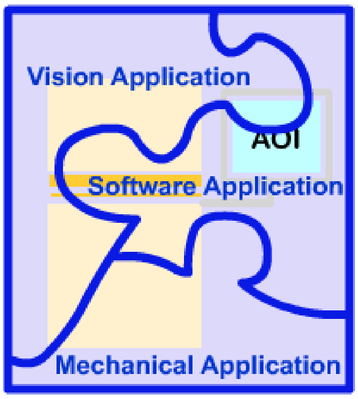

Figure 1.2: The Distribution of the Project on AOI System Design

This project concentrates on the software application. It emphasizes on the AOI files conversion. In other words, this is an AOI files conversion project. There are three tasks to be completed in this project. They are CAD files conversion, Gerber file conversion and view frames optimization. Gerber file conversion is developed for the AOI of solder paste inspection while CAD files conversion is applied to the AOI for pre-reflow inspection. The view frames optimization is applied to both of the AOI systems.

In Gerber file conversion, the input file of the AOI for solder paste inspection is presented in Gerber file format. The AOI system requires the inspection file format instead of Gerber file format. Therefore, Gerber file is converted into inspection file. Similarly, AOI for pre-reflow inspection converts the CAD files into inspection file. The view frames optimization is performed by generating image optimization file from the inspection file in both of the AOI systems.

1.5 Objectives of the Project

This project is carried out as to contribute to the software application part of the developed AOI system. The target of the project is the program that is able to convert the input files to the inspection files and image optimization files subsequently. The program developed must be accurate and effective. It should be able to provide the correct output.

Another objective of the project is to commence on .NET programming language. .NET is a powerful platform that had been approved by its wide application in the industry and commerce (MSDN, 2005). In order to update to the point, TT Vision Technologies Sdn. Bhd. has put this project as their renovation point. The program is developed using Microsoft Visual C# 2005 Express Edition. The C# language is chose to be used in the project due to its advantages over other programming languages. Moreover, it is a new programming language that is expected to dominate the future programming arena (Arthur Gittlemen, 2003).

1.6 Project Preparation and Implementation

In order to carry out the project, it is important to have a good understanding on the project. After getting a clear picture on the project, the studies on the related knowledge are carried out. These include the studies on the AOI system and the formats of various files such as Gerber file, Sanyo CAD file, Siplace CAD file, GSM CAD file, inspection file and image optimization file. The sources of the information are the printed reading materials, web sites, files documents, and oral conversations. At the same time, there is also a study on the C# programming using Microsoft Visual C# 2005 Express Edition.

The project implementation is all about the software programming using C# language. The flow charts are drawn to express the programming ideas. They are the guidelines to be referred during the programming process. The completed program is tested and improved. The project is completed when the program has fulfilled the objectives of the project.

1.7 Report Guides

This report is organized into five chapters. Chapter 1 introduces the background of the projects, including the introduction on the project organizer, the concept of the project, the coverage of the project, and the objectives to be achieved in the project. The followed Chapter 2 describes further on the study background. It includes the introduction of AOI system, files conversion and C# programming. Next, Chapter 3 describes the methodology of the software implementation. It provides the concept of the programming flow on the files conversion. In conjunction, Chapter 4 shows the implementation, testing and discussions on the developed program. The implementation on the program is described and discussed in details. As a summary of Chapter 5, it draws the conclusion of the project while suggesting the future development for advance performance of the project.

CHAPTER 2

BACKGROUND STUDY

2.1 Automated Optical Inspection (AOI)

Automated optical inspection (AOI) is one of the machine vision systems used for inspection purpose in manufacturing industry. It is used especially in the surface mount technology (SMT) production line. Synthesizing the knowledge of vision, optic, mechanic and electronic, AOI is an advance technology that marks the milestone of the manufacturing industry (D.T.Pham, R.J. Alcock, 2003). Due to its high reliability, accuracy and compatibility, AOI had gained its value in the SMT manufacturing nowadays, gradually washing out the traditional method of manual visual inspection.

2.1.1 SMT Production Line

In the evolvement of the electronic manufacturing, surface mount technology (SMT) has replaced the through-hole technology to fulfil the market requirements for higher board density and compatibility (personal conversation: E.T. Ong, 2005). In the SMT production line, the components involved in manufacturing are called surface mount devices (SMDs). The compact-sized components are mounted on the printed circuit boards (PCBs) to produce the electronic assemblies. SMT results in reduced size board assemblies. In return, it also raises the complexity of the board assemblies (personal conversation: E.T.Ong, 2005).

SMT manufacturing is a process of assembling a PCB with the components mounted on the PCB. By referring to Figure 2.1, the PCBs are loaded into the screen printer (solder paste printer) in the first place. The PCBs will undergo the screen printing process, and followed by solder paste inspection. During the screen printing, the solder paste is deposited within the solder pads on the PCBs through a stencil with designed circuit apertures. The solder paste provides joint between the board and the components that are to be mounted on it in the following stages. The passed PCBs are sent to pick and place machines where the SMDs and ICs are placed onto the designated locations on the boards. After that, the boards with components are inspected. In this stage, the boards with defects will be marked and repaired at the rework station. After the pre-reflow inspection, the boards are sent to reflow oven and the solder paste is hardened under the reflow process. The temperature of the reflow oven must be controlled to avoid the occurrence of the defects. Next, the boards are inspected again. The boards that pass the inspection are accepted as the completed PCB assemblies (personal conversation: E.T.Ong, 2005).

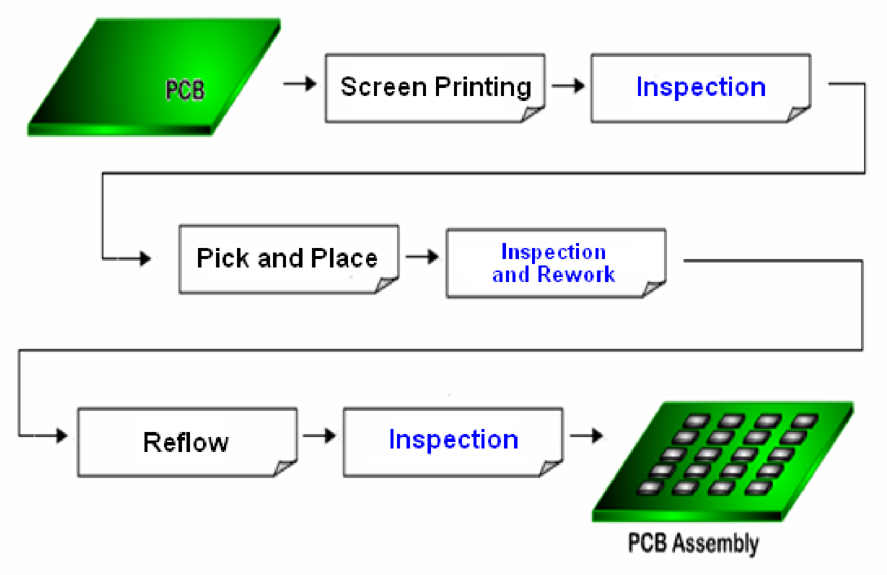

Figure 2.1: SMT Process Flow

Throughout the SMT manufacturing process, it is noticeable that the inspection element is applied frequently. Inspection is carried out at almost every stage. It is implemented after the screen-printing, after pick and place and after reflow process. There are reasons that inspection are carried out from stage to stage in the SMT manufacturing process. Inspection is important to ensure the quality of the products. From the view point of investment, inspection is a necessity to gain higher Return-On-Investment (ROI) (Todd O'Neil and Marc Peallet, 2000). There are also manufacturers that only apply end-of-line inspection. Although this solution has its advantage in saving time and costs, it increases the risk in tracing the root causes of the defects. It also increases the complexity and the degree of difficulty in solving the defects (Hou Yi Xue, 2003). Therefore, it is a wise decision to apply inspection from stage to stage in the SMT production line. Immediate action can be carried out to repair the defects before they trigger another defect in the subsequent processes (Colm Stephens, 2000).

2.1.2 The Roles of AOI Systems in SMT Production Line

AOI system is introduced for inspection purpose in the SMT production line. Figure 2.2 shows the placement of the AOI systems in alternate positions with the SMT production machines (Todd O'Neil and Marc Peallet, 2000).

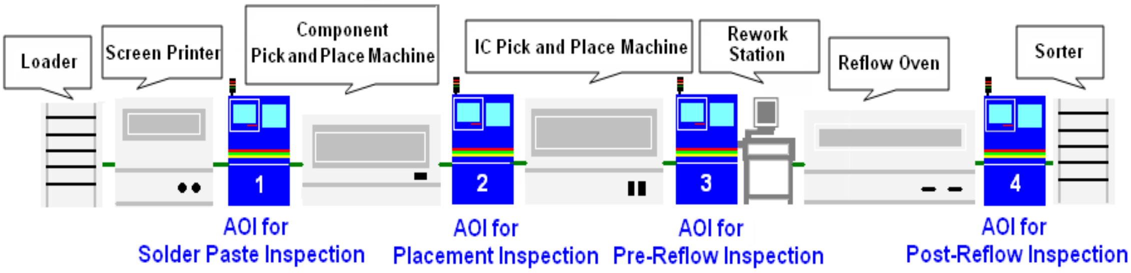
Loader
Screen Printer
Component Pick and Place Machine
IC Pick and Place Machine
Rework Station
Reflow Oven
Sorter
1
2
3
4
AOI for Solder Paste Inspection
AOI for Placement Inspection
AOI for Pre-Reflow Inspection
AOI for Post-Reflow Inspection

Figure 2.2: The Placement of AOI Systems in SMT Production Line

There are four in-line AOI systems in the SMT production line. The first AOI system is placed after the screen printer. It is an AOI for solder paste inspection. Right after the components pick and place machine is an AOI for placement inspection while AOI for pre-reflow inspection is placed between the ICs pick and place machine and reflow oven. Some manufacturers might choose to eliminate the placement of AOI system after the component pick and place machine. The AOI for pre-reflow inspection will take over the duty to inspect on the overall components and ICs. There is a rework station comes together with the AOI for pre-reflow inspection. Finally yet importantly, AOI for post-reflow inspection is placed after the reflow oven. (Todd O'Neil and Marc Peallet, 2000).

2.1.2.1 AOI for Solder Paste Inspection

The main inspection target of the AOI system for solder paste inspection is the solder paste that printed on the PCBs. The solder paste should be deposited within the solder pads. There are several defects caused by solder paste printing. AOI system is able to inspect all the defects such as insufficient solder paste, excessive solder paste, missing solder paste, as well as solder bridge (personal conversation: Shirley Gan, 2005). Figure 2.3 shows the sampled defects.

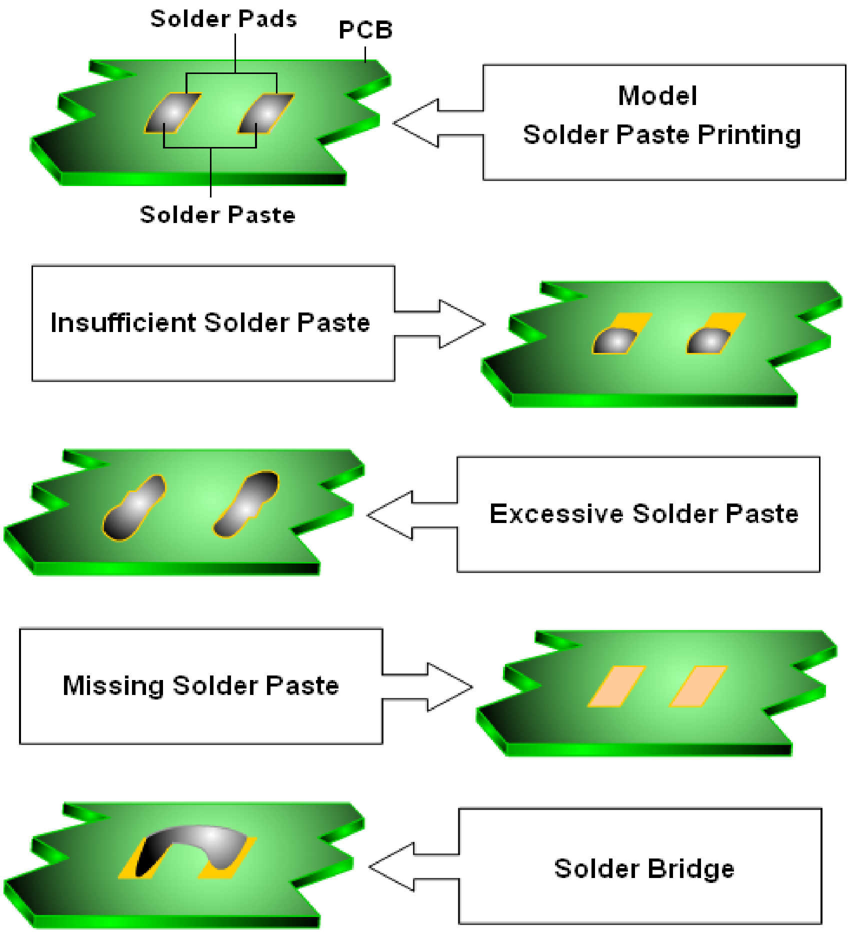

Figure 2.3: Defects of Solder Paste Printing

2.1.2.2 AOI for Placement Inspection and AOI for Pre-Reflow Inspection

AOI for placement inspection and AOI for pre-reflow inspection inspect on the components and ICs placement on the boards before the boards are sent to reflow oven to undergo the reflow process. The components and ICs are SMDs that mounted on the surface of the boards. The AOI systems detect the defects of the components and ICs placement on the boards. The defects of the components and ICs are typically broken, blur marking, damaged, excess metalize, incomplete metalize, missing, misalignment, mounted side way, tombstone and high up (personal conversation: Shirley Gan, 2005). Figure 2.4 shows the sampled defects of components and ICs placement.

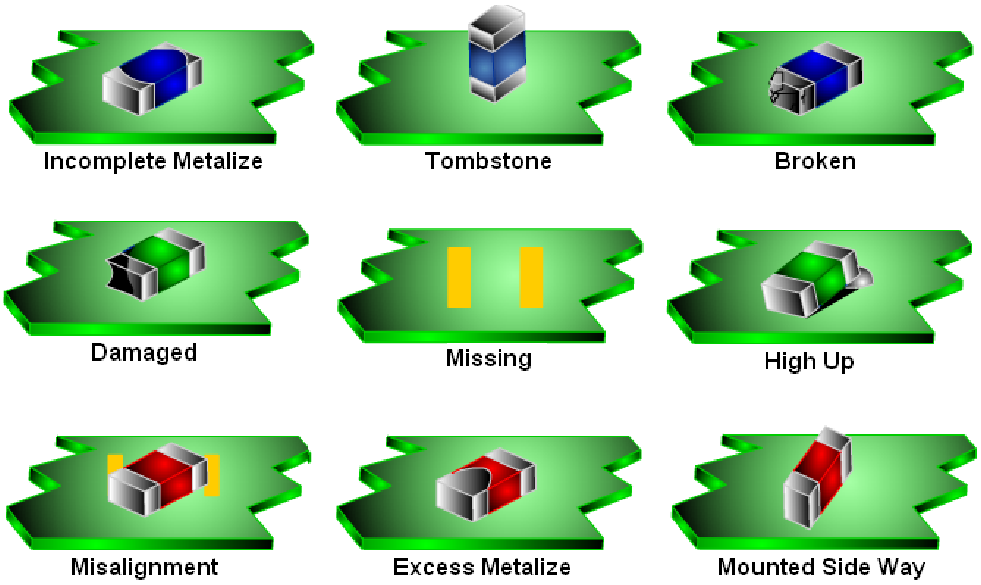

Figure 2.4: Defects of Components and ICs Placement

AOI systems are able to inspect and identify the coordinates and types of the defected components. Certain AOI systems are also inspecting on the colour and the text on the components to increase the reliability of the inspection (personal conversation: Shirley Gan, 2005).

2.1.2.3 AOI for Post-Reflow Inspection

The post-reflow inspection inspects on the boards after the boards had gone through the reflow process. As the location of the AOI placement is at the end of the production line, it inspects all the features on the boards, including the solder joint, the components and the ICs (personal conversation: E.T. Ong, 2005). There might be faulty in operating the reflow oven. The defects occurred only can be detected by AOI for post-reflow inspection. The AOI for post-reflow inspection can be the stand-alone AOI in the SMT production line and it is recognised as end-of-line AOI (Todd O'Neil and Marc Peallet, 2000). Nevertheless, this method is only applied if all the root causes of the defects are known in prior and the board assemblies are in reduced complexity (Todd O'Neil and Marc Peallet, 2000).

2.1.3 Automated Optical Inspection (AOI) versus Manual Visual Inspection (MVI)

In the early age of the electronic manufacturing industry, manual visual inspection is the solution for the inspection task. Work force is used in the manual visual inspection. As the components of the board assemblies became smaller and appeared to be in high density, AOI had gradually replaced the manual visual inspection (MVI) (Jim Fishburn, 2005).

It is not a coincidence that AOI exceeds the manual visual inspection. AOI systems have numerous advantages over manual visual inspection. There are some drawbacks in applying manual visual inspection. Human cannot guarantee uniform and consistent inspection. Human might get tired after a long inspection period. The inspection performance might degrade. This problem will not occur in AOI systems since machine can function in ever consistence and uniform condition (Jim Fishburn, 2005).

Human has vision quality limitation, especially when the boards are getting smaller due to the reduced size components. Human is facing more difficulties in visual inspection as the board assemblies are getting complex. AOI systems can always upgrade its visual ability by developing the vision equipments. In addition, AOI systems are able to visualize the micron-sized objects that humans are not able to see. (Brewster Barclay, 2005).

Besides that, the inspection criteria and inspection skills might vary among the people. This will trigger the issues on the reliability and accuracy of the inspection. In contrast, AOI systems do not have such problems as its operation is controlled by the same program. Human’s performance in inspection also will be affected by environmental factors and this will not happen in the AOI systems (Brewster Barclay, 2005).

AOI is more productive and effective than manual visual inspection (Brewster Barclay, 2005). In the long-term running, AOI saves the expenses on the human resource and gain higher profits in the SMT production (Brewster Barclay, 2005).

2.1.4 Structure of Automated Optical Inspection (AOI)

Automated optical inspection (AOI) is categorized as machine vision system. Thus, the structure of the AOI system is fundamentally similar to the typical structure of machine vision system (D.T.Pham, R.J. Alcock, 2003).

AOI system is constructed by the combination of computer, camera, lighting, handling system, visual display unit, also known as monitor, and conveyor belt (D.T.Pham, R.J. Alcock, 2003). Figure 2.5 shows the structure of the AOI system.

In the system structure, computer is recognized as the centre control part. It is also known as the brain of the AOI system. Computer has its control on the camera, lighting and handling system. All the machine parts are linked together by the computer so that all the parts can interact and synchronize with each other to carry out the operations of the AOI system. Computer controls on the handling system and conveyor belt to load the products into the vision inspection area. The camera that controlled by the computer will acquire images of the products with the existing of the lighting. After that, the computer analyses the images acquired by camera using image-processing routines and then issues an appropriate action to be performed by the handling system. The computer will analyse the images to get the information on measurement, colours and other visual features. The results of the analysis will decide the products that are to be rejected. The computer will also send the statistics and process data to a database. All the images from the inspected objects will be displayed on the monitor. Besides the indication of the defects occurred, the monitor will also inform the number of accepted and rejected products (personal conversation: S.K. Tan, 2005).

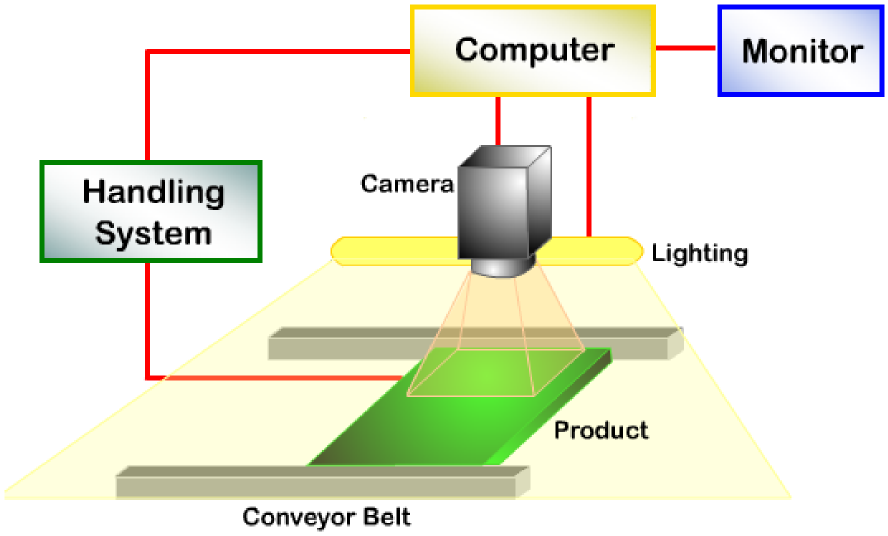

Figure 2.5: Structure of AOI System

In order to achieve better vision performance, camera and lighting are the key factors. There is a need to specify the suitable resolution and field of view (FOV) for the camera. The features of the cameras should be studied carefully so that it can fit well and perform well in image acquisition. After acquiring the images, camera translates the pattern of light from the part into an electronic image. The camera of AOI system has features such as square pixels to simplify measurements, progressive scanning instead of interlaced scanning, a fast shutter, and an asynchronous trigger for acquiring images. The progressive scanning and fast shutter are required in order to avoid the effect of blur image due to the movement of the object inspected (Ben Dawson, 2005). For optimum contrast and image definition, there should be different types of programmable lighting. The light source and the colour mixed have to be defined to get the best lighting effect. Lighting will affect the quality of the image acquired by the camera. The adopted lighting must be able to amplify features of interest and suppress visual features that are noise (Ben Dawson, 2005). As for the handling system, it should be able to perform all the related motion and synchronized with the other parts to reduce variability in part images. The structure of AOI system is simple, yet it deals with wide variety of concepts.

2.1.5 Software Implementation of AOI System

AOI system is a machine that applies both software and hardware. In the software implementation, AOI system imports files that contain the information required by the AOI system for inspection. In order to perform the inspection on a product, the AOI system would require the information on the coordinates and the details of the products such as part number, reference designator and names of the machines involved in the SMT production line. AOI system will perform file conversion on the imported files so that the data is arranged in the file format that is comprehended by the AOI system (personal conversation: P.K. Choong, 2005).

The input file of the AOI system for solder paste inspection is Gerber File. It is used in the designing of the printed circuit boards (PCBs). Gerber File contains the information on the solder pads coordinates and the shapes of the apertures on the PCBs. AOI for pre-flow inspection does not require Gerber File, but CAD files that are created by the machines of components and ICs placement. Different models of machines create different file formats. AOI systems obtains x and y coordinates, angle, part number, device type, reference designator, and the shapes of the components. If there are series of placement machine in the production lines, the AOI for pre-reflow AOI will have to merge the information extracted from each of the CAD file. When importing the CAD data, the AOI system automatically creates a root task for the assemblies. It also looks for existing templates and models in the system repository to use for each part number found in the CAD files. If the templates do not exist, it will create new templates and models for the part number. Consequently, it creates libraries to store the templates and models (personal conversation: P.K. Choong, 2005). Both Gerber Files and CAD files contain information on fiducial that is also required by the AOI systems for board alignment purpose. Fiducial marks on the boards always act as reference points in the AOI inspection (personal conversation: Shirley Gan, 2005).

The AOI system will calculate the board dimensions before the operation of the inspection starts. The overlap size of the image is defined by considering the field of view (FOV) of the camera image capturing to optimize the image during inspection.

The image optimization results in more systematic and effective performance in image capturing and analyzing (personal conversation: P.K. Choong, 2005).

When AOI performs inspection on the board assemblies, the captured images will be stitched together to resume the complete board image (personal conversation: P.K. Choong, 2005). The related features are inspected by referring to the templates and models stored in the libraries. Any unmatched features will be reported as failure and displayed on the monitor. The handling system will separate the boards with defects from the boards that have passed the inspection process. Figure 2.6 illustrates the software implementation flow of AOI system.

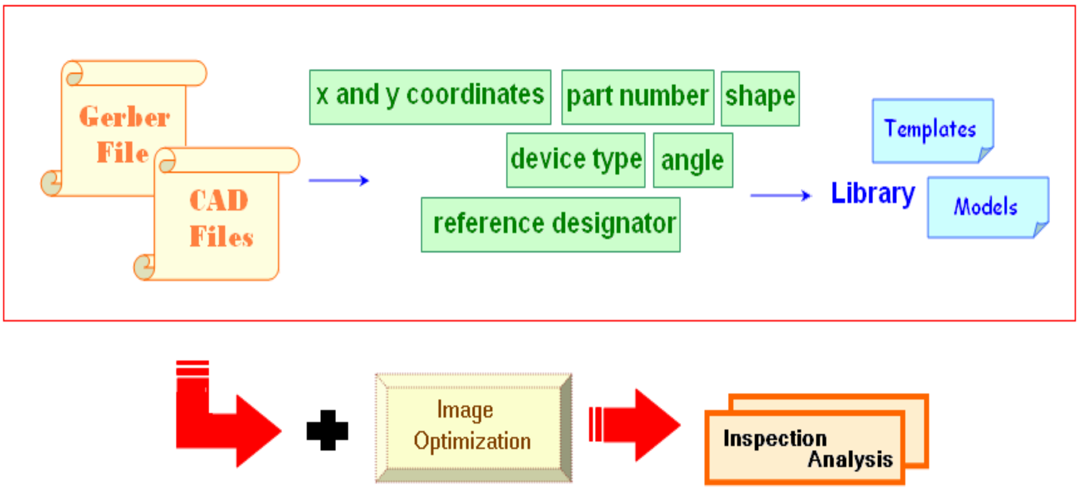

Figure 2.6: Software Implementation Flow of AOI

2.2 AOI Files Handling

AOI system handles several files that provide information required for inspection. Each AOI system at different station requires different input files. The AOI for solder paste inspection and the AOI for pre-reflow inspection are the two AOI systems of interest, as illustrated in Figure 2.7. Both of the mentioned AOI systems are working on file conversion and image optimization in sequence.

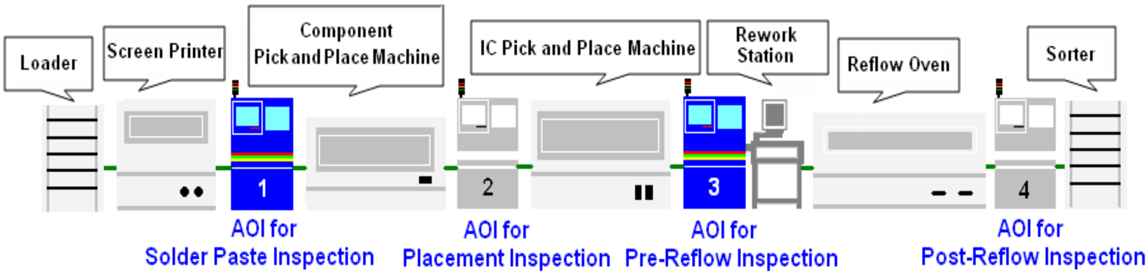
Loader
Screen Printer
Component Pick and Place Machine
IC Pick and Place Machine
Rework Station
Reflow Oven
Sorter
1
2
3
4
AOI for Solder Paste Inspection
AOI for Placement Inspection
AOI for Pre-Reflow Inspection
AOI for Post-Reflow Inspection

Figure 2.7: AOI Systems of Interest

2.2.1 Files Conversion

The objective of the files conversion is to improve the inspection performance of the AOI system. When an input file is converted, the file format is changed and the output file is redefined by different file extension (personal conversation: P.K. Choong, 2005).

2.2.1.1 Conversion on Input Files

The formats of the input files are varying from one file to another file depend on the operations of the AOI systems. Those input files are adopted from the machines that handle the boards or the board assemblies in the prior stages. Most of the information contained in the input files is not relevant to the AOI systems. In file conversion, the useful information is extracted from the input file and the information is rearranged in the output file format.

Even though both AOI for solder paste inspection and AOI for pre-reflow inspection operate on files conversion, both require different form of input files. While AOI for solder paste inspection is working on Gerber file, AOI for pre-reflow inspection is handling the CAD files. The files conversion on the Gerber file and CAD files yield the same output file that is known as inspection file. Inspection file focuses on the information required by the AOI systems.

The files are identified by the file extensions. The file extension of Gerber file is **.gbx*. As for CAD files, different models of components and ICs placement machines generate different file formats with different file extensions. Three machine models are taken into account, namely Sanyo, Siplace and GSM. The relevant file extensions are *\.*ncz*, *\.*nc*, and *\.*gsm* respectively. On the other hand, the inspection file is attached to the file extension of *\.*plx* (personal conversation: P.K.Choong, 2005). Figure 2.8 shows the files conversion of AOI for solder paste inspection and AOI for placement inspection.

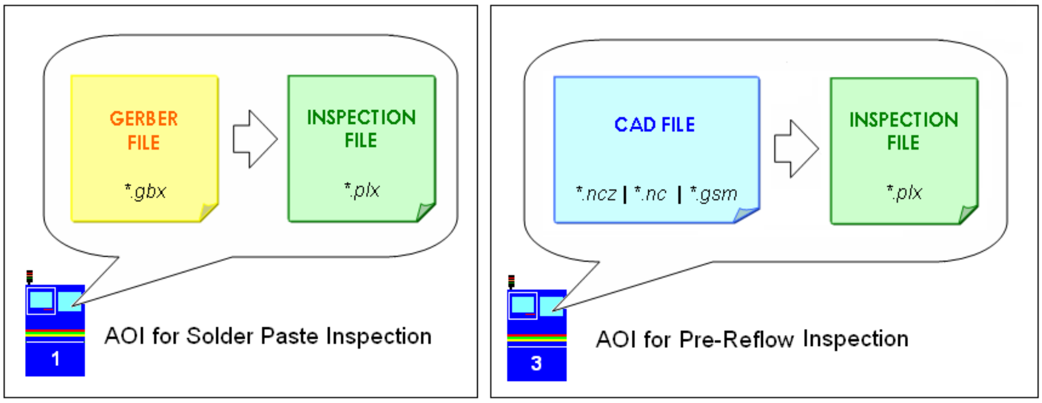

Figure 2.8: Files Conversion on Input Files

2.2.1.2 Generation of Image Optimization File

In manufacturing industry, there is not a second to be lost. The industry always aims for higher yield rate while maintaining the products quality. AOI system is responsible in reducing the consumed time during the inspection. As the efforts to achieve the target, the operation of the AOI system is optimized. As for this, the image capturing process is optimized.

One of the aspects to be considered is the camera movement during the image capturing. The camera is instructed in the optimized sequence so that the distance from one position to another position is agreed as the shortest distance. The optimized image capturing process chooses the best path that consumes the least time. As for this, AOI system produces a file, known as image optimization file with data in optimized pattern (personal conversation: P.K. Choong, 2006). The AOI system refers to the image optimization file to program the movement of the camera. The study on the image optimization file reveals the steps taken by camera in performing the inspection. Figure

2.9 shows the comparison between inspection with image optimization and inspection without optimization. The numbers indicate the images capturing sequences.

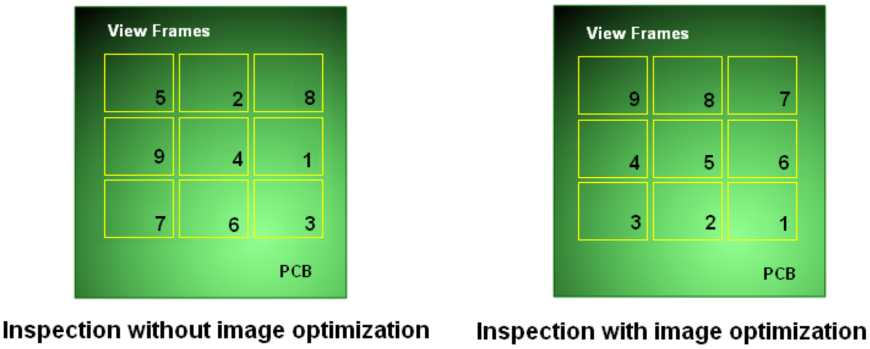
View Frames
5
2
8
9
4
1
7
6
3
PCB
Inspection without image optimization
View Frames
9
8
7
4
5
6
3
2
1
PCB
Inspection with image optimization

Figure 2.9: Optimization on Board Image

Figure 2.10 illustrates the generation of the image optimization file. The image optimization file is sources from the inspection file that is converted from the input files such as Gerber file and CAD files. There is only alteration in the data sequence in order to obtain the optimized sequence (personal conversation: P.K. Choong, 2006). The file extension for inspection file is **.plx* while **.vew* is the file extension for image optimization file.

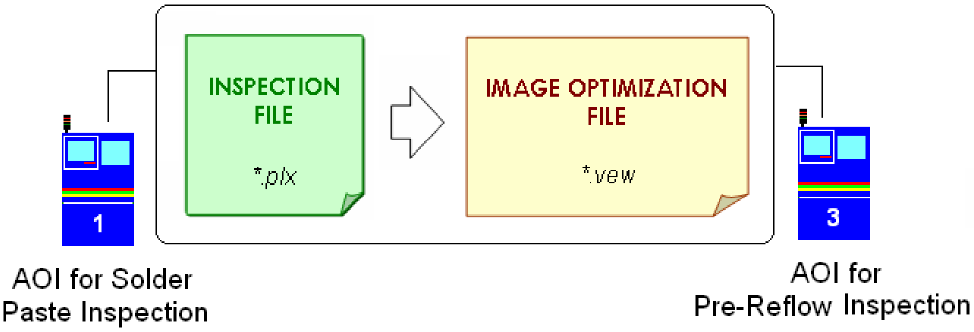
INSPECTION FILE
*.plx
IMAGE OPTIMIZATION FILE
*.vew
1
AOI for Solder Paste Inspection
3
AOI for Pre-Reflow Inspection

Figure 2.10: File Conversion on Image Optimization

2.2.2 File Formats

The formats of the files are identified by the file extensions. There are four categories of files in this project, namely Gerber file, CAD files, inspection file and image optimization file.

2.2.2.1 Gerber File

Gerber file is originated from printed circuit board (PCB) industry. The Gerber data is read by the photoplotter that is used for producing PCB (Steve DiBartolomeo, 1995). Gerber file is known by its simplicity and integrity characteristics. It consists of *x* and *y* coordinates. It has to be supplemented by commands that define the starting and the ending coordinates of the PCB images. Besides that, it also provides information on the shapes of the images (Barco Graphics N.V., 2001).

The Gerber file format in use today is called RS-274X (Barco Graphics N.V., 2001). It is also known as *Extended Gerber Format*. It is a superset of the RS-274D format and provides enhancements that handle polygon fill codes, positive or negative image composition, custom apertures and other features. RS-274X supports parameter data codes (G codes) and aperture codes (D codes) of RS-274D format, as well as mass parameters (X data) that are only defined in RS-274X format (Barco Graphics N.V., 2001). Gerber file is indispensable with the existing of the PCB.

The sample of Gerber file is shown as Figure A-1 in Appendix A-1.

2.2.2.2 CAD Files

In SMT production line, pick and place machines line after the screen printer. The number of pick and place machine might vary from one SMT line to another SMT line. There might be only one pick and place machine in the SMT line, as well as several pick and place machines that handle different components line in series in a SMT line. Every pick and place machine produces CAD file for each product handled by the machine. Although those files are collectively named as CAD files, individual machine producer presents them in different format. There is no standardization of the CAD files format. Nevertheless, the files provide the fundamental information needed for component and fiducials, such as component reference, part number, x and y coordinates, angle, and additionally component type (personal conversation: P.K. Choong, 2005). In brief, CAD files are the files that contain engineering data about a specific product, such as the size of the board, the position and orientation of each component, and the location of fiducials.

There are three format types to be discussed, namely Sanyo CAD file, GSM CAD file and Siplace CAD file.

2.2.2.2.1 Sanyo CAD File

Sanyo CAD file is recognized with its file extension of **.ncz*.

The file provides information on fiducial marks, feeder number used by the machine, part number of the components, x coordinate, y coordinate and angle of the components placement, component designator and offset coordinates for repeating the pattern of component placement.

There is additional information contained in the file but it is not necessary for an AOI system. The additional information is stated for the reference of the component placement machine (personal conversation: P.K. Choong, 2005).

The structural Sanyo CAD file is shown as Figure A-2 in Appendix A-2.

2.2.2.2.2 Siplace CAD File

Siplace CAD file is recognized with its file extension of **.nc*.

The format of Siplace CAD file is complex compared to the CAD files format of Sanyo and GSM. The readability of the file is unsatisfied due to the German description language and overabundance data in the file. The Siplace CAD file combines data of the Siplace machines that line up in series in SMT line into a single file. This makes the file appeared bulky. The information provided by this file is machine name, x coordinate, y coordinate, angle, component designator and part number (personal conversation: P.K. Choong, 2005).

The structural Siplace CAD file is shown as Figure A-3 in Appendix A-3.

2.2.2.2.3 GSM CAD File

GSM CAD file is recognized with its file extension of **.gsm*.

The GSM CAD file is simple and compact. There are machine name, fiducial coordinates, offset coordinate for repeated blocks, component designator, part number, x coordinate, y coordinate, angle, and feeder number in the file (personal conversation: P.K. Choong, 2005).

The structural GSM CAD file is shown as Figure A-4 in Appendix A-4.

2.2.2.3 Inspection File

The inspection file is a text file that keeps information relating to fiducials and components on the board. The file extension of inspection file is **.pls*. The file name usually denotes the board name. Each line of the inspection file indicates a fiducial or a component of the board.

The inspection file is the output file that formed by information extracted from the input files, Gerber file and CAD files. It is the output of the input file conversion (personal conversation: P.K. Choong, 2005).

Inspection file contains information of the x and y coordinates for both fiducials and components. As for components, there is also information on the reference designator of the component, device type, angle of orientation of the component, part number of the component, machine feeder from placement machine, and the shape of the component.

The sample and description on the inspection file is shown as Figure A-5 in Appendix A-5.

2.2.2.4 Image Optimization File

Image optimization file is converted from the inspection file. It has improved the features of image optimization compared to inspection file. It retains all the information in the inspection file whereby the data will be sorted according to the view frames.

The sample and description on the image optimization file is shown as Figure A-6 in Appendix A-6.

2.3 Introduction on C#

As high level programming languages such as C, C++, Visual Basic, and Java had been applied widely in the programming for years, C# was still an unbeknown language and appeared novelty to most of the people. C# was introduced as part of the .NET initiative, as the concept of .NET Framework was realized in the early of 21st century (Bradley L. Jones, 2001).

C# is pronounced as *C Sharp* and it is an object-oriented programming language (Bradley L. Jones, 2001). It is developed by Microsoft and it is introduced as the flagship programming language of the .NET platform (Stephen Randy Davis, 2002). The introduction of C# language is associated with the C and C++, the programming language that have been the most widely used language in developing the commercial and business software (Chris H. Pappas and William H. Munray, 2002). However, there are some drawbacks on the C and C++ language. C and C++ require the tremendous amount of fine-grained control and it reduces the flexibility of the languages, as well as degrades the productivity. The C and C++ language also needs longer duration to develop compared to Visual Basic language. It is the complexity and the long time cycle of the C and C++ language that drive the programmers to search for a language with improved power and productivity (C# Help, 2006).

As the result, Microsoft has its solution on this problem by introducing the C# language. Therefore, C# is a progression of the C++ language. C# has an object-oriented syntax base on C++ that includes aspects of several programming language, such as Visual Basic and Java (Wikipedia, 2006). It also emphasizes on the simplification, such that fewer symbolic requirements compared to C++ and fewer decorative requirements compared to Java (Wikipedia, 2006). In fact, the introduction of C# programming language has threatened the status of Java developed by Sun Microsystems.

C# has been gaining in its popularity after years since it was introduced. The language has added its value with its potential in the commerce and business applications (Chris H. Pappas and William H. Munray, 2002). There are reasons that C# gains its success. After all, it has its advantages over other programming languages.

2.3.1 The Advantages of C#

C# programming language is a predominant language with several advantages as shown in Figure 2.11 (Stephen Randy Davis, 2002).

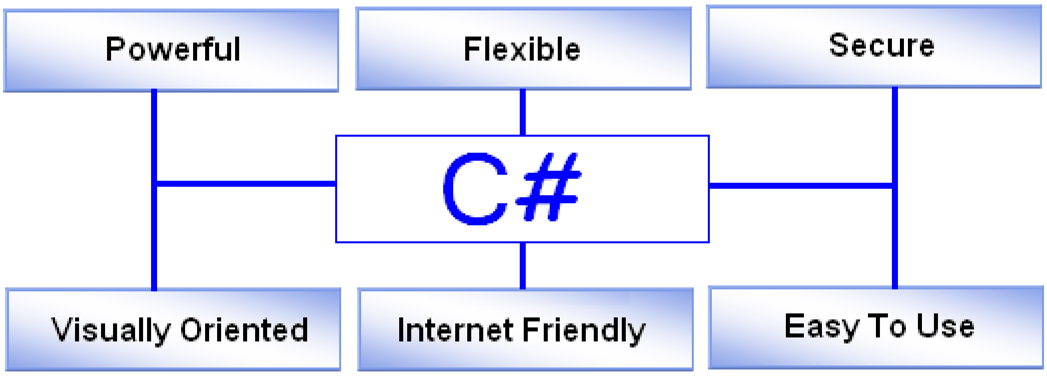

Figure 2.11: The Advantages of C#

Firstly, C# is flexible. Any machine with .NET Framework can execute the C# program. Even though the .NET Framework need to be externally installed on the machine in order to execute the C# program, the coming version of operating system released by Microsoft will have internally installed .NET Framework with it. C# program can be sent over the web and executed on computer at some distance without installing the C# programming software (Stephen Randy Davis, 2002).

Besides that, C# is powerful (Stephen Randy Davis, 2002). While C++ is well known with its powerful programming feature on the complete command set, C# that has essentially inherits the command set of C++ also inherits the advantage of C++. In addition, C# has refined the features on C++ and it is more powerful than C++. It is equipped with fully ANSI-compliant C# compiler. There is also powerful debugger for finding and fixing errors for C# program. On the other hand, C# can be used for diverse projects such as creating word processors, graphics, spreadsheets, and even compiler for other languages (Bradley L. Jones, 2001). In brief, C# is a powerful object-oriented, type-safe programming language (Setul Verma, 2001).

C# is easier to use (Stephen Randy Davis, 2002). This refers to the C# program that had modified the command responsibility for most C++ errors. As a result, the time to be spent on tracking the errors had been reduced. Besides that, the integrated developer environment (IDE) with IntelliSense™ makes entering and building the application as easy as possible (MSDN, 2005). C# also had removed some of the complexity of languages such as Java and C++. For instance, the macros, templates, multiple inheritance, and virtual base classes that cause confusion or potential problems for C++ developers are being removed in C# (MSDN, 2005).

C# also gain its advantages from the .NET code library that enables C# readily creates complicated display forms (Stephen Randy Davis, 2002). C# is visually oriented and has full support for Windows Forms and controls. The visual features used by C# are supported by the .NET code library (Stephen Randy Davis, 2002). C# is able to create graphic user interface (GUI) features using the form and variety controls such as text box, radio button, check box, button and others that applied both in Windows application and in web application.

C# is internet friendly (Stephen Randy Davis, 2002). The application of C# can be integrated seamlessly with the internet. In other words, C# has the ability to consume the web services (MSDN, 2005). It can be used to program the internet application and not only limited to the Window application.