UNIVERSITI TEKNIKAL MALAYSIA MELAKA

DETECTION OF DEFECT OF AN AUTOMOTIVE PART USING IMAGE PROCESSING APPROACH

This report is submitted in accordance with requirement of the University Teknikal Malaysia Melaka (UTeM) for Bachelor Degree of Manufacturing Engineering (Hons.)

by

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DECLARATION

I hereby, declared this report entitled "Detection of Defect of An Automotive Part Using Image Processing Approach" is the result of my own research except for the data received from the company and as cited in references.

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APPROVAL

This report is submitted to the Faculty of Manufacturing Engineering of Universiti Teknikal Malaysia Melaka as a partial fulfilment of the requirement for Degree of Manufacturing Engineering (Hons). The member of the supervisory committee is as follow:

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ABSTRAK

Di sektor pembuatan, jabatan kawalan kualiti memainkan peranan penting untuk memastikan produk yang dihasilkan adalah berkualiti tinggi. Salah satu elemen penting dalam kawalan kualiti adalah pemeriksaan. Namun, ketika berurusan dengan pemeriksaan, ada beberapa masalah yang timbul seperti tidak dapat mengesan kecacatan, kekurangan ketepatan dan ketidakcekapan untuk mengenal pasti kecatatan. Menggunakan pemeriksaan manual dan peralatan yang salah membawa kepada masalah besar kerana ia akan memakan masa pemprosesan yang lebih lama. Di samping itu, masalah ini juga mendorong kadar pertumbuhan aduan pelanggan. Oleh itu, ada keperluan untuk mencadangkan penyelesaian menggunakan pendekatan pemprosesan gambar berkaitan dengan pemeriksaan untuk menyelesaikan masalah ini. Projek ini bertujuan untuk mencapai tiga objektif iaitu mengenal pasti kekerapan bahagian acuan suntikan yang dihasilkan, merancang algoritma melalui teknik pemprosesan imej untuk mengesan bahagian yang rosak dan menganalisis keberkesanan teknik pemprosesan gambar untuk pemeriksaan kualiti dari segi ketepatan dan masa pemprosesan. Terdapat lima bahagian yang disertakan untuk menjalankan projek ini mengikut prosedur iaitu pengecaman frekuensi kecacatan, pemilihan kaedah untuk pemprosesan gambar, pengembangan pengkodan MATLAB, debugging pengkodan MATLAB, dan menganalisis pemeriksaan automatik. Perisian MATLAB Simulink akan digunakan untuk menghasilkan algoritma dan Antaramuka Pengguna Grafik (GUI) dalam projek ini. Sebanyak 100 sampel telah diperiksa dan ketepatan yang diicapai ialah sebanyak 96% dengan 8.81 saat masa pemeriksaan yang dapat dikurangkan. Persekitaran pemeriksaan harus dikawal dengan mengawal pengcahayaan untuk meningkatkan kualiti pemeriksaan. Akhir sekali, keupayaan sistem ini boleh dinaiktaraf untuk mengesan kecacatan 3D supaya sistem menjadi lebih baik dan berguna untuk syarikat.

ABSTRACT

In manufacturing sector, quality control department plays a significant role to ensure the product produced are high quality. One of the important elements in quality control is inspection. However, when dealing with inspection, there are several issues that arise such as being unable to detect defect, lack of accuracy and inefficiency to identify defect. Using manual inspection and incorrect equipment leads to major problems due to lack of accuracy which will consume longer processing time. Besides, this issue also encourages the growth rate of customer complaints. Owing to this reason, there is a need to propose a solution using image processing approach with regards to inspection to solve this problem. This project is aimed to achieve three objectives which are to identify the frequency of defective injection moulded part produced, to formulate an algorithm via image processing technique to detect defective part and to analyse the effectiveness of image processing technique for quality inspection in term of accuracy and processing time. There are five parts included to conduct this project according to the procedure which are defect frequency identification, method selection for image processing, development of MATLAB coding, debugging MATLAB coding, and automatic inspection analysis. MATLAB Simulink software is used to generate the algorithm and Graphical User Interface (GUI) in this project. A total of 100 parts sample was inspected and the accuracy achieved is 96% with 8.81 seconds of processing time reduced. The inspection environment must be controlled by controlling the illumination to improve the inspection quality. Finally, the ability of this system may be upgraded to detect 3D defects so that the system will perform better and more useful for the company.

DEDICATION

For my parents Azman Bin Wahid and Zushahidah Binti Mohd Said,

who always gives endless support and motivation,

My supervisor Ir. Dr. Lokman Bin Abdullah,

who have encouraged, guided and inspired me throughout the process,

And myself.

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LIST OF ABBREVIATION

ABS	-	Acrylonitrile Butadiene Styrene
ADF	-	Anisotropic Diffusion Filter
AQL	-	Acceptance Quality Level
CAR	-	Customer Claim and Action Report
CAT	-	Computer Axial Tomography
CMOS	-	Complementary Metal Oxide Semiconductor
FYP1	-	Final Year Project 1
FYP2	-	Final Year Project 2
GUI	-	Graphical User Interface
HE	-	Histogram Equalization
HIS	-	Hue, Saturation, and Intensity
IPQC	-	In-Process Quality Control
IPT	-	Image Processing Tool
ISO	-	International Organization for Standardization
K1	-	KEYTOP 1
K2	-	KEYTOP 2
LED	-	Light Emitting Diode
NG	-	No Go
OK	-	Okay
PDCA	-	Plan-Do-Check-Act
QC	-	Quality Control
QM	-	Quality Management
QP	-	Quality Procedure
RGB	-	Red Green Blue
RoHS	-	Restriction of Hazardous Substance
SDD	-	Surface Defect Detection

UCD	-	User-Centred Design
UD	-	Unique Diamond Sdn. Bhd.
UL	-	Underwriters Laboratories
USB	-	Universal Serial Bus
UTeM	-	Universiti Teknikal Malaysia Melaka
2D	-	2 Dimension
3D	-	3 Dimension

LIST OF SYMBOLS

s	-	Second
Sqm	-	Square meter
%	-	Percent
×	-	Multiply
Kg/m^3	-	Kilogram per meter cube
MYR/kg	-	Malaysian Ringgit per kilogram
GPa	-	Giga Pascal
MPa	-	Mega Pascal
HV	-	Vickers Hardness
$MPa.m^{0.5}$	-	Mega Pascal meter
°C	-	Degree Celsius
W/m. °C	-	Watt per meter degree Celsius
J/kg. °C	-	Joule per kilogram degree Celsius
μ	-	Micro meter
Ω	-	Omega
V/m	-	Volt per meter
MJ/kg	-	Mega Joule per kilogram
Kg/kg	-	Kilogram per kilogram

CHAPTER 1

INTRODUCTION

1.1 Background of Study

This report is aimed to discuss on creating a new inspection method approach for a plastic injection moulding company. Plastic injection moulding has become one of the most important and widely used polymer processing operations nowadays in the plastic industry. Unique Diamond Sdn. Bhd (UD) is first incorporated on 26^{th} of August 1992 and is located at Taman Sentosa, Klang, Selangor, Malaysia. Other than its main process which is injection moulding, this company also provides other 3 secondary processes which are spray painting, pad printing and sub-assembly. The factory area is approximately 7000 sqm and has 2 buildings which are Block A for office and industrial area and Block B for warehouse. The company shareholders are 100% Malaysian and also has an approved UL Code which is H1131. Manufacturing license number for this company is B10-G6-2010-00000014-A and has gained two ISO namely; ISO9001:2015 Quality Management and ISO14000:2015 Environment Management. The company has incorporated the RoHS procedures into ISO9001 and ISO14000 in April 2009.

Most of the moulded polymer are made for automotive parts, accessories, power meter or flow meter, professional camcorder and also vacuum metalizing part with various and complex design of the plastic components which have triggered the concern regarding its cost and easiness. This process would also produce defective part due to wrong selection of machine parameters and also from a poorly maintained mould. These problems are able to be solved by developing model optimisation that correlates with their responses and process parameters, although optimising its parameter needs an endeavour (Hentati and Masmoudi, 2020). The study is about detecting defects that are invisible to the naked eyes without any help of instrument such as dented, scratches, black dot, drag, and sink mark and at the same time to propose the best solution for inspector to perform quality control inspection method by using advanced technologies. Image processing is a technique that is introduced to the company as one of the effective inspection methods that convert image into a digital form that needs to perform some operations to receive an enhanced image or extract useful information from it.

In industrial inspection, In-Process Quality Control (IPQC) where it is implemented in QP-019 under ISO9001:2015, is a crucial task for inspector as they are dealing with the accuracy and specification of the raw part directly from production. The process flow of this quality process is attached in appendix A for further reference. Based on the observation received from industrial training with a duration of 10 weeks long from 20th July 2020 to 25th September 2020, the company is required to have both soft copy and hard copy documents. Sorting and rework must be performed and filled in the rework sheet when there is a detection of defective part before delivery. Presence of leakage in defective part that has reached to customer, a Customer Claim and Action Report (CAR) will be sent to the company for a complaint. Pictures with defect highlight are attached with CAR and QC needs to fill up the action taken, why it happens and how to prevent it from happening again as requested in the CAR. The defect that occurs on the part eventually creates problem in term of the production subsequent processes and also the customer. The main purpose of Surface Defect Detection (SDD) is to avoid the defective parts containing defects on the surface and prevent it from reaching out to customer (Han and Shi, 2007).

Surface defects need to be converted into pixels that can be differed from its original image pixels (Chisti, Srinivas and Prasad, 2015). Each quality problem requires different techniques of inspection for its precise evaluation. For image processing, reflectivity and colour are the appearances absolute measurements and several numbers can be given as its value. Local defect considers the surface area with a view that does not match the actual surface quality which makes the image parameters relative values more important. It is necessary to conduct large figure of parameters measurements and at the same time analyse the change in parameters over the examined area while detecting the local defect (Chisti, Srinivas and Prasad, 2015).

1.2 Problem Statement

In current situation, Unique Diamond Sdn. Bhd (UD) is using manual inspection most of the time and Smart Scope to perform IPQC for 4 samples every 4 hours during the production of the automotive part sampling. Based on 10 weeks observation from 20th July 2020 to 25th September 2020, defect overlook among the IPQC inspectors frequently happened due to ineffective method. Surface Defect Detection (SDD) by manual control has its own disadvantages and quality control provides important feedback loop that creates potential impact in manufacturing business. Due to the part micro-defects on the surface and overlook by IPQC inspector, the raw part has passed QC check for outgoing to be delivered to customer upon request. There will be an on-hold part or production issued which will interrupt the production and delivery planning. Due to having on-hold issue, it will indirectly reduce the manufacturing productivity. Over the year 2020, the customer has requested at least eight times for 100% checking for the delivered lot that contains defect with a result of 1.80% scratches, 0.34% dented, and 0.12% black dot using manual inspection. This will require the company to withdraw some money for transportation and also employment cost. Owing to this reason, it has caught the top management's attention and there is a need to use different approach to cater for this problem.

1.3 Objectives

The objectives of this project are as follows:

a) To identify the frequency of defective injection moulded part produced.

b) To formulate an algorithm via image processing technique to detect defective part.

c) To analyse the effectiveness of image processing technique for quality inspection in term of accuracy and processing time.

1.4 Scopes of Research

The scopes of this research are as follows:

a) This research was carried out at the In Process Quality Control (IPQC) Area in Quality Control Department of the plastic injection moulding industry.

b) The study is limited to inspection on the part's surface only.

c) The software used for defect detection is MATLAB Simulink.

1.5 Significants of Study

a) There are some potential benefits that can be gained by the company after the completion of this study when the company adopts the idea proposed since it is able to solve their problem that relates with their customer.

b) The output of this research project is expected to reduce the processing time during inspection process.

c) The efficiency and accuracy of detecting defect will increase in term of percentage.

1.6 Organization of Report

a) Chapter 1: Introduction

This chapter is the introduction of the study where it begins with the research background that discusses about the study of this research and also the company background. Problems are identified through verbal communication with industrial supervisor and observation during internship is stated in the problem statement. Objectives, scope of research and significants of study are delineated in order to define the particular aspects of research on using the image processing approach for detecting defective automation part. The impact of this study is shared to the company.

b) Chapter 2: Literature Review

This chapter covers the basic theories regarding the research topic and the previous studies from journals, articles, books and the search engine. It explains about the study deeply with the aid of the previous data and journals which focus critically on the project related studies.

c) Chapter 3: Methodology

The methodology describes about the preparation required and also describes the method selected to be performed for this project. Each process from analysing data to detecting defect is explained in detail for clearer information.

d) Chapter 4: Algorithm & GUI Design

This chapter emphasize the formulation of the algorithm to create an inspection method using image processing using image processing toolbox and app designer features in MATLAB. The process of converting image is shown step by step in this chapter. Besides, the graphical user interface (GUI) is designed based on the end user preference.

e) Chapter 5: Results & Discussion

This chapter analyses the information collected after performing testing through the image processing operation and data received by the software for the results recording. Then, the effectiveness of using image processing approach is discussed according to the result received.

f) Chapter 6: Conclusion

Recommendation about this project is examined and the effectiveness and the benefits for application of the method to real world industry are discussed in this chapter.

1.7 Summary

This chapter consists of 6 subchapters. Firstly, the background of the study explains about the importants of identifying defective part in a plastic injection moulding company where the study is conducted in a Quality Control Department. Next, problem statement of this research states the limitation of the current situation that require improvement from the instrument used for detecting defect since inspectors always overlook. There are three main objectives that must be achieved by the end of this study, meanwhile description about the priority things in developing this approach and study limitation are explained in the scope of research. Lastly, significants of study describes about the importance of improvement to the current problem faced by the company and how this study can contribute for the betterment in their industry and thus this concludes the important things in introduction of the project.

CHAPTER 2
LITERATURE REVIEW

This chapter will describe the theory and research that have been defined and conducted by various successful researchers years ago. Related information of previous studies is extracted as references and discussion based on their research about the defect, quality control, image processing, injection moulding and, also the raw material which is Acrylonitrile Butadiene Styrene. The injection moulding subchapter will describe how the moulding cycle works to produce a product. Next is the raw material used to produce the automation part. The material properties are described in detail with its benefit correlated with the suitable properties for injection moulding. The defect subchapter will cover the types of defects occurring on the selected automation part and its countermeasure for troubleshooting. For the quality control subchapter, it is generally explained about how quality works in the manufacturing industry and what standard is used for quality management. Lastly, image processing is explained in the next subchapter with detailed surface defect detection steps and technique that can be adopted.

2.1 Injection Moulding

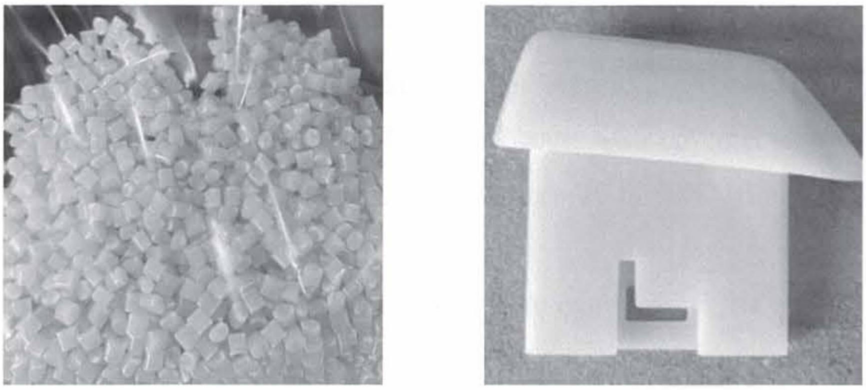
Injection moulding is one of the manufacturing processes that produces parts from thermoplastic and thermosetting materials. In fact, it is the most widely used process that is evolved from metal die casting. The transformation of plastic pallets to a moulded part is primarily a sequential operation of injection moulding. In comparison, Kale, Darade & Sahu (2020) said that polymer material contains higher viscosity, and it cannot be poured simply inside the mould and thus requires a high force to inject the molten polymer into the mould cavity. In the industry, the polymer is referred to as resins and the wide term of thermoplastics, thermosets, and elastomers are used.

Figure 2.1: Injection Moulding Machine

2.2 Acrylonitrile Butadiene Styrene (ABS)

The raw material used for the automation part is Acrylonitrile Butadiene Styrene (ABS) polymers that mainly contain three monomer units which are Acrylonitrile, Butadiene, and Styrene. The combination requires 15-35% of Acrylonitrile, 5-30% Butadiene, and 40-60% of Styrene depending on how the different properties can be achieved by blending these monomers (Salleh, 2013). It is a common thermoplastic polymer with a tough and heat-resistant engineering polymer. Originally, butadiene rubber has modified styrene-acrylonitrile copolymer. ABS is a combination of the polybutadiene resilience with rigidity and hardness of polyacrylonitrile with polystyrene.

ABS material has the highest impact resistance compared to other polymer materials. This material is UV resistant if any stabilisers are added for the use of an outdoor application. ABS polymer is considered as hygroscopic which means before thermoforming, it may require to be oven-dried. The rigidity of ABS can be dramatically increased when glass fibre is added. By depending on the amount of acrylonitrile, the colour may vary from in between water white to pale yellow. With a protective coating, loss of strength and yellowing can be avoided and slowed down with the presence of UV stabilizer (Edupack, 2013).



(a) (b)

Figure 2.2: ABS Resin (a) and Final Product (b)

2.2.1 Properties of ABS

ABS polymer properties are important and need to be familiarise with those who are in charge for material handling especially when it relates with the occurrence of defects. However, ABS offers great properties in terms of general, mechanical, and thermal properties. The density of ABS is in a range from 1010 – 1210 kg/m^3 with a reasonable price that starts from RM8.85 to RM9.76 per kilogram. This polymer allows detailed mouldings with complex shape and design, accepts colour well and friendly to children and even the environment since it is recyclable with a recycle mark as shown in figure 2.3, with a CO2 footprint and primary production between 3.64 – 4.03 kg/kg.

Figure 2.3: ABS Recycle Mark

ABS also offers favourable mechanical properties which are toughness, impact resistance, and rigidity, to name a few when comparing to other common polymers. This material has an average Young Modulus of 2 GPa and it offers such good elasticity. Besides, Shear Modulus for ABS polymer is from 0.319 to 1.03 GPa, a Yield Strength of 18.5 to 51 MPa, an average compressive strength of 58.6 MPa, and a fracture toughness between the range of 1.19 to 4.29 MPa m$^{0.5}$ (Edupack, 2013). Various modifications can be made in order to improve its mechanical properties as mentioned. For example, increase in polybutadiene proportions in relation to Styrene and Acrylonitrile can amplify its impact resistance, although changes in the properties may occur. ABS polymer also would provide great characteristics from a range of temperature within -20 to 80°C (Edupack, 2013).

Moulding ABS polymer at a high temperature can improve its glossiness and also improve heat resistance. Meanwhile high impact and strength resistance can be obtained by moulding ABS material at low temperature. ABS polymer has a glass temperature between 87.9 – 128°C and it is important to ensure the average maximum service temperature of ABS is at 69.4 °C and its average minimum service temperature is at -98.1 °C (Edupack, 2013). ABS can become a flammable material when it is being exposed directly to high temperature or exceeding its glass transition temperature, T_g, and melting point, T_m which is approximately at 105°C. The table below shows the summary of the overall ABS properties:

Table 2.1: ABS Properties Table Summary

Types of Properties		Value	Unit
General Properties	Density	1010 – 1210	Kg/m^3
	Price	8.85 – 9.76	MYR/kg
	Date first used	1937	–
Mechanical Properties	Young's Modulus	1.1 – 2.9	GPa
	Shear Modulus	0.319 – 1.03	GPa
	Bulk Modulus	3.8 – 4	GPa
	Poisson's Ratio	0.391 – 0.422	–
	Yield Strength	18.5 – 51	MPa
	Tensile Strength	27.6 – 55.2	MPa
	Compressive Strength	31 – 86.2	MPa
	Elongation	1.5 – 100	% strain
	Hardness - Vickers	5.6 – 15.3	HV
	Fatigue Strength at 10^7 cycles	11 – 22.1	MPa
	Fracture Toughness	1.19 – 4.29	MPa.m$^{0.5}$
	Mechanical Loss Coefficient	0.0138 – 0.0446	–
Thermal Properties	Glass Temperature	87.9 – 128	°C
	Maximum Service Temperature	61.9 – 76.9	°C
	Minimum Service Temperature	-123 – -73.2	°C
	Thermal Conductor / Insulator	Good Insulator	–

	Thermal Conductivity	0.188 – 0.335	W/m. °C
	Specific Heat Capacity	1390 – 1920	J/kg. °C
	Thermal Expansion Coefficient	84.6 – 234	µstrain/°C
Electrical Properties	Electrical Conductor / Insulator	Good Insulator	–
	Electrical resistivity	$3.3e^{21} - 3e^{22}$	µΩ.cm
	Dielectric Constant	2.8 – 3.2	–
	Dissipation Factor	0.003 – 0.007	–
	Dielectric Strength	13.8 – 21.7	1000000 V/m
Optical Properties	Transparency	Opaque	–
	Refractive Index	1.53 – 1.54	–
Eco Properties	Embodies energy, Primary Production	90.3 – 99.9	MJ/kg
	CO2 Footprint, Primary Production	3.64 – 4.03	kg/kg

2.3 Defect

Products manufactured are prone to defects which cause considerable economic opportunities and wasted resources other than increase in production cost (Oh et al., 2018). A defective product is a product that unreasonably reduces its surface value that comes directly from its primary process which, in this case, is injection moulding process. Injection moulded part's quality issue may vary from minor surface defects to serious surface defects that may affect the product performance and function.

A defective product is inevitable and well known among manufacturing industries. Almost all factories are imperfect and defective parts are usually occur at an uncertain rate. To sort these defects, a classification is required to allow clearer acceptance sampling according to the most product inspection method which is the acceptable quality level (AQL) (Niggl, 2017). Defects are usually classified into three types according to the severity which are the minor, major, and also critical defect. Minor defects are unacceptable in high quantities but they will not result in product returns. Meanwhile, major defects are likely to result in product return but do not pose any safety risk to the users. Lastly, critical defects will violate the regulations or pose threats to user safety.

2.3.1 Moulding Defect and Its Countermeasure

Parts manufactured by injection moulding uncertainly contain defects that will influence the quality of the part. The defective raw part that has been produced by the primary process which is the injection moulding process may be difficult to address. Some moulding defects are able to be prevented by adjusting the machine parameters, and some defects require proper management by the person in charge as the defects may originate from the material and method of handling. There are generally four types of critical defects from the existing automation part studied, and there are also other frequently occurring defects in injection moulding discussed for the moulding defect. The types of defects are identified along with their root cause that is either from the machine parameters, the mould cavity, or the resin itself according to the defects. The defects mentioned are studied through the fundamental of the mould machining and it is a general cause that always occurs for all injection moulding industry in the whole world.

The first defects are the sink mark which are justified as the localised depression. The causes of this types of defects are due to slow cooling of the material that is near to the exterior part that results in shrinkage which pulls outside material inward. Knack (2015) said that the common countermeasure for this defect is by increasing the holding pressure and time for the material to cool. Increasing the cooling time is needed as it allows for shrinkage limit. Designing mould with thinner wall component may allow for rapid cooling near the surface. Besides, reducing the mould temperature also may help to prevent the sink mark to occur because it will allow for more adequate curing and cooling.

Scratches defects usually occur on a deep cavity product and is particularly a common problem for injection moulding process. The main cause of scratches in term of production is the mould design. Mould design plays an important role that needs to be considered carefully. This includes mould structure, gate design in the mould, and mould cavity surface (Jackie, 2019a). This is because improper mould design will cause the mould core and cavity to be misaligned during the mould opening and cause product scratches. The countermeasure for this defect is considering the mould gate to not apply too much pressure on the product. By this, the gate design on the mould must be far from the side surface. This is because pressure at the gate and holding time is relatively high.

The other possible and frequent defect to occur in the automation part is the black dot. Black dot defect comes from foreign material in the machine environment or in the raw material itself which is also considered as contamination. The other general cause of the black dot as stated by Rozaimi (2019) is the presence of empty space inside the nozzle and also by grease at the lifter mechanism or at the side pull. The black dot in moulded part may reduce the injection moulding process yield and profitability. Spalding and Campbell (2012) mentioned that the metering section of the injection moulding machine must operate as the controlling step rate and should always be verified by the trouble-shooter. One of the solutions for black spot defects is to lower the mould temperature. Jackie (2019b) also said that it is crucial to check the temperature setting of the machine if it is unsuitable. Black spot is prone to appear in the check ring and the screw thread inside the barrel and nozzle. Thus, frequent and thorough cleaning is needed before starting production.

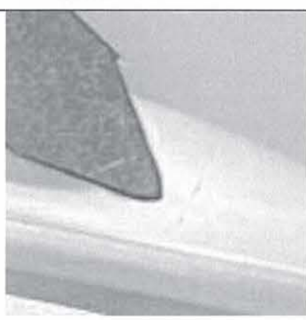
Other than that, drag mark is also one of the frequently happened defects during injection moulding process. Drag mark is similar to scratches but it always occurs during ejection of part from the mould. This defect usually occurs when other parts produced on the same machine and mould contain scratches on its surface. This makes the ejection becomes difficult when the designed draft angle is insufficient and it will accommodate drag on the parts. The troubleshoot for this defect is to improve through redesign or adjustment of the mould by increasing the draft angle or replacing the parting line position. Besides, some cases only require a mould release agent to reduce the drag on the part surface.

The last frequent defect is dented or shrinkage where the part does not any close contact with the mould cavity cooling surface, which results in bad cooling efficiency. This happens when the part starts and continues to cool and it shrinks gradually. By referring to the information given by Industry (2017), the shrinkage rate will depend on the various action factors combined. Theoretically, the corners of the part tend to cool first and harden earlier compared to the other area. The indentation of the part is caused by the contraction and thermal expansion of the polymer because its thermal expansion coefficient is relatively high. The remedy for dented defect is to adjust the process conditions that can avoid indentation and maintain the reinforced materials that contain a low shrinkage rate. Shrinkage able to be reduced when improving the mould cavity condition which requires frequent maintenance. The lower the temperature of the mould and barrel, the higher the injection pressure, although it may produce internal stress residual. The table of defect summary related with the study can be referred in table 2.2.

Other than the mentioned defects, there are various types of defects that occur from the injection moulding including the flow line which is caused by variation and inconsistent cooling speed as the material flows throughout the injection mould. Other than that, burn mark defects also typically appear when there is a presence of trapped air or the resin is overheat in the mould during the injection process. Warping defects are known as the deformation of moulded parts that occur when different areas of the part shrink and dry unevenly, which is caused by fast cooling.

Manufacturing part using the process of injection moulding usually requires outstanding tooling upfront investment. The defects stated are frequently caused by process problems, material storage or usage, and by poor mould maintenance and design. Thus, it is essential to have a precise with right, and detailed mould design in the first place rather than restart the whole process after detecting defects. Although the defect that is related to the process and material is simple and did not cost a value to solve, it is important to remind that defects occurrence will affect the production bottom line.

Table 2.2: Study-related Defect Summary

Types of Defects	Image	Cause	Countermeasure
Sink Mark		1. Slow cooling of the material that is near to the exterior part	1. Increase the holding pressure and time. 2. Increase the cooling time. 3. Reduce the mould temperature.
Scratches		1. Improper mould design	1. Apply less pressure on the product.
Black Dot		1. Foreign material in the machine environment or in the raw material. 2. Presence of empty space inside the nozzle 3. Grease at the lifter mechanism or at the side pull.	1. Lower the mould temperature. 2. Clean the barrel and nozzle frequently and thoroughly.
Drag		1. Difficulty to eject due to insufficient draft angle.	1. Improve or redesign mould draft angle.
Dented		1. High thermal expansion coefficient that causes contraction and thermal expansion of the polymer.	1. Frequently maintain the mould cavity. 2. Adjust mould and barrel temperature.

2.4 In-Process Quality Control

In-Process Quality Control (IPQC) functions to monitoring and checking the adaptation of the manufacturing process to comply with the provided specifications which are conducted before, during and after production (Kshirsagar, 2017). The monitoring and checking include control of equipment and environment. In-process parts are required to be tested for their strength, purity, and quality whether to approve or reject by the IPQC inspector and unit during the production of the part. Rejected parts collected during the inspection should be controlled under a designed system of quarantine for prevention in production (Verma & Tangri, 2014). IPQC controls the procedure involved in manufacturing to prevent error during processing.

The main objectives of the IPQC system are to observe the features of a product that may affect its quality and functionality and to prevent errors from occurring during the process. IPQC is also concerned with providing specific, accurate, and definite procedure descriptions to be adapted. Besides, IPQC also detects variations of the product tolerance limits for prompt and corrective actions to be taken if required and to immediately detect abnormality of the product and indicate the action needed. This indicates why IPQC checking plays a major role during manufacturing in auditing the quality of the product produce at any stage of production.

Defective part is required to be located, troubleshot and removed when assuring the quality because the standard and particular needs from client and their industry is crucial for different process and practice to meet their standard and quality (Mold, 2019). One of the standards performed during manufacturing plastic injection moulding part is achieving and following the standard of ISO 9001:2015 Certification.

2.4.1 ISO 9001:2015

ISO stands for the International Organization for Standardization is a federation of the worldwide national standard ISO member bodies. It is a specific requirement for a quality management (QM) system when any organizations need to demonstrate their ability to provide product with consistency and service that is applicable with the customer requirement, statutory, and regulatory. Besides, ISO 9001:2015 aims to enhance customer satisfaction by the system effective application that includes system improvement process and provide assurance of conformity and apply statutory and regulatory requirements to customers (ISO, 2015).

The ISO 9001:2015 is structured to introduce certain changes and revisions to compare with the previous standard version which is to accommodate the modern world by changing the business environment. The update made in ISO 9001:2015 urges organisations to review the current approach. Researcher Al-Rub (2020) stated that the process change in respect to the proposed version is required to engage by any business leader with their team members and process owners. Business leaders should identify modifications, manage and control quickly to minimise the impact.

In every organisation, it is important to apply the principles of quality management to enhance their business for an improvement in term of sustainability. This standard provides the most benefit in ISO certification and it is beneficial for all organisations which include small, medium and large industries organization around the world. It is a strategic decision to adopt a quality management system for an organisation because it is able to help and improve the organisation overall performance and provide a sustainable development initiatives sound basis. This standard employs the process approach that incorporates the risk-based thinking and Plan-Do-Check-Act (PDCA) cycle (refer figure 2.4). This approach enables organization to discover the factors that could cause the process and its quality management system to diverge from the planned results for preventive controls in order to minimise negative effects and maximize the use of opportunities (Al-Rub, 2020).

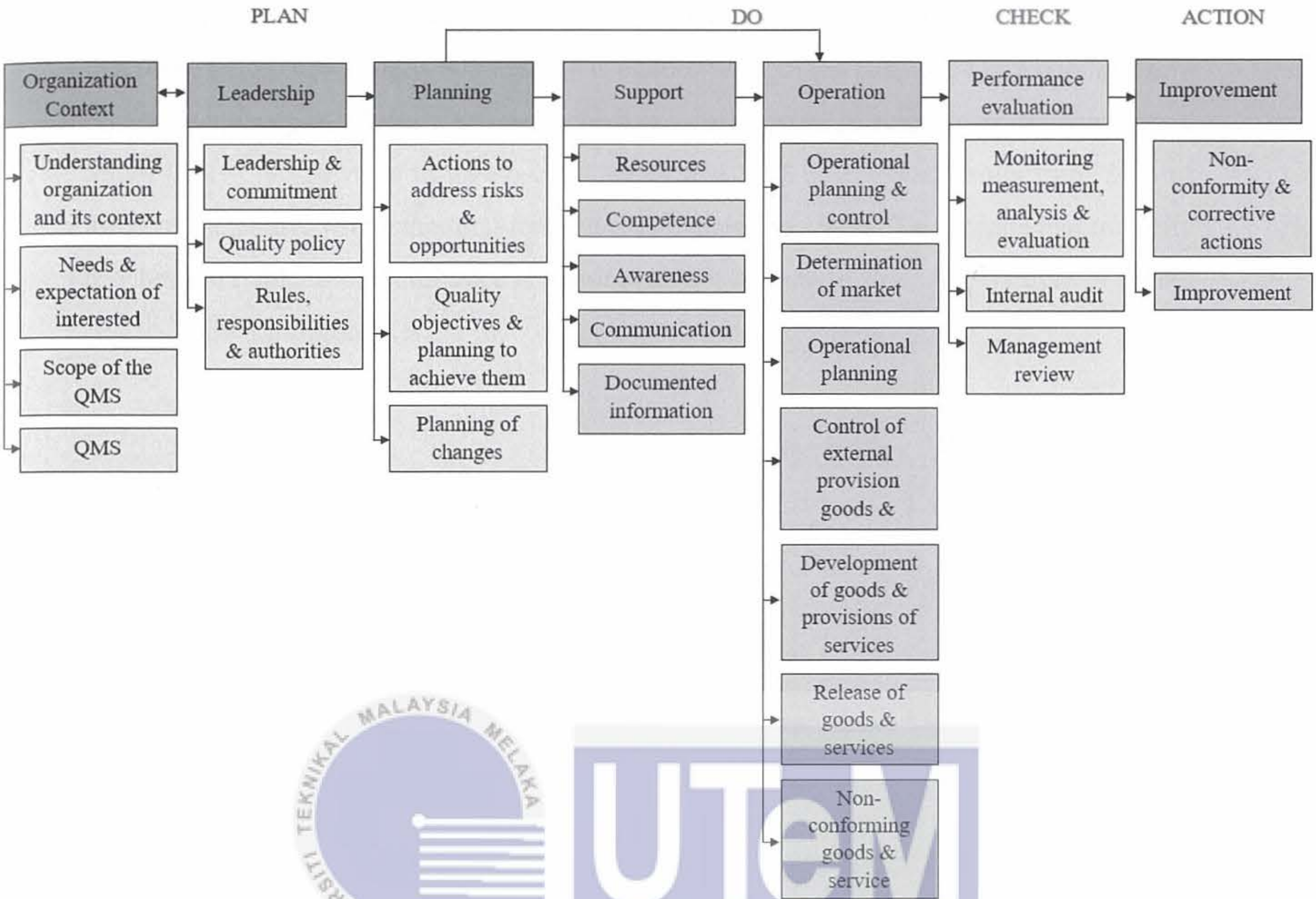


Figure 2.4: Plan-Do-Check-Act (PDCA) Cycle (Al-Rub, 2020)

2.4.2 Pareto Chart

Pareto Chart is a method and technique in quality control to improve quality and is often known as Quality Control tools or QC tools. There are a total of seven QC tools available to be used depending on the issue or scenario involved to overcome the problem. It is used to solve process improvement steps that is able to provide solution for most of the problems related with quality. This tool is used for data coordination and consolidation to concern the quality, making decisions for the batch size production quality based on the analysis sampling collected, and process control to meet high level quality (Nicolae et al., 2015). This method is a statistical tool to rank data by referring to the frequency of occurrences from highest to lowest frequency.

This QC tools is a bar graph that shows one bar for each cause category, which in this case is the types of defects. Each bar is generated from the frequency in a column from highest frequency to lowest frequency which is termed as 80/20 rule. Based on Kumar and Singh (2019), 80/20 rules in pareto chart states that 80% defect that results from 20% of the possible cause, where the total frequency is equated to 100%. This means that majority problems are able to be eliminated if major problem is focused first. An example of pareto chart is shown in figure 2.5.

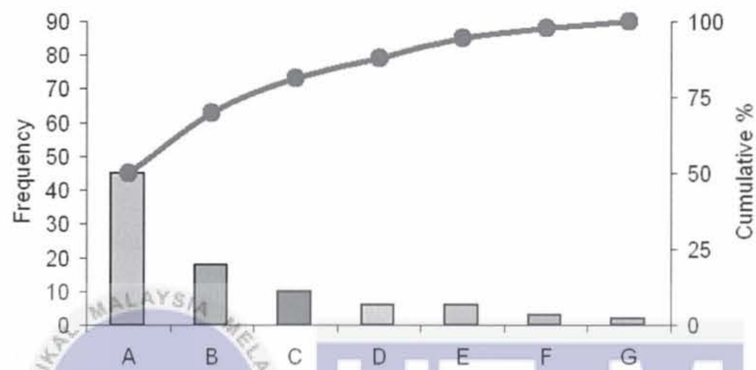


Figure 2.5: Pareto Chart

2.5 Image Processing

Defect identification from image has increased significantly for a variety of applications due to prominent role of quality control in manufacturing. There are a lot of development for inspection using vision-based approaches to detect defect on part's surface and one of the most reliable and effective ways is using image processing. Rahaman & Hossain (2009) have conducted a research and said that image processing shows the most increasing approaches in quality control since analog imaging has switched to digital system these days as the technology advances. There are three levels from the established methodology of defect detection using image processing which are the lowest, middle and highest level. The techniques available for the lowest level is dealing directly with the possible noise pixel value with edge detection and de-noising. In the middle level, Rahaman & Hossain (2009) also said that the algorithm such as segmentation and edge linking is used to utilise low level and at the highest level, extracting semantic meaning from lower-level information is attempted for its method.

This approach is essential for a signal processing method where the images are used as input. The image may be identified as a two-dimensional function which is $f(x,y)$ where x and y are considered as a plane coordinates. The image is in grayscale if $d=1$ and the image is coloured (RGB) if $d=3$. Higher d dimension corresponds to hyperspectral imaging (Özseven, 2018). Hyperspectral imaging is very common in remote sensing. The need to extract information and interpret content for image processing has become its driving factor for the image processing development.

2.5.1 Image Processing Technique

In todays industry, image processing has become one of the most important and increasingly used areas because it includes the conversion of digital image from the analog image. Different features are extractable using automatic process and software such as MATLAB for digital image (Chavan & Shinde, 2016). Recognising and categorising types of defects require operation on digital image and some methods to recognize types of defects on the image have already been established and sited. Image intensity function discontinuities demonstration are generally from edges. Differences of reason in term of object geometry, surface texture related with the material, their interaction and lighting condition should also be considered.

One of other image processing techniques available is anisotropic diffusion filter (ADF) where its iterative methodology is used to restore the magnetic resonance image intensities. It is known as a filter that is capable to smooth noisy pixels and at the same time preserving the edges intensity. This technique can achieve an accurate result by setting the parameters and edge stopping function according to the image nature, acquisition protocol, scanned subject, and signal-to-noise ratio. Palma et al. 2014 has stated that in the context of image processing to remove noise with high frequency while conserving the existing main edges, ADF technique has been successfully employed and used in several different automated ways.

Another mostly used technique is the convolution neural network where it has achieved such excellent results in many tasks such as object recognition due to their network structure that able to extract image of multi-level features. This technique has become a research favourite in computational vision field. Deep convolution neural network contained multi-layer perceptron that can automatically learn the data distribution low from big data, other than having a powerful learning and the ability of feature expression (Mo et al., 2019). Researchers Mo et al. (2014) also prove that improvement of the convolutional neural network based on integrated learning algorithm is possible to improve the recognition reliability and target recognition under the premise of increasing parameters number.

2.5.2 Image Processing Historical Aspect

Newspaper industry was the first area to use the digital image processing in the early development of technology. The function was to produce a better image or converting the black and white to coloured images. Digital images were electronically transmitted between New York and London in the 1920s. Image coding capability was one of the Initial Bartlane picture system ability which use five levels of grey which is then enhanced to 15 levels of grey in 1929 (Tyagi, 2018). After the invention of digital computers and other related technologies, actual digital image processing was started with more advanced used including image transmission, storage and display.

Meaningful digital image processing was originated from a powerful computer in the 1960s because Ranger 7 United State speechcraft has taken a satellite image of the moon which is then processed at the Jet Propulsion laboratory located in California. Digital image processing was also beginning to use in variety of activities that relate with medical image processing, astronomy, remote sensing and more. The use of image processing techniques has tremendously grown starting in the year 1960 and onward (Tyagi, 2018). In the year 1970's digital image processing applications begins to be used in medical area where Sir Godfrey N. Hounsfield and Prof. Allan M. Cormack share the noble prize in medicine for their invention about tomography. Tomography is a technology behind the Computer Axial Tomography (CAT) scans. Nowadays, image processing techniques has become an important use in every part of the use in industries that have various applications in the field of medicine, defence, astronomy and more.

Examples of the field that has already adopted digital image processing in their system includes fingerprint recognition, face recognition, character recognition, product inspection and assembly, processing of satellite images and weather prediction. Image processing also can be used for artistic effects where it is used to make images more visually appealing and to add special effects to make a composite image. In industrial inspection, human operator is expensive, unreliable and slow. Thus, machine such as image processing using machine vision is applicable in the production to do the job instead since this kind of system are used in all kinds of industries.

2.6 Image Processing using MATLAB

MATLAB is a contraction platform for matrix laboratory that is used to solve mathematical and scientific problems using a propriety programming language that has been developed by MathWorks. It allows matrix algorithm implementation, function and data plotting, manipulation, interfacing user interface creation using a program written in programming language. The Image Processing Tools (IPT) is a bunch of functions that able to extend the MATLAB numeric computing environment capability (Maini, 2019). This tool provides a reference-standard algorithm for a comprehensive set and a workflow application for image processing, visualization, analysis, and algorithm development. Maini (2019) also stated that MATLAB IPT can be used to perform image enhancement, segmentation, noise reduction, geometric transformation and, 3D image processing operations.

The size of an image is usually a rectangular array of values or pixels and each pixel represents the measurement of property scene measured over a finite area. The property measured is either the average brightness of the filtered image brightness's through blue, green, and red filters. Average brightness has one value meanwhile filtered image through the coloured brightness has three values. These values are usually represented by the integer of eight bit and give a range of 256 different levels of brightness (Morris, 2004). Raw image always takes up more space and a method to compress the image is defined using coding redundant data. Reading common image formats is also supported by MATLAB although image coding did not address in the course unit.

2.7 Data Acquisition

Surface Defect Detection (SDD) process in image processing includes four major steps according to the set of data used, the types of defects examined, the method to be used, and the results intended. The first step in SDD is data acquisition. Banica et al. (2017) shared that this system was designed to acquire data from the equipment used for inspection. This step includes the acquisition of sets of data to be used such as cracks in the surface of the part, steel surface defects, and textured surfaces.

Camera and lighting process is not required when using existing data. Camera and lighting processes are used when images collected are from the production line. Researchers Min et al. (2018) said that the lighting process is used to reduce the ambient lighting that creates a negative effect on the SDD other than to prevent shading by giving constant light. Meanwhile, the usage of camera able to collect images under a constant source of light. According to Özseven (2018), the camera for this step is a standard camera for a simple operation meanwhile array camera is used for professional use and for industrial processes.

2.7.1 True Colour Image

In a normal living world, colour is an important perception since people eyes are perceptive to colour compared to brightness under normal illumination conditions. Colours can be expressed in the basic colour components which is red, green, and blue (RGB). However, according to Mohan et al. (2016), colour perception is better to be expressed in the I coordinate system. RGB as stated, are the most frequent additive colour used and image also have its subtractive colour mixing that is idealized with primary filters such as cyan, yellow and magenta.

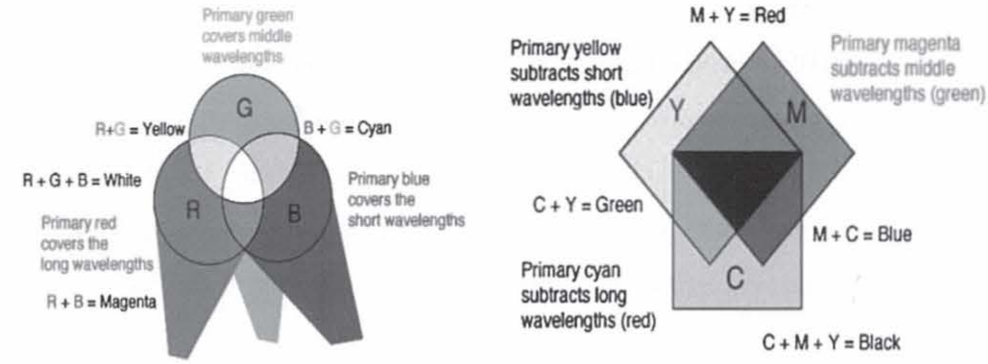


Figure 2.6: Additive and Subtractive Colour Mixing (Mohan et al., 2016).

2.7.2 Cropping

Cropping in image processing is used to remove the unwanted are from the image frame. This is to ensure that the meaningful parts of images are identified and able to crop out the unwanted area from images and focus on one object only. Generally, images represent the visual information which include the pixels value. Over the year, image cropping has been an essential task to identify and focus on the common and visible object. As stated by Rahman et al. (2018) Properties such as image background colour, illumination condition and viewpoint disparity make the task to be more complex.

2.8 Pre-Processing

In the pre-processing step, removal of the data unnecessary part is the largest drawback in data processing processes because the data collected will affect the result. Besides, the data collected is ready for extraction of features. This step is performed to avoid drawbacks and this process does not need any obligations. Özseven (2018) also stated that Pre-processing allows noise removal contained in the image other than filtering out the parts that did not provide any effect on the results from filtering various changes such as colour mode, size, and more on the image.

The general method used in pre-processing for SDD process are changing colour mode, image resizes, image rotation and noise reduction (Özseven, 2018). Changing colour mode includes changing colour mode of an image where the image colour can be converted into grey or black and white. Image resize is used to increase or decrease the size of the image meanwhile image rotation is used to rotate the image to the desired angle. Lastly, noise reduction is used to remove the image pixels that gives a negative impact.

2.8.1 Grayscale Image

Grayscale image is often recognized as black and white image. The description of this image representations is achromatic or colour exclusive description. Every pixel in the image is a significant of a grayscale illustration that corresponds to brightness. Mohan et al. (2016) also described that the term brightness is utilized frequently in order to illustrate apparent strength among psychological intelligence in optical sensitivity in physics realm. Most of the computer vision application required colour to grayscale algorithm conversion in order to preserve the image's salient features (Günes et al., 2015). Image salient features include brightness, coloured image structure and contrast.

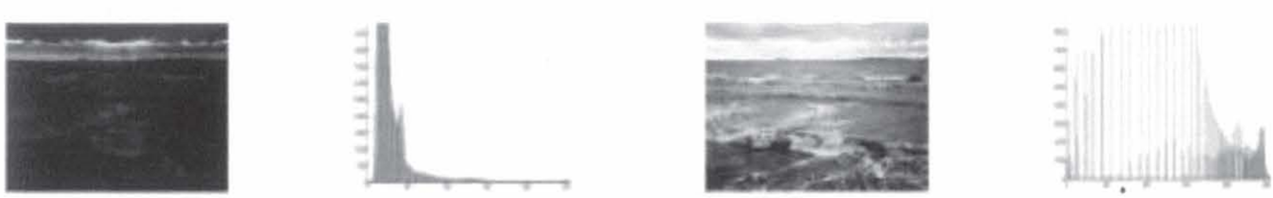
Figure 2.7: Grayscale Image

2.8.2 Image Enhancement

Image enhancement in term of image processing usually refers to enhancement of image contrast. Contrast is always referred to the difference between image intensity of two adjacent pixels. Non-uniform lighting conditions, small dynamic range or non-linearity of image sensor will emerge a low-contrast images (Iwasokun, 2014). It is basically an improvement for the image information interpretability or perception in order to provide better input for the image processing technique. Researcher Kaur & Kaur (2015) stated that more than one of image attributes are able to be modified according to its requirement and this modification process vary according to the task given.

2.8.3 Histogram Equalization

Spatial domain-based method is constantly used by many researchers due to its simple computation complexity and easiness to understand. Histogram equalization (HE) is a technique that is general in image enhancement because it provides a better performance on all images format (Roomi & Ganesan, 2015). HE will try to spread the image pixels intensity based on the whole image information to enhance the image. From this method, an issue such as low intensity pixels may be transformed at a high rate and thus create an over-enhancement image as shown in figure 2.8. According to Rahman et al., 2014, this technique might result in a mean shift where the input image mean brightness may create an undesirable artifact.



(a) (b)

Figure 2.8: Test Image (a) Original Image and Its Histogram, (b) HE and its Histogram (Rahman et al., 2014)

2.8.4 Filtering

In the pre-processing process, filtering to reduce the noise in the image is compulsory in order to improve the image quality. The famous two types of algorithms for filtering are classified to linear and non-linear filter. In general, linear filter achieved through a Fourier multiplication and convolution meanwhile non-linear filter is not achievable through this method (Desai et al., 2020). This is because the non-linear output is not linear with its input and will result in a variation of non-intuitive manner. Filtering is applicable to remove blur, edge detection and more, other than remove noise. The right filter application should be used regarding its purposes. If the image has small amount of noise but has high magnitude, non-linear is the most suitable to be used.

2.8.5 Median Filter

According to Fisher et al. (2003), median filter is normally used for this method because it considers each pixel in the image and looks at its neighbour nearby to decide if it is representative or not for its surrounding. Median filter replaces the neighbouring pixel value and it is calculated by sorting all the pixel values first from its surrounding neighbourhood into a numerical order before replacing the pixel with the middle pixel value. Calculating the median value of a pixel neighbourhood as shown in figure 2.6 use a 3×3 square neighbouring. If larger neighbour is considered, it will produce a more severe smoothing. In figure 2.8, the central value (150) is unrepresentative of its surrounding pixels and thus it will be replaced with a new median value. The neighbourhood values shown are 115, 119, 120, 123, 124, 125, 126, 127 and 150. From the ascending values stated, the new median value that will replace the central value of 150 are 124.

123	125	126	130	140
122	124	126	127	135
118	120	150	125	134
119	115	119	123	133
111	16	110	120	130

Figure 2.9: Median Filtering Pixel values

Using median filter allow great details deal of high spatial frequency to pass but able to remain its effectiveness at removing noise on image where the pixels in the neighbourhood is less than a half is affected. However, median filter could be less effective when the image is corrupted from a Gaussian noise. Median filtering has its own problem where it is complex to be computed. The basic algorithm of median filter able to enhanced in term of speed since it is slow to sort all the neighbourhood values into a numerical order. Some advantages of using median filter are that new pixel value is not needed to be generated, other than it is easy to implement. Besides, the extreme pixels value are removed effectively since the median is less sensitive compared to the mean extreme values.

2.8.6 Wiener Filtering

Wiener filter is the most important technique to remove blur of an image that is caused by unfocussed optics or linear motion. Blurring caused by linear motion comes from a poor sampling in a signal processing standpoint. Wiener filtering execute an optimal trade-off between inverse filtering and noise smoothing because it able to inverts the blurring and remove the additive noise simultaneously (Rice, 2008). This filtering method minimize the overall mean square error since it is optimal in those terms for the inverse filtering and noise smoothing process. Wiener filter is a linear estimation of the original image and is approached by a stochastic framework.

Wiener filter can be characterized into three character which is assumption, requirement, and performance criteria. For assumption, the signal and noise of the image are a stationary linear stochastic process known auto-correlation and cross-correlation or known spectral characteristics. For the requirement characteristics, Das et al. (2015) mentioned that wiener filter must be physically realizable where it will result in a non-casual solution when the requirement can be dropped. Whereas the performance criteria of this filter are a minimum mean-square error. For wiener filter, large window can be used to smooth the speckle noise and small window can be used to avoid blurring edges. Despite of the advantages mentioned, wiener filter is difficult to estimate its power spectra and also, difficult to obtain a perfect restoration for the random noise nature.

2.9 Feature Extraction

Feature extraction is a part of dimensionality reduction process, where it is a method of dividing and reducing initial set of the raw data to more manageable groups for easy processing. Large data sets have a large number of variables and these variables require a lot of computing for processing. Feature extraction helps to get the best feature from big data sets by selecting and combining variables into feature and reduce the amount of data. These features able to describe the actual data set with its accuracy and originality and also easy to process.

Various methods can be used for defect detection in the SDD process. These methods include statistical, spectral, model-based and learning-based groups (Ngan, Pang, & Yung, 2011). By depending on the expert's opinion, outcome success, and data, the methods will be chosen for the extraction to detect the defect. For instance, spectral or learning-based methods are suitable to be used to find a defect in a standard pattern. Meanwhile, structural or model-based methods are suitable to be used for detecting the deformation on a steel surface.

Feature extraction in image processing represents an interesting part of the image as a vector with compacted feature. Feature extraction was accomplished with a specialized feature extraction, feature detection, and feature matching algorithm in the past but nowadays, deep learning has become famous for its ability to make the input from raw image data and skipping the feature extraction step. Computer vision application require effective representation of image features, either by deep network of first layer or applying some of the longstanding image feature extraction techniques.

2.9.1 Morphological Process

Imperfection of enhancement results may occur in the image structure. Morphological process is performed only to remove the imperfection that affect the image texture. In a context of image processing, morphology signifies a description of structure and shape of the object in the image (Srisha & Khan, 2013). Morphological process works on the basis of sets of theory and more relied on pixel relative ordering instead on its numerical value. The characteristics that is available in morphological process makes it more useful for image processing use. There are two input data for the operations of mathematical morphological which is raw image and primitive image. Morphological process can be used in various applications. This includes hole filling, connected component extraction, objects boundary extraction, thinning and also thickening of an object. The morphological process fundamental are dilation and erosion where dilation operation increases the size of an object and erosion operation reduce the size of an object. The dilation and erosion of image will depend on the structuring elements. Example of dilution and erosion in morphological process is shown in figure 2.10.

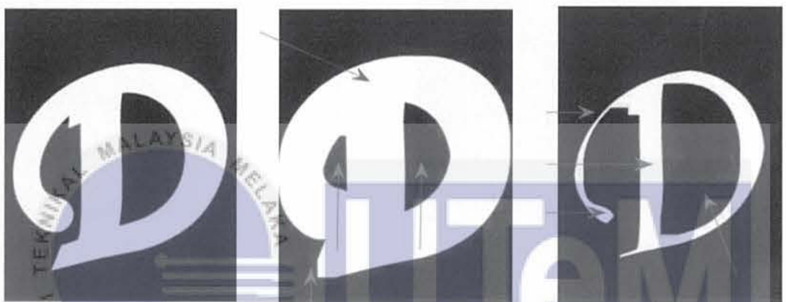


Figure 2.10: Dilated and Eroded image (Srisha & Khan, 2013)

2.9.2 Segmentation

Image segmentation has become one of the most important part to perform image processing. Since it is been used everywhere to process the image and recognise object inside the image. Segmentation process splits the image into several areas or objects. Image segmentation has two basic properties which it will be discontinuity or otherwise. As stated by Dar, (2020), the aim of segmentation process is to recognise the object in the image. Splitting image using multiple chunks able to ease the process and image will be re-joined after completing the operations. Using segmentation technique can increase the accuracy to recognise the object in the image.

2.9.3 Thresholding

Thresholding process creates a black and white image from grayscale image by setting the pixels to white if its value is exceeding a given threshold and black for below threshold. Thresholding a grayscale image creates binary image and it is the most effective way to partitioning image into foreground and background. Guruprasad and Mahalingpur (2020) has categorize thresholding into six group based which is the histogram shape-based method, clustering-based method, entropy-based method, object attribute-based method, spatial method, and local method.

(6) (b)

Figure 2.11: Original Image (a) and Threshold image (b) (Dar, 2020).

2.10 Defect Detection

SDD technology is mainly to detect the surface of the product by referring to the detection technology and defect on the surface. Several methods are suitable to be used to detect the surface defect as stated by Yang et al. (2020) include deep learning, magnetic powder, eddy current testing, ultrasonic testing, and machine vision detection method. In this project, machine vision defect detection is considered to be use because machine vision detection mainly consists of the subchapter discussed earlier. Due to its accurate, fast, non-destructive and low-cost characteristics, machine vision is widely used nowadays in most of the industrial field.

Deep learning technology for defect detection has developed rapidly and it has made a great success among detection application. Deep learning has deep neural network structure with multiple convolutions layer. Such data can be reached in abstract ways when low-level features is combined to form a more abstract high-level representation of attribute categories or features. Some researchers in Yang et al. (2020) research papers have proven that 95.3% of defect detection accuracy by using machine vision-based defect detection over scratches, holes, scales, pitting, edge cracking, crusting and inclusions can be reached.

2.11 Graphic User Interface (GUI)

Graphic user interface or GUI is an interface containing pictorial to a system where it has the ability to make the program easy to be used by providing consistent appearance along with intuitive controls. In MATLAB, there are three required principal elements which is the components, figures, and also callbacks. GUI in MATLAB is designed to integrate various functions of image processing. In order to generate the interface, callbacks of the component selected need to be used when user trigger or manipulate the components with keystrokes (Nayana et al., 2016). Since GUI invented, usage of computers has become easier to use.

The aspects of GUI help making the interface attractive, easy and effective for user. GUI aspects mentioned by Abdo (2016) include loading time, consistency, navigations, easy form, search and list, and contact. The important requirement that should be considered and given attention when designing a GUI is to understand the wants, needs, and limitations of the user where the design philosophy is often called as User Centred-Design (UCD). As stated by Stopper (2012), there are some of the techniques that should be used wisely are the GUI controls and user's attention. The control of GUI is known as tools that allow user-system interaction and there are four GUI control groups which is the input elements, the output elements, the selection elements and the action elements. Since GUI normally contains many elements, the components used must be decorated with design rules such as the icon used for push button must clearly identify the action, the style of drawing must be kept in a symbolic way, and the mode, state, or action of each component initiates must be shown clearly. In order to catch user's attention, several techniques that should be considered to be used are animation, colour, sound and graphic adornments.

2.12 Analysis of Reference

As a total of 50 resources have been analysed in this chapter which covers about the injection moulding defect, quality control, image processing and its fundamental technique, injection moulding process and Acrylonitrile Butadiene Styrene (ABS). The general description technique for image processing that will be used for this project and the explanation about the types of defects in relation with quality control is based on the journals. The summarized of the total paper review for this chapter is shown in appendix B.

2.13 Summary

Chapter 2 consist of 11 subchapters which is the defect, quality control, image processing, image processing using MATLAB, data acquisition, pre-processing, image enhancement, filtering, feature extraction, defect detection, injection moulding, Acrylonitrile Butadiene Styrene (ABS) and Graphical User Interface. To summarize this chapter, the method and study related topics is discussed. The classification and analysis of the journals, books, articles, conferences and websites is included to show the significant between each resource. This research can be easily conducted as wide information related with this project is explained from its background, to its historical aspects, until the fundamental and system of the related works. Some improvement and suggestion can be made to the information gathered for literature review might be added to the public after the research has fully completed.

CHAPTER 3

METHODOLOGY

In this chapter, the methodology of this project is explained in schedule planning starting from registration of the project until the evaluation of the project which is shown in the project flowchart and also the Gantt chart. This chapter will also describe and explain the method used to conduct this project with its suitable technique and its step of performing the technique. The purpose of this chapter is to recommend the most suitable methods with recommended tools and techniques to complete this project.

3.1 Schedule Planning

In order to conduct this project, it is compulsory to know and have a plan of the flow for the overall research which consists of the method used for this project and method of how the data is being collected. The purpose of this methodology is first to identify the appropriate method and technique, and then to recommend the suitable method and technique to complete this project.

3.1.1 Flowchart

The project flowchart activities include the identification of the problem statement including the objectives and scope of research. Apart from that, literature review was conducted and completed by analysing, reading and summarizing many resources. The flowchart is further and will be explained regarding the specific steps on how the project is carried out by referring to the objectives. Lastly, the end phase of the flowchart will be judged and presented to the panels for the project improvement and suggestions.

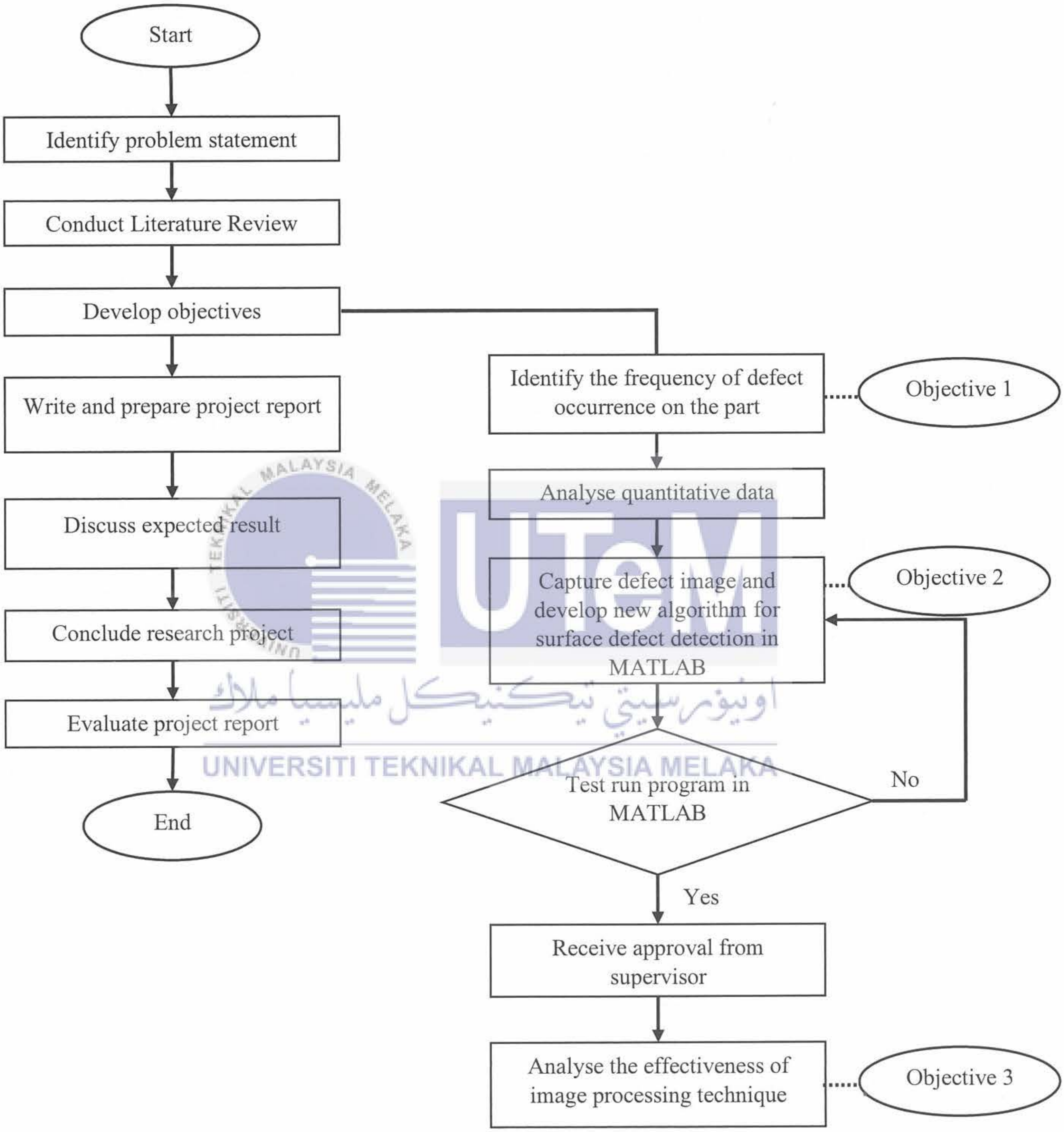


Figure 3.1: Project Flow Chart

3.1.2 Gantt Chart

The Gantt Chart prepared are based on the flow chart completed. Starting from the registration of the project until the end of the semester which is conclusion and recommendation. The duration is based on project planning in accordance with the available time to complete the project. The purpose of creating a Gantt chart is to ensure that the project are able to be completed within the given time and at the same time able to managed time equally for each task according to the available time and resources. The Gantt chart for FYP1 planning is shown in appendix C and Gantt chart for FYP2 is shown in appendix D.

3.2 Equipment Setup

This research was conducted at Faculty of Manufacturing Engineering of Universiti Teknikal Malaysia Melaka (UteM) and IPQC inspection area in Unique Diamond Sdn. Bhd. (UD), a plastic injection moulding company. Mainly, this research required the use of MATLAB software with camera embedded with controller. To set up the surface image, a CMOS camera was attached to a stand. For the purpose of reflecting surface, a while LED light source was used as illumination to capture the picture clearly. The camera was adjustable to have a flexibility that could tilt to 30° angle and adjusted to a fixed lens focus and lighting brightness to get the best image with visible defect on the plastic product surface. The figure below is an illustration on how the equipment for capturing image was setup.

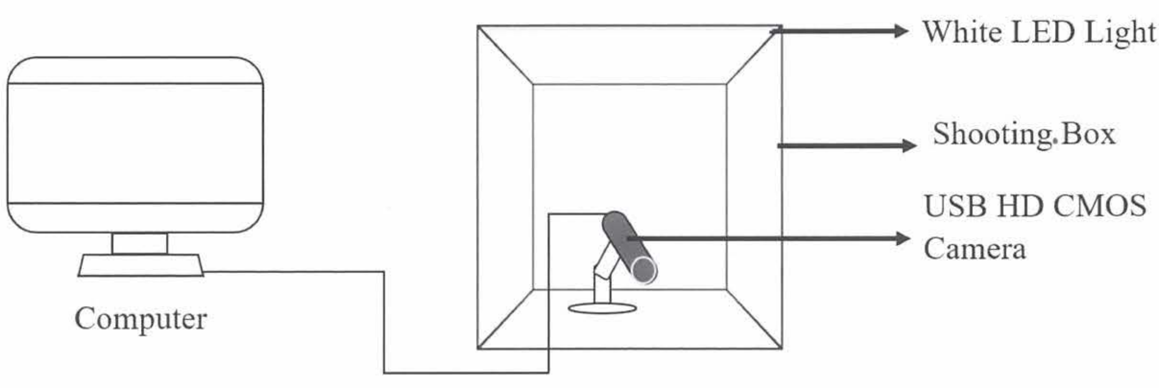


Figure 3.2: Schematic Diagram of Experimental Setup

3.3 PART A: Defect Frequency Identification

Defect frequency identification need to be collected to study the types of defect encounter during mass production. Besides, the data collection for sure helps to know the frequencies of certain types of defects occur on the part's surface. Apart from that, this data is able to identify the problem encounter whether the defect is from the material, mould, or the machine.

3.3.1 Data Collection

Certain data collected in this project is to study the encounter of various types of defects that may occur during production and to know the frequencies of the defects to occur on the automotive part. By collecting and identifying the types of defects, the root cause of this problem is able to be detected and avoided. This data was collected using two methods which was using the customer complaint action report and rework sheet. Customer complaint action report mainly shows the overall defect frequencies according to the defect classification meanwhile rework sheet shows the amount of reject part and action taken. The data was then extracted accordingly to calculate the frequency percentage of defects available during the 100% checking per batch. Data collected was restrict to rework sheet of selected part from the year 2020 only.

3.3.2 Data Analysis

The data collected can be analysed using Pareto chart because this technique can identify the most frequent defects or customer complaints. Pareto chart is one of the useful QC tools to analyse data, especially defect data. Since the defect gathered in this project were classified into five types, Pareto chart helps to visualise which defect is the most critical. This technique is able to narrow the project area to be proceeded since only the critical defects are going to be inspected using the image processing method.

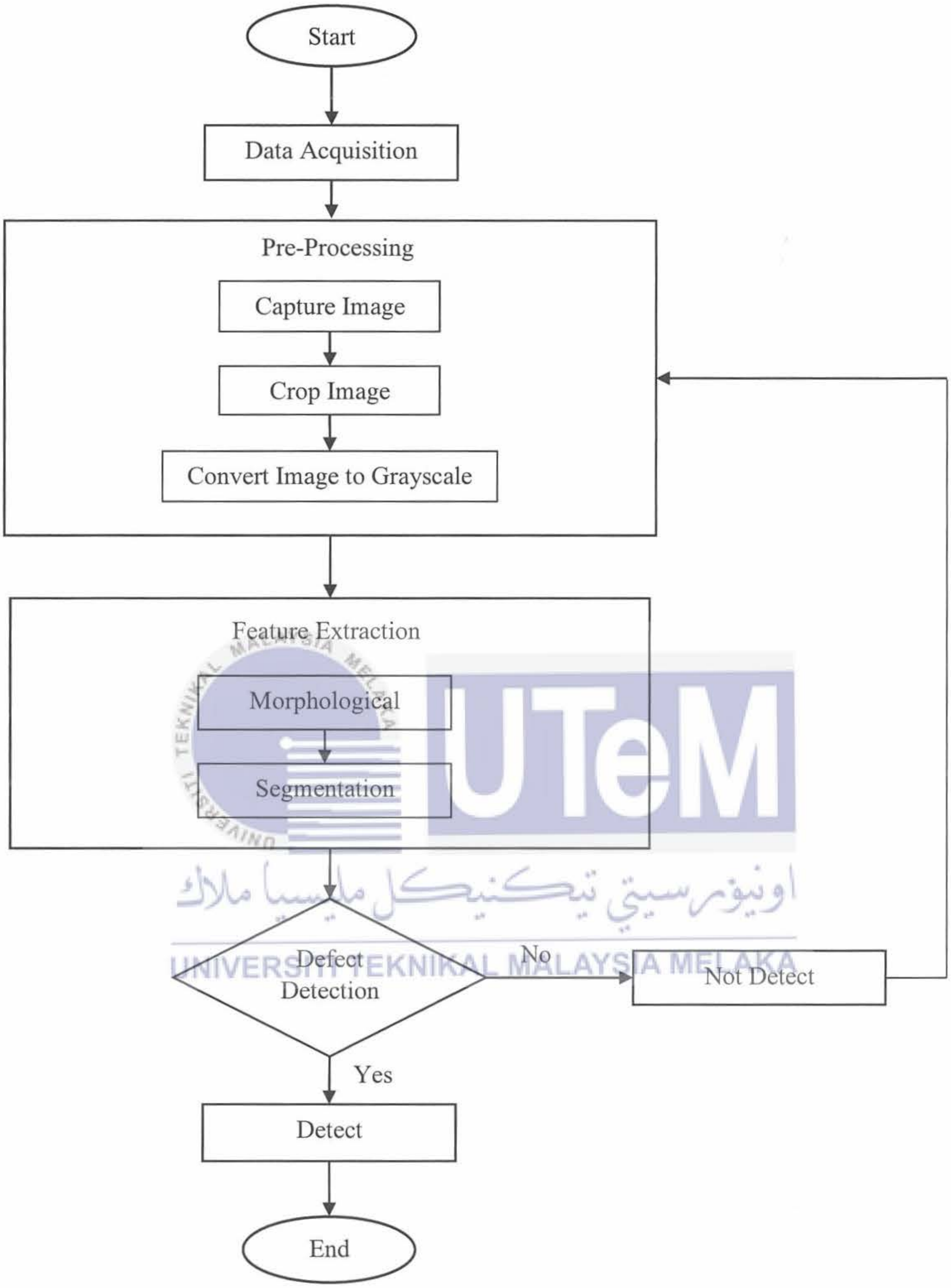


Figure 3.3: Image Processing Steps

3.4 PART B: Method selection

In this part, the flow of the processes is explained according to its step as shown in figure 3.3 which starts by data acquisition, pre-processing the image, perform feature extraction and lastly detect the defect on the image.

3.4.1 Data Acquisition

For data acquisition step, the image captured only show the part that was being inspected with specific tools such as magnification and specific lightning and lighting intensity used to reveal the surface defect clearly. The resolution when evaluating image quality is an important factor alongside light sensitivity, dynamic range and also signal to noise ratio. The focal length of the lens determines the image scale and the distance between camera and object.

To identify the camera properties, 'cam = webcam' function is required which then shows the resolution which is 640 × 480 with available resolution of {1 × 9 cell}. Other properties such as contrast, saturation, hue, gamma, white balance mode, gain, sharpness, brightness and white brightness is also shown of the selected webcam used.

1. Capture image

From the preview of the live webcam video, the part was inspected thoroughly until defect is detected. The image was then captured from the button provided on the camera or by the function 'snapshot(cam)'. To display the image data, the function that need to be used were the 'imshow' function. The image can be read into the workspace and then display the image in a figure window by that function. The function also attempts to display 100% magnification of the image in its entirety, although the image scale is too big, the function scaled the image to fit onto the screen and issue a warning message.

3.4.2 Pre-processing

Pre-processing process remove the unnecessary parts of the data collected from the previous step because it will affect the result. There are four methods used in pre-processing which is the colour changing mode, image cropping, image rotation and noise reduction but in this project, only colour changing mode and image cropping are used. This process required MATLAB software to conduct and the algorithm of the pre-processing method.

1. Crop Image

After the image has been captured, the image needs to be cropped at the area of where the defect occurs. Image cropping is required to remove the unwanted part of the image to improve framing in order to focus on the defective area in the image. This can be done automatically or manually in the MATLAB software. The function 'imcrop' will crop the image manually at a rectangle shape in any area wanted containing defect. The cropped image will include every pixel in the image that are enclosed by the rectangle.

2. Convert image to grayscale

Image captured need to be converted to grayscale due to the inherent complexity of low grey level images compared to coloured image. In the normal RGB coloured image, they are representing each value levels of the given channel which is subjected to red I, green (G), and blue (B) primary colour components. The function 'rgb2gray' converts the true image colour into the grayscale by eliminating hue and saturation information while retaining the luminance.

3.4.3 Feature Extraction

Feature extraction for this project is accomplished automatically by using specialized algorithms. The method used for feature extraction are statistical methods since this method are based on the spatial distribution of pixels value. This process refers to the transformation of raw data into a numerical feature which can be processed while preserving the original image data set and information. Automated feature extraction uses specialized algorithm to automatically extract the features from image. This technique becomes very useful since the raw data to develop machine learning algorithm is fast.

1. Segmentation

Image segmentation technique in image processing is often based on the characteristics of the image pixels. This technique involves in separating foreground from background and also clustering pixels region based on similarities in colour or shape. Important segment of the image can be process by dividing the image into segments, instead of processing the entire image. There are variety of image segmentation techniques available including thresholding. Using edge and 'sobel' operator can calculate the threshold value. The threshold value is required to be tuned and use edge detection to obtain a binary mask that contain the segmented defect.

2. Morphological Process

This operation applies a structuring element (se) or 'strel' operator to an input image and creating the same size output image. Each pixel's value in the output image was compared based on the input image corresponding pixel with its neighbour. Dilation and erosion are the most basic morphological operations in feature extraction. To compare, dilation function 'imdilate' adds pixels to the boundaries of the defect in the image whereas erosion function 'imerode' removes pixels on the defect boundaries. The size and shape of the 'se' will affect the addition or removal of the number pixels. The function 'imfill' will fill in the interior gap available after dilation, and lastly is the 'imclearborder' function where it helps to clear the border of the image from any noise left inside the cropped image.

3.4.4 Defect Detection

After the image has done feature extraction, the surface defect detection process of the part was according to the technique used. When the algorithm of feature extraction was completed and able to functioned correctly, the occurrence of defect was able to be detected by calculating its area. If the total area in the system shown is 0, it means that the image has no defect but if the defective area is greater than 1, the system will detect the occurrence of defect. The function 'bwarea' with 'total operator is used to calculate the image pixels value and thus will show the results of defect detection of 'OK' or 'NG'.

3.5 PART C: Development of MATLAB Coding

MATLAB software is the most ideal and recommended software to be use for this project because it includes the Image Processing Toolbox (IPT) that allow image processing technique to be applied using matrix-oriented language and manipulating the image to detect the surface defect. It is ideal to use MATLAB because the availability of application and function in IPT helps to defect detect easily using selection of function according to the suitability of the image to be inspect. Based on the subchapter 3.4, the algorithm can be created with detail variable and numerical value in order to achieve the results of defect detection.

3.6 PART D: Debugging

Checking of algorithm generated in MATLAB is compulsory since it will affect the results of this project. Testing and debugging of the program is a must in order to ensure the program can run smoothly without any problem as expected. The program needs to be test more than once to get the accuracy of the system. The objectives of debugging are to achieve a functional algorithm to detect defect without any error. The next process after complete debugging of MATLAB coding is to design the GUI according to the coding to make the interface. Designing GUI can be performed by adding components into the editor layout. The coding of the GUI created are generated automatically by MATLAB meanwhile the callbacks need to be added in order to make the interface functional.

3.7 PART E: Analyse Image Processing Technique Results

The data analysis for the result obtained in Part D can be performed based on the accuracy and repeatability. A random sampling quantity and condition that contain the most critical defect will be utilized by confusion matrix to analyse the accuracy of this technique. Meanwhile, the processing time of the inspection was conducted by recording the time taken from searching the defect on part's surface using stop watch for manual inspection and using the 'tic' 'toc' function in MATLAB for automatic inspection.

Table 3.1: Confusion Matrix

True Class	**Predicted Class**	
	Positive	Negatives
Positives	TP	FN
Negatives	FP	TN

$$Recall = \frac{TP}{TP+FN} \quad \text{(Equation 3.1)}$$

Where,

Recall = Proportion of positive samples that are correctly identified

TP = True Positive

FN = False Positive

$$Precision = \frac{TP}{TP+FP} \quad \text{(Equation 3.2)}$$

Where,

Precision = Proportion of real positive samples among identified positive samples

TP = True Positive

FP = False Positive

$$F1 = 2\frac{Precision \cdot Recall}{Precision + Recall} \qquad \text{(Equation 3.3)}$$

Where,

F1 = Weighted average of Precision and Recall

Precision = Proportion of real positive samples among identified positive samples

Recall = Proportion of positive samples that are correctly identified

$$Accuracy = \left(\frac{TP+TN}{TP+TN+FP+FN}\right) \times 100\% \qquad \text{(Equation 3.4)}$$

Where,

Accuracy = Ratio of correctly predicted observation to the total observation

TP = True Positive

TN = True Negative

FP = False Positive

FN = False Negative

3.8 Summary

To summarize the methodology chapter, it requires five approaches in order to obtain the final results in this project. The subchapter in this chapter include the overall process flow and planning throughout the semester, the data collected for analysis, the experimental setup to conduct the project, the steps and methods required to perform image processing surface defect detection using selection of function according to the suitability of the image, the generation of MATLAB programs to analyse the image, debugging the program to ensure it can be tested and run smoothly without any problem, and to analyse the efficiency of this technique in order to evaluate the results of this project findings. As the expected result, the outcome of this result is to identify the percentage of accuracy of the system created and reduce the processing time if compared to the current method used by the company.

CHAPTER 4

ALGORITHM & GUI DESIGN

In this chapter, the algorithm formulated is explained in detail on how each line of the function used in MATLAB works with diagrams of illustration for each function, and this chapter mainly focused on the design of algorithm that is applied to activate the camera in MATLAB software. The process is explained according to the line created in MATLAB and it has been classified into four steps. In this chapter, image from samples 'K2.12' for NG and 'K1.40' for OK is used for the aided diagram that is attached in the appendix.

4.1 Data Acquisition

Figure 4.1: System Setup

```
%Step 1= Data Acquisition

cam = webcam(2); %call webcam 2 {'GL USB2.0 UVC Camera Device'}
tic
preview(cam); %Preview live video
A = snapshot(cam); %Take picture from the video
```

Figure 4.2: The First Step

Data acquisition part requires camera set up in a system that is equipped as shown in figure 4.1. To use the camera, algorithms need to be generated in order to perform inspection. In this part, the algorithm in figure 4.2 was set to call out the camera that is going to be used for this system. Since this project is an off-line inspection for Quality Control, the webcam GL USB 2.0 UVC Camera Device will be used with complete information regarding the camera pre-set usage as shown in figure 4.3. As the 'preview(cam)' line was activated, it shows the preview of the live video from the camera used. To capture the image, press the 'SNAP' button on the camera's body, and an image 'A' data will be stored in the workspace for the next step. The captured image can be seen in table 4.1. the 'tic' function will start recording the time for the sample's inspection.

```
>> cam = webcam(2)

cam =

  webcam with properties:

                    Name: 'GL USB2.0 UVC Camera Device'
    AvailableResolutions: {1×19 cell}
              Resolution: '640x480'
            WhiteBalance: 6500
   BacklightCompensation: 1
                    Gain: 15
                Contrast: 31
               Sharpness: 7
        WhiteBalanceMode: 'manual'
                     Hue: 0
                   Gamma: 3
              Brightness: 0
              Saturation: 56
```


Figure 4.3: Camera Information

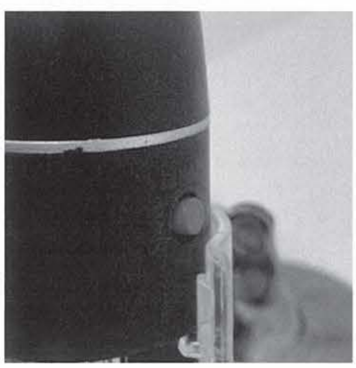
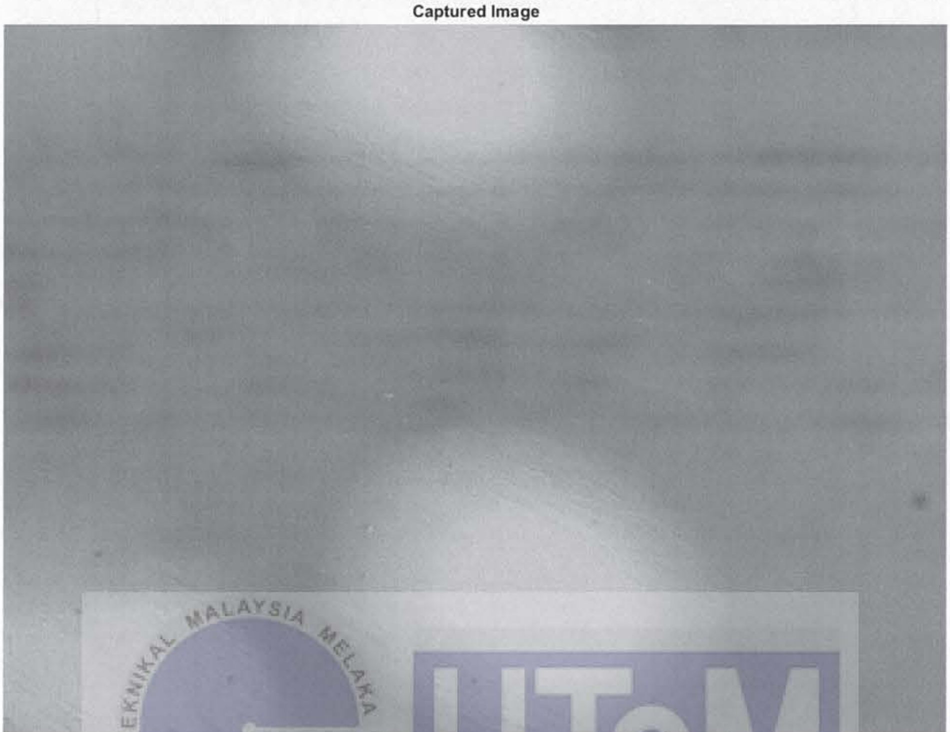


Figure 4.4: SNAP button

Table 4.1: Captured Image

OK

NG


4.2 Pre-Processing

```
%Step 2 = Pre-Processing Image

A1 = imcrop(A); %Crop image to focus on defect
A2 = rgb2gray (A1); %Convert Image To Grayscale
```

Figure 4.5: The Second Step

Pre-Processing part is where the image will be cropped and converted into grayscale. The image is required to crop out at the area where the defect occurred. In this step, the image was manually crop fixed in square-shaped since the defective area was not fixed for each sample. For the cropped image, the image 'A1' data was stored in the workspace and the image cropped for an OK and NG sample, and the image data 'A2' for the converted image into grayscale is as in appendix F.

4.3 Feature Extraction

```
%Step 3 = Feature Extraction

[~,threshold] = edge(A2, 'sobel'); %Calculate threshold value for edge detection
fudgeFactor = 0.5; %Variable to calculate threshold
A3 = edge(A2, 'sobel', threshold * fudgeFactor); %Create binary mask containing segmentation
se90 = strel('line', 3, 90); %Detect straight line above 3 pixels at 90 degree
se0 = strel('line', 3, 0); %Detect straight line above 3 pixels at 0 degree
A4 = imdilate(A3,[se90 se0]); %Dilate the image
A5 = imfill(A4,'holes'); %Fill interior gap
A6 = imclearborder(A5, 4); %Remove unwanted objects on border
seD = strel('disk',3,4); %Detect object around 3 radius with 4 sructure elements line
A7 = imerode(A6, seD); %Erode image
figure %Show Image
subplot(1,2,1), imshow(A1), title('Original image'); %Preview original image
subplot(1,2,2),imshow (A7), title ('Processed image'); %Preview processed image
```

Figure 4.6: The Third Step

Feature extraction part will change the grayscale image to binary which consists of segmentation and morphological process. In figure 4.6, the image was converted automatically at the first, second, and third line into binary mask by multiplying the threshold with fudge factor value. It is easier to deal with image data when the value varies between 0 and 1 only. With the binary mask image created in 'A3', the next step was dilating the line in image using the 'strel' function and filling up the interior gap. Unwanted objects such as leftover noise could be eliminated by clearing the image border, and lastly erode the line in the image to achieve the similar before and after the image has been processed. In this step, one of the outputs was called out and can be seen in table 4.2 and the figure that shows how each function changes the data of the image is shown in appendix G.

Table 4.2: The Output in Step Three

Results	
OK	
NG	

4.4 Defect Detection

```
%Step 4 = Defect Detection

total = bwarea (A7); % Calculate Total Area In Image
if any(total > 0)
    disp('NG')
else
    disp('OK')
end
for X = total % Classify Scratch Class According to Range
if any(0<X)&&(X<300)
    disp("class 1 scratch")
elseif any(301<X)&&(X<600)
    disp("class 2 scratch")
elseif any(601<X)&&(X<900)
    disp("class 3 scratch")
elseif any(901<X)&&(X<1200)
    disp("class 4 scratch")
elseif any(1201<X)&&(X<1500)
    disp("class 5 scratch")
end
end
toc
```

Figure 4.7: The Final Step

Defect detection part will calculate the total area of the image pixel inside the image data 'A7'. To ensure the results are generated correctly, statements such as 'if' and 'else' were used for the total area of the image. As stated in subchapter 3.4.4, the total area of more than 1 is considered defective meanwhile total area of 0 is non-defective samples. The results can be called out as the output that shows OK or NG in MATLAB. As an additional output to this system, the class defect can be categorized into 5 classes according to the defect size indication provided by the customer. By this, the statement function was used to classify the classes of defect and to show the defect detected in which class. Lastly, the algorithm ends with the 'toc' function where it records the time taken to detect the defect and shows the elapsed times as its output.

Table 4.3: The Output in Final Step

Results	
OK	**NG**

`>> testwebcam`
`OK`
`Elapsed time is 12.076018 seconds.`
	`>> testwebcam`
	`NG`
	`class 1 scratch`
	`Elapsed time is 8.080582 seconds.`

4.5 Design Graphical User Interface (GUI)

To design the GUI in MATLAB, an app designer is required for the interface for the image processing algorithm and output created. Using app designer provides sets of tools for designing and creating any type of graphical user interface. Using the editor layout provided in the app designer allows users to create GUI layout easily with a specific component library assigned for each output. These components are aligned in the editor layout according to the user's preference. App designer automatically generates M-file that controls how the GUI operates and at the same time initializes the GUI that contain frameworks for all the GUI callbacks. The commands will execute when components in the GUI are triggered, and user also is able to add code to the callbacks to perform functions using the M-file.

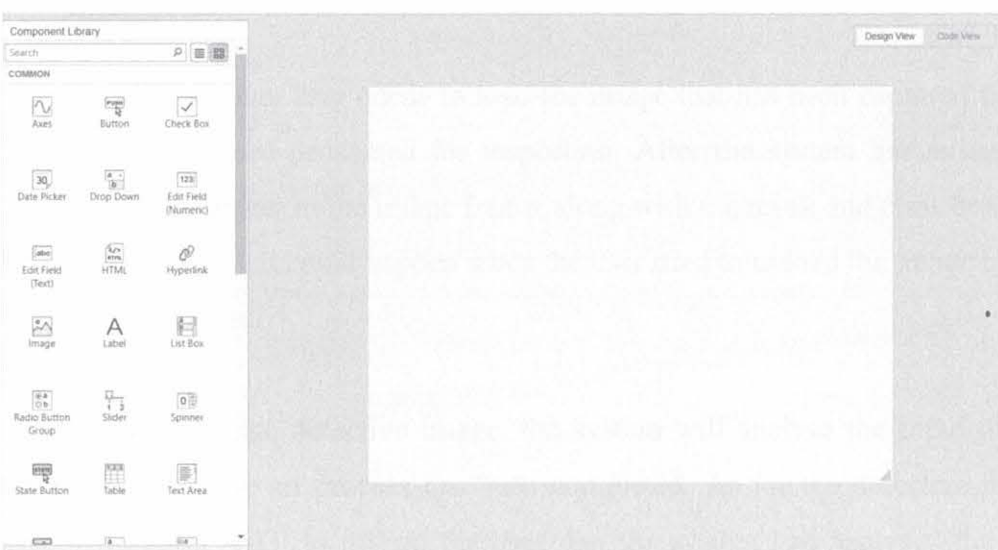


Figure 4.8: App Design Editor Layout

To create the interface, one layout window preview is presented that contains label component for title, and image titles, two image components to display the original and processed image, a single push button component to load the image, and two edit field components to display the results for the image being inspected. Apart from that, the layout was also designed with a template of faculty and user information. MATLAB automatically generated the coding that allows users to add callbacks for each component as in appendix H when components is assigned into the layout.

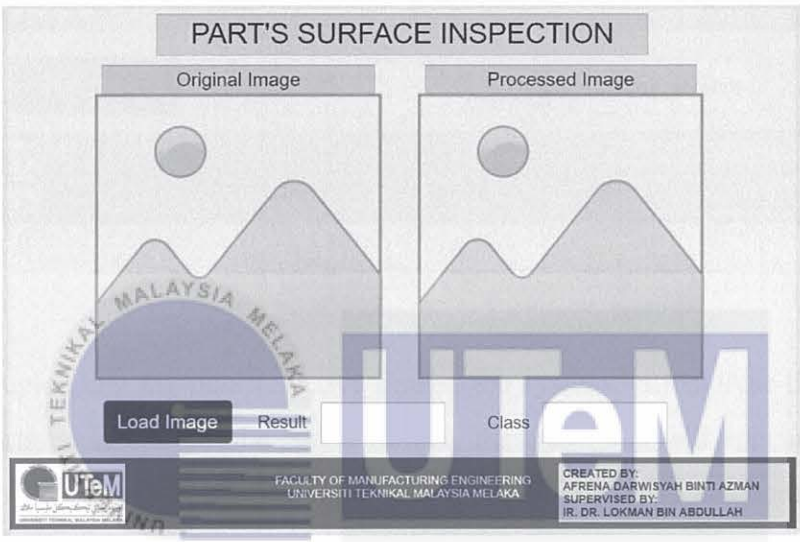


Figure 4.9: Image Processing Interface

4.5.1 Input and Output Function

For the GUI system, user needs to load the image that has been captured from the MATLAB which has been processed for inspection. After the system has analysed the image, the result will appear in the image frame, along with the result and class box. There are only two conditions that could happen when the user tried to upload the image by using GUI in obtaining the result.

When uploading the defective image, the system will analyse the input data and show the results after the all process has been completed. As for the defective part, the result box will appear 'NG' to inform the user that the system had analysed the image. Meanwhile, the class box will show which class does the defective part belongs to.

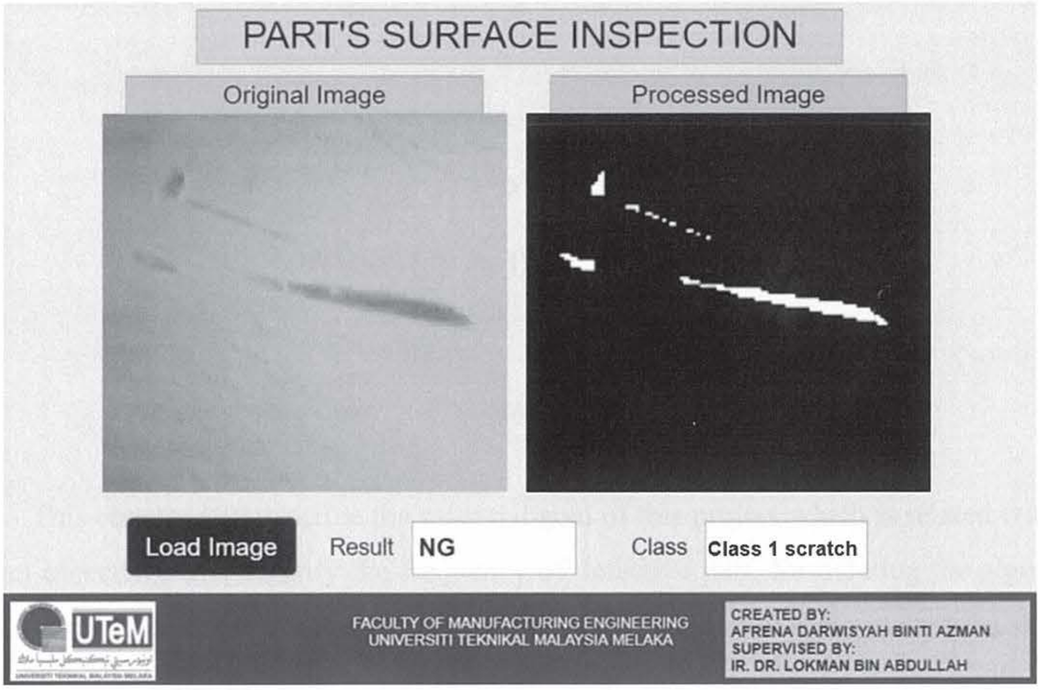


Figure 4.10: Defective Part's Inspection

When uploading the non-defective image, the system will analyse the input image data. If it detects no scratch on the part's surface, the result box will appear 'OK' with an empty class box. This is to indicate and inform the user that the part has no defect.

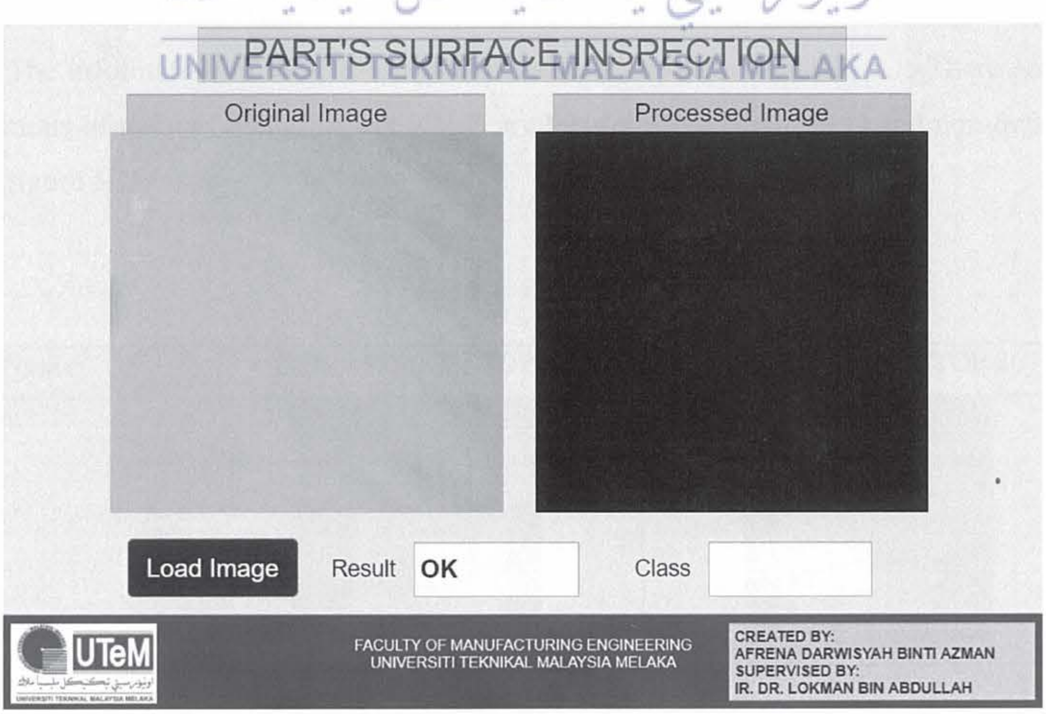


Figure 4.11: Non-Defective Part's Inspection

CHAPTER 5

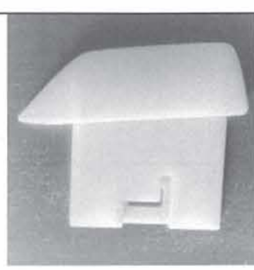
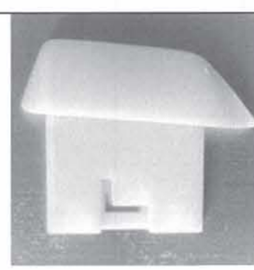
RESULT & DISCUSSION

This chapter will describe the essential goal of this project which is related with the product objectives that identify the frequency of defective part, formulating the algorithm in MATLAB to detect the defect, and to analyse the efficiency of the system created. This chapter also presents the final result obtained from the system created and evaluate its performance.

5.1 Part Sample

For this system, the plastic part named KEYTOP 1 and KEYTOP 2 was used since Unique Diamond Sdn. Bhd has received most of the customer complaint regarding this part. The information of the part or part's matrix is as shown in table 5.1. There are two conditions of the part being inspect which are the defective (figure 5.1) and non-defective part (figure 5.2).

Table 5.1: Part Matrix

Part Name	CPH0482A KEYTOP 1	CPH0482A KEYTOP 2
Image		
Model	TYAA	TYAA
Part Number	5700408800	6410897200
Colour	Natural	Natural

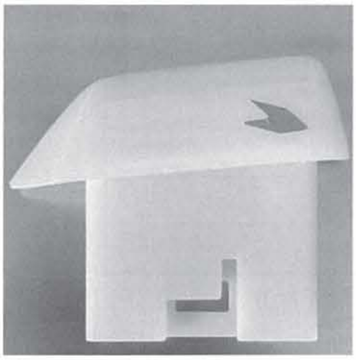


Figure 5.1: Defective Part

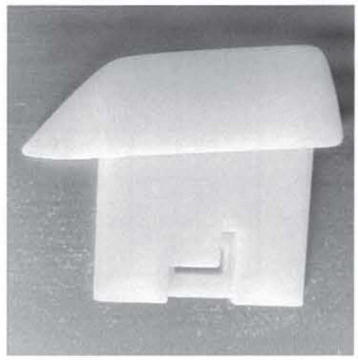


Figure 5.2: Non-defective Part

5.2 Analyse Defect Frequency

In this subchapter, the selected types of defects such as scratches, dented, drag, black dot, and sink mark were gathered from 2020 rework summary report which can be referred in appendix I. From the report, the percentage of defects found according to the batch during the 100% checking was calculated with a total result of 9,603 parts inspected, and 218 parts were found defective. As in table 5.3, the percentage of defects calculated according to the types was recorded and classified in the table. As a result, only three out of five types of defects considered were found during 100% checking in 2020 for KEYTOP 1 and KEYTOP 2 which is scratches (1.80%), dented (0.34%), and black dot (0.12%).

Table 5.2: Percentage of Defect According to Batch

Date	Types of defects	Qty	NG	%
19.06.20	Scratches	3320	7	0.21
24.06.20	Dented	480	23	4.79
24.06.20	Dented	480	10	2.08
24.06.20	Scratches	480	154	32.08
21.09.20	Black dot	1620	12	0.74
23.09.20	Scratches	540	0	0
25.09.20	Scratches	2683	12	0.45
Total		**9603**	**218**	

Table 5.3: Percentage of Defect According to Types

Types of defects	Total	%
Scratches	173	1.80
Dented	33	0.34
Black dot	12	0.12

5.2.1 Data Analysis

Each data collected needs to be analysed and, in this case, the main purpose is to utilize the QC tool mentioned earlier which is the Pareto Chart to identify the frequency of the defective part produced and to proceed for the next method. The results from the 100% checking rework summary report were able to come up with a Pareto Chart Calculation as shown in table 5.4, and the Pareto Chart in figure 5.3. The greatest use of Pareto Chart analysis is the complete quality control where it is used as the Six Sigma framework, a mathematical method to track the company performance.

Table 5.4: Pareto Chart Details

Defect	Sorting result				
	Quantity	OK	NG	Cumulative	Percentage
Scratches	7023	6850	173	173	79%
Dented	960	927	33	206	94%
Black Dot	1620	1608	12	218	100%
Sink Mark	0	0	0	218	100%
Drag	0	0	0	218	100%
			218		

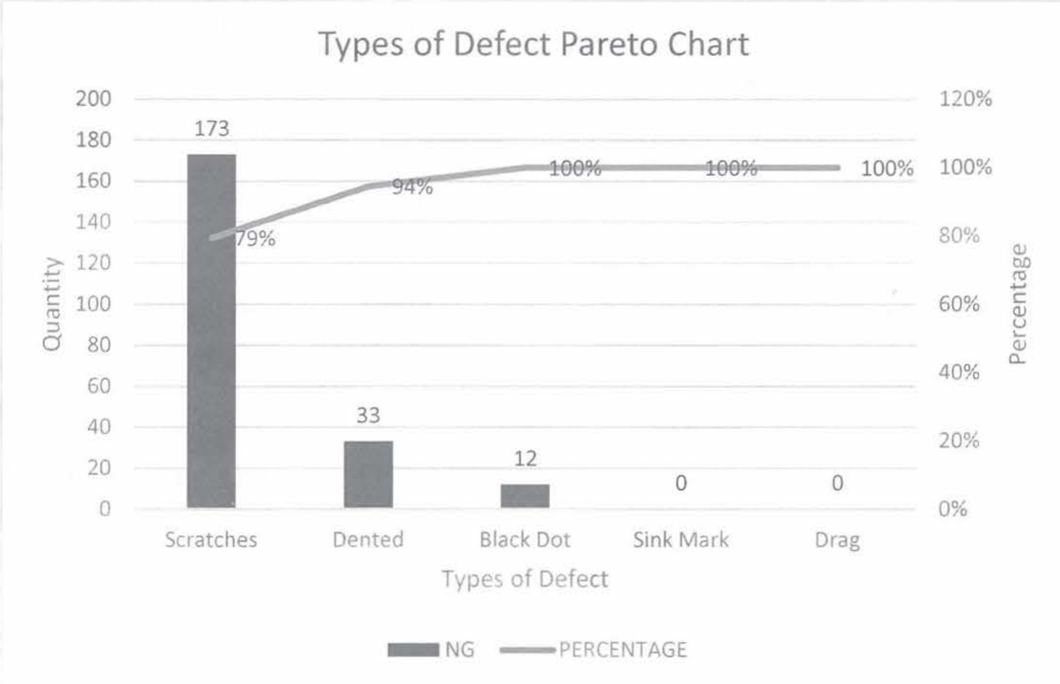


Figure 5.3: Types of Defect Pareto Chart

The Pareto Chart generated can be interpreted in several points. Firstly, the bars are placed in rank order where the bar at the left which is scratches has the highest defect quantity. The cumulative line is used to add the percentage from each bar which can be defined that the scratches defect (79%) contributed the most problems, and it shows that scratches are the defect that the company should focus more on. By taking care of scratches defect, it will counter 80% of the other minor defects listed. As for black dot, sink mark, and drag, the cumulative line is straight or is at 100% which tells that the frequency or contribution was even and there is least to no problem that stands to help to solve this problem. Thus, from the analysis of this part, scratches defect that has the highest bar with the highest quantity will be used as a sample to be tested on the system created.

5.3 Final Outcome Evaluation

From the result obtained, 50 samples of KEYTOP 1 and 50 samples of KEYTOP 2 have been used and inspected. In this subchapter, the evaluation of the method used to analyse the efficiency of the system created is classified into two evaluations which is in terms of processing time and accuracy.

5.3.1 Processing Time

In this evaluation, the processing time was categorized into two methods used which are the semi-automatic method, and the manual method where it is the current method used by the company to perform sampling inspection. For the semi-automatic inspection method, the time was recorded using the 'tic' and 'toc' function where it works to measure the elapsed time starting from finding the defects on the part's surface from a preview webcam video shown in MATLAB. Meanwhile, the processing time for the manual method was recorded using a stopwatch starting from when the inspector inspects the part under a magnifying lamp until the defect is found and confirmed. The table of processing time evaluation for both methods can be referred in appendix J. Table 5.5 shows the average processing time comparison of the proposed method and current method used by the company for both KEYTOP 1 and KEYTOP 2.

Table 5.5: Average Processing Time

Part's Name	Method	Processing time (s)
KEYTOP 1	Semi-automatic	8.99
	Manual	12.93
KEYTOP 2	Semi-automatic	7.74
	Manual	12.62

From table 5.5, the results show that the proposed method (semi-automatic) for both parts has reduced by 3.94 seconds for KEYTOP 1 and 4.88 seconds for KEYTOP 2. This can be interpreted that using image processing is able to reduce 8.81 seconds compared to using manual inspection.

5.3.2 Accuracy

In this evaluation, the accuracy of the algorithm designed was evaluated using confusion matrix. Confusion matrix was used because it is a technique to summarize the performance of a classification algorithm. Sufficient number of samples for observation is important to classify the accuracy. From the table in appendix K, the true class column recorded the condition of the samples whether the sample is defective (P) or non-defective (N) where 'P' stands for positive and 'N' stands for negative. Apart from that, the predicted class column is the results obtained from the algorithm output. The green row indicates that the algorithm shows the same result as the true class, meanwhile the red row indicates that the algorithm shows the opposite result as the true class. For 100 samples tested, only 4 samples show misleading results. The overall results can be referred in appendix K.

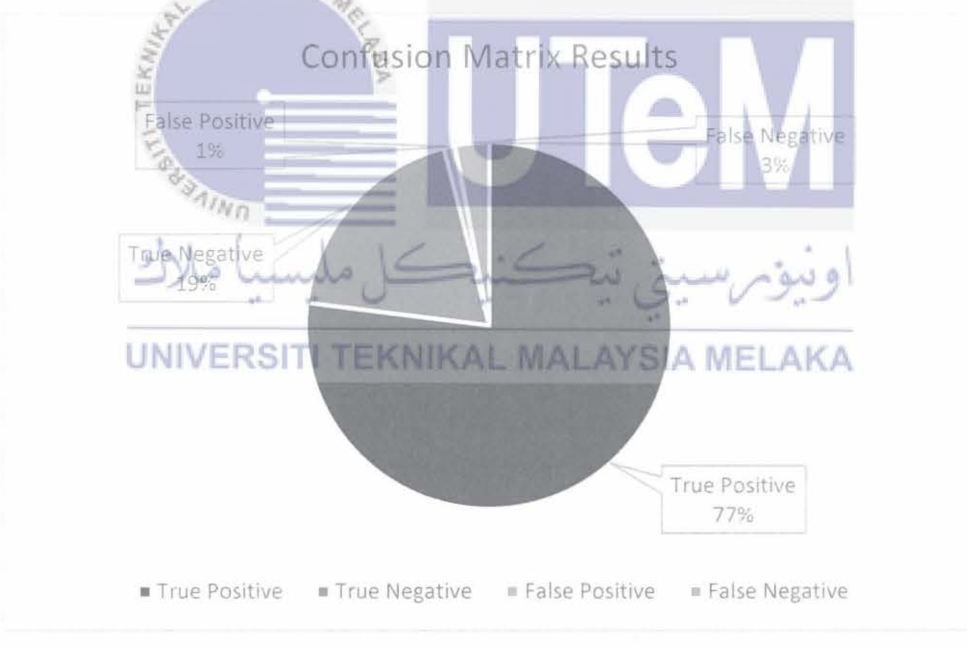


Figure 5.4: Confusion Matrix Results

From the results shown in figure 5.4, the data for true class and false class can be collected. From the pie chart, the value of true positive samples is 77, the value of true negative samples is 19, the value of false positive samples is 1 and the values of false negative samples is 3. From those values, equation 3.1 to equation 3.4 can be completed by substituting the value inside the equation to achieve the value of accuracy for the algorithm.

$$Recall = \frac{TP}{TP+FN}$$ (Equation 3.1)

$$= \frac{77}{77+3}$$

$$= 0.96$$

$$Precision = \frac{TP}{TP+FP}$$ (Equation 3.2)

$$= \frac{77}{77+1}$$

$$= 0.99$$

$$F1 = 2\frac{Precision \cdot Recall}{Precision+Recall}$$ (Equation 3.3)

$$= 2\left(\frac{0.99 \cdot 0.96}{0.99+0.96}\right)$$

$$= 0.97$$

$$Accuracy = \left(\frac{TP+TN}{TP+TN+FP+FN}\right) \times 100\%$$ (Equation 3.4)

$$= \left(\frac{77+19}{77+19+1+3}\right) \times 100\%$$

$$= 96\%$$

In this calculation, equation 3.3 and equation 3.4 are the one that was considered to evaluate the accuracy of the algorithm and the system on its whole. Using confusion matrix provides a better idea of what the classification model is getting the correct result and what types of error it made F1 or the weighted average of precision and recall of this system is at 0.97. Note that F1 score is considered perfect when the value is 1. By this, it can be concluded that the system creates a good weighted average for positive samples that are correctly identified and real positive samples among identified positive samples. As for the system accuracy, the calculation shows that it has achieved an accuracy of 96%. From here, the system error can be calculated by using equation 5.1. with an error rate of 0.04, the system created is trusted enough to be used for an IPQC inspection.

$$Error\ Rate = 1 - accuracy$$ (Equation 5.1)

$$= 1 - 0.96$$

$$= 0.04$$

5.4 Environmental Control

Based on the results in subchapters 5.2 and 5.3, several findings have been identified and are needed to undergo further discussion. This includes environmental control which affects the overall performance of this system.

Several images captured from the camera tend to have their own difficulties and problems. One of the problems was when the part is defective but the algorithm does not properly detect the defect on the sample's surface (K2 No. 32) as in figure 5.5. Even though the scratches are obvious, sometimes the algorithm detects the minor scratch that has more defined and sharp edge instead of focusing on the segment of the more obvious defect. In this case, the illumination is required to be adjusted while conducting the inspection to ensure that the scratches segment can be detected properly in the frame.

Figure 5.5: Defective Part with Inaccurate Detection

CHAPTER 6

CONCLUSION & RECOMMENDATION

This chapter summarizes the overall project and work accomplished which takes approximately a year to complete. As a sequence, some achievements have been attended during this period and are highlighted in this chapter. By the end of this chapter, suggestions and recommendations for future work that may be used and carried out is explained and proposed for a better outcome.

6.1 Conclusion

The goals and objectives of this project have been achieved successfully and resolving the completion of the issue faced by the company is done by identifying the problem. It is crucial to analyse the data from rework that required 100% checking for the selected part because from there, frequency of defect detection is able to be identified throughout the production produced. The problem statement has been resolved by identifying and fulfilling the objectives and scope that has been stated for this project, and the process and application of this project has been thoroughly explained and understand.

The system created contains main equipment such as computer and camera, and other supporting equipment for illumination such as shooting box and white LED light. This system is able to detect 2D defect on a complex shape of a plastic surface by using machine vision sensor set up by the algorithm that had been created using MATLAB software. Part's surface needs to be defectless and thus summarize the use and importance of vision inspection system in quality control. Vision inspection system acts as a sensor that is capable to operate in various ways with functions variation though, the chosen function had to be appropriately decided in order to achieve the best vision inspection system. The chosen programming software has been understood and several key for formulating a vision system programming using MATLAB were recognized. Since this project is a success, this system may be use as a different alternative for the company to replace their current inspection method which is manual inspection to ensure the parts been delivered to customers are non-defective, other than able to reduce inspection processing time and increase accuracy.

Throughout completing this project, there are several difficulties that have been detected. Since the parts are made from Acrylonitrile Butadiene Styrene (ABS) polymers, the level of reflection is higher especially when the part's colour is natural. The reflection on the parts sometimes gives a false information to process the image in the inspection system. This indicates the main reason of importance of environmental control in inspection system especially when dealing with sensitive materials.

Table 6.1: Conclusion Summary

	Objectives	Method	Findings
1	Identify the frequency of defective injection moulded part produced.	Collecting and evaluating data from company in the year 2020.	Able to create one of the 7 QC tools which is Pareto Chart and identify the defect frequency.
2	Formulate an algorithm via image processing technique to detect defective part.	Using MATLAB R2021a version that equipped with IPT and App Designer.	Able to detect 2D defects even on curved area of the plastic's surface.
3	Analyse the effectiveness of image processing technique in term of accuracy and processing time.	Using Confusion matrix to evaluate the algorithm accuracy and stop watch and 'tic toc' function to record the processing time.	Able to achieve 96% accuracy with a reduction of 8.81 seconds compared to using manual inspection.

6.2 Recommendation

In order to improve the vision inspection system, the environment for inspection needs to be controlled first by reducing the illumination of the inspection area to avoid reflection are glare from occurring to the part's surface. the types of white LED light used must be covered so that the light reflection will not directly reflect to the part's surface.

The MATLAB software used for this project is the latest version which is R2021b which is equipped with improved toolbox for image processing. The GUI created may be upgraded to display the original and processed video preview that allow user to directly get the results. By using this method, the time taken to analyse the defect occurrence may be reduced and end user would be interested to use the interface by having this feature.

Since this project is conducted to help the company to detect defects, 3D types of defects such as sink mark and dented should be considered other than scratches, black dot, and drag mark because there are also some possibilities such defects may occur if production is being handled poorly especially when the material used is sensitive to heat. By upgrading to inspect 2D and 3D defects, the system will be much more useful and may perform better to control the quality of the product.

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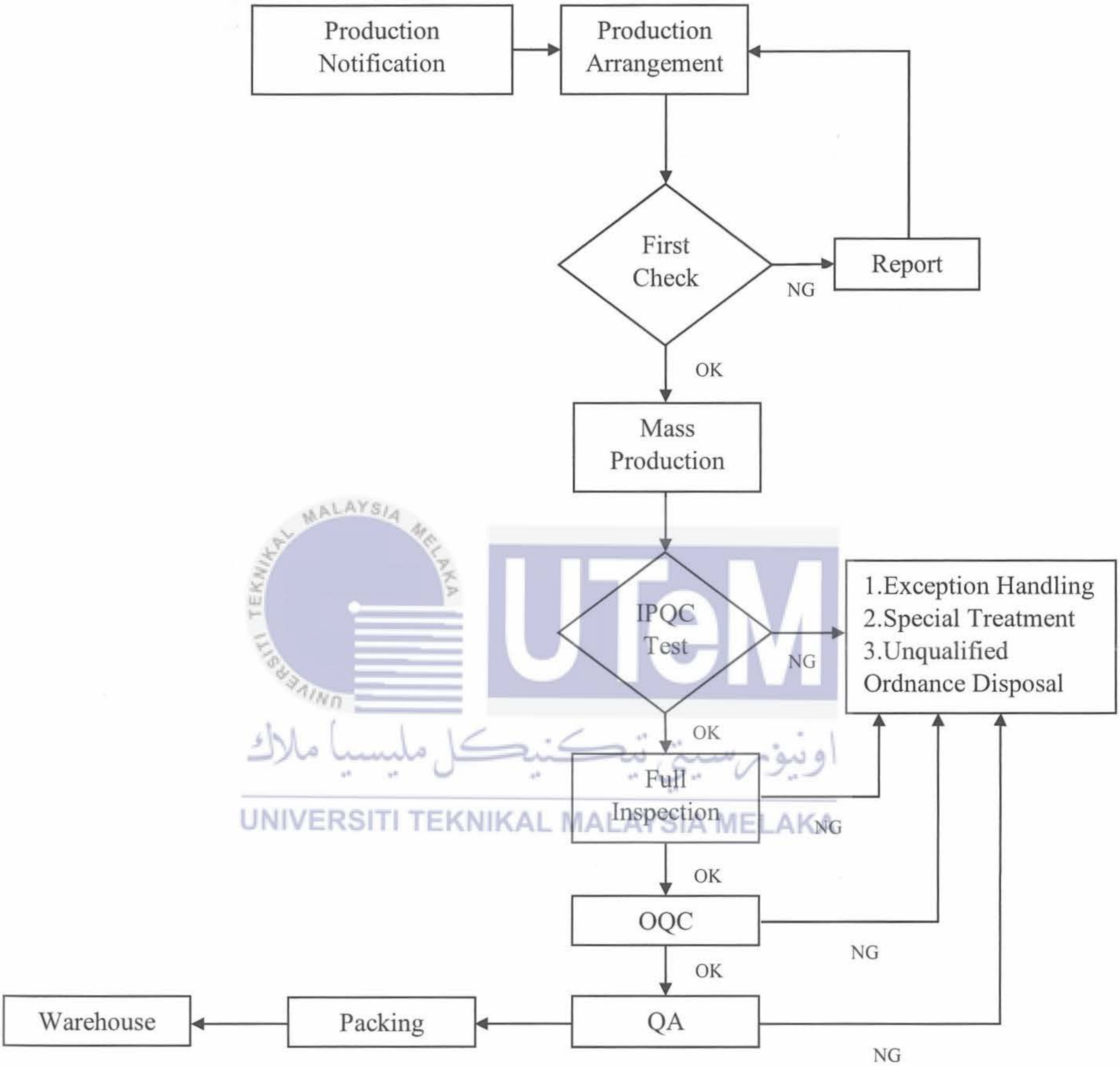
APPENDIX A



In-Process Quality Control

APPENDIX B

Literature Review Analysis Gap

No.	Title	Author	Year	Source	Method	Parameter	Discussion
1	Graphical User Interface Features In Building Attractive And Successful Websites	Abdo, A. M.	2016	European Scientific Journal May 2016 edition vol.12, No.15 ISSN: 1857 – 7881 (Print) e - ISSN 1857- 7431	Graphical User Interface	▶ Loading time ▶ Consistency ▶ Navigations ▶ Easy form ▶ Search and list ▶ Contact	Graphic user interface or GUI is an interface containing pictorial to a system where it has the ability to make the program easy to be used by providing consistent appearance along with intuitive controls.
2	Quality Management Systems (ISO 9001:2015)	Al-Rub, F. A.	2020	Gavin eBooks	Revised ISO 9001:2015 standard from ISO9000:2015	▶ Quality standard	The update made in ISO 9001:2015 urges organizations to review the current approach and the proposed version are required to engage by any business leader with their team members and process owners.
3	Data Acquisition and Image Processing System for Surface Inspection	Banica, C., Paturca, S. V., Grigorescu, S. D., & Stefan, A. M.	2017	THE 10th International Symposium On Advanced Topics In Electrical Engineering, 28-33	Image processing technique	▶ Image data ▶ Contrast ▶ Noise ▶ Defect detection	Surface Defect Detection (SDD) process in image processing includes four major steps according to the set of data used, the types of defects examined, the method to be used and the results intended.

4	Defective Product Detection Using Image Processing	Chavan, H. L., & Shinde, S. A.	2016	International Journal of Science and Research (IJSR), Volume 5 Issue 6, June 2016, 2092-2095	Defect detection in image processing	▶ Defect recognition	Recognizing and categorizing types of defects required operation on digital image and some methods to recognize types of defects on the image has already been established and sited.
5	Quality Control: Meaning, Process Control, SQC Control Charts, Single, Double And Sequential Sampling	Chhabra, N	2020	Unit 4 Notes By Neha Chhabra	IPQC inspection	▶ Quality standard	The quality control major aspect is to establish a well-defined control that helps to standardize production and reactions to quality issues. Besides, the totality characteristics and quality features of products and services satisfy the implicit and explicit customer needs.
6	2D Gabor filter for surface defect detection using GA and PSO optimization techniques	Chisti, K. M., Srinivas, K. S., Prasad, G.	2015	AMSE J., vol. 58	Quality inspection	▶ Quality ▶ Surface defects ▶ Surface area	Each quality problem requires different techniques of inspection for its precise evaluation. Local defect considers the surface area with a view that did not match the actual surface quality which makes the image parameters relative values more important.
7	Image Segmentation Techniques and Its Applications	Dar, N. H.	2020	Image segmentation Techniques and its Applications (pp. 1-10)	Feature extraction using Segmentation technique	▶ Image pixel ▶ Image texture ▶ Thresholding	Segmentation process is used to recognise the object in the image. Using segmentation technique can increase the accuracy to recognise the object in the image.

8	A Comparative Study of Different Noise Filtering Techniques in Digital Image	Das, S., Saikia, J., Das, S., & Goni, N.	2015	International Journal of Engineering Research and General Science Volume 3, Issue 5, 180-189	Filtering image using Wiener Filter	▶ Mean square value ▶ Stochastic framework	Wiener filter must be physically realizable where it will result in a non-casual solution when the requirement can be dropped. Large window can be used to smooth the speckle noise and small window can be used to avoid blurring edges.
9	Image Filtering - Techniques, Algorithm and Applications	Desai, B., Kushwaha, U., & Jha, S.	2020	GIS Science Journal, Volume 7, Issue 11, 2020, 970-975	Filtering image using linear and non-linear filter	▶ Fourier ▶ Filter	Linear filter achieved through a Fourier multiplication and convolution meanwhile non-linear filter is not achievable because the non-linear output is not linear with its input and will result in a variation of non-intuitive manner.
10	Acrylonitrile Butadiene Styrene (ABS)	Edupack, C.	2013	CES Edupack Software	Identifying ABS properties	▶ Material properties	ABS polymer is considered as hygroscopic which means before thermoforming, it may require oven-dried. By depending on the amount of acrylonitrile, the colour may vary from in between water white to pale yellow.
11	Optimizing The Colour-To-Grayscale Conversion for Image Classification	Günes, A., Kalkan, H., & Durmuş, E	2015	Signal Image and Video Processing, Volume 10, 853-860	Converting image to grayscale	▶ Colour ▶Grayscale	Most of the computer vision application required colour to grayscale algorithm conversion in order to preserve the image's salient features. Image salient features include brightness, coloured image

							structure and contrast.
12	Overview Of Different Thresholding Methods in Image Processing	Guruprasad, P., & Mahalingpur, K.	2020	TEQIP Sponsored 3rd National Conference on ETACC, (pp. 1-5)	Feature extraction in image processing	▶ Thresholding	Category of thresholding is classified into six group which is the histogram shape-based method, clustering-based method, entropy-based method, object attribute-based method, spatial method, and local method.
13	An adaptive level-selecting wavelet transform for texture defect detection	Han, Y., Shi, P.	2007	Image Vis. Computer, vol. 25, no. 8	Defect detection	▶ Surface defect detection	The main purpose of Surface Defect Detection (SDD) is to avoid the defective parts containing defects on the surface and prevent it from reaching out to the customer
14	Hypermedia Image Processing Reference	Fisher, R., Perkins, S., Walker, A., & Wolfart, E.	2003	The HIPR Copyright	Filtering image using Median Filter	▶ Image pixel ▶ Pixel value	Median filter replaces the neighbour pixel value and it is calculated by sorting all the pixel values first from its surrounding neighbourhood into a numerical order before replacing the pixel with the middle pixel value.
15	The Analysis of Causes for Dents on Plastic Injection Molding Products	Industry, N.	2017	Topper website	Controlling machine parameter	▶Cooling efficiency ▶Shrinkage rate ▶Mould temperature ▶Barrel temperature	- Defect: dented - Cause: the part is not having any close contact with the mould cavity cooling surface

						▶ Injection pressure	- Countermeasure: adjust the process conditions that can avoid indentation and maintain the reinforced materials that contain a low shrinkage rate.
16	ISO 9001:2015 Quality Management Systems - Requirements	ISO	2015	ISO official website	ISO 9001:2015 standard	▶ Quality standard ▶ Quality assurance	ISO 9001:2015 aimed to enhance customer satisfaction by the system effective application that includes system improvements process and provide assurance of conformity and apply statutory and regulatory requirements to customers.
17	Image Enhancement Methods: A Review	Iwasokun, G.	2014	British Journal of Mathematics & Computer Science, 2252-2270	Increase image contrast	▶ Image contrast ▶ Image intensity ▶ Lighting	Image enhancement refers to enhancement of image contrast. Contrast is always referred to the difference between image intensity of two adjacent pixels. Non-uniform lighting conditions, small dynamic range or non-linearity of image sensor will emerge a low-contrast images.
18	Black spots -plastic injection molding defects	Jackie	2019	Ecomolding Website	Cleaning machine and mould components	▶ Pressure ▶ Holding Time	- Defect: black dot - Cause: black spot prone to appear in the check ring and the screw thread inside the barrel and nozzle. - Countermeasure: frequent and thorough cleaning is needed before starting

							production.
19	What Causes Scratches in Injection Molded Products?	Jackie	2019	Ecomolding Website	Improve mould components	▶ Structure ▶ Gate design	- Defect: Scratches - Cause: mould structure, gate design in the mould, and mould cavity surface. - Countermeasure: not applying too much pressure on the product.
20	A review of Injection moulding process on the basis of runner system and process variables	Kale, P. D., Darade, P. D., & Sahu, A. R.	2020	National E-Conference on Research and Developments in Mechanical Engineering (NCRDME-2020). NCRDME-2020 (pp. 1-6)	Injection Moulding process	▶ Viscosity ▶ Force	Polymer material contains higher viscosity and it cannot be poured simply inside the mould and thus requires a high force to inject the molten polymer into the mould cavity.
21	Review and Analysis of Various Image Enhancement Techniques	Kaur, S., & Kaur, P.	2015	International Journal of Computer Applications Technology and Research, Vol 4, Issue 5, 2015, 414-417	Increase image contrast	▶ Image contrast ▶ Image brightness	Image enhancement is basically an improvement for the image information interpretability or perception in order to provide better input for the image processing technique. More than one of image attributes can be modified according to its requirement and this modification process vary according to the task given.
22	11 Injection Moulding Defects And How To	Knack, O.	2015	Asia Quality Focus. Intouch eBook	Increase machine holding	▶ Cooling time ▶ Holding pressure	- Defect: sink mark. - Cause: slow cooling of the material.

	Prevent Them				pressure and time	▶ Holding time ▶ Shrinkage limit	- Countermeasure: increasing the machine holding pressure and time to allow material to cool and allow shrinkage limit.
23	Quality control: Meaning, process control, SQC control charts, single, double and sequential sampling	Kshirsagar, V.	2017	Indo American Journal of Pharmaceutical Research, Vol 7, Issue 01, 2017, 7369-7373	IPQC inspection	▶ Quality standard	In-Process Quality Control (IPQC) is functioned for monitoring and checking the adaptation of the manufacturing process to comply with the provided specifications which is conducted before, during and after production.
24	Agile Manufacturing: A Literature Review and Pareto Analysis	Kumar, R., & Singh, K.	2019	International Journal of Quality & Reliability Management Volume 2, Issue 37, 2019, 207-222	Pareto analysis	▶ Frequency ▶ Quality ▶ Quantity	80/20 rules in pareto chart states that 80% defect results from 20% of the possible cause, where the total frequency is equated to 100%. This means that majority problems can be eliminated if major problem is focused first.
25	Image Processing Using MATLAB: Basic Operations	Maini, D. A.	2019	Electronicsforu.com website	Image Processing Tools (IPT) in MATLAB	▶ Algorithm	Image processing tools is available in MATLAB for the application. It is a bunch of functions that able to extend the MATLAB numeric computing environment capability and provide a reference-standard algorithm for a comprehensive workflow.

26	Real Time Detection System for Rail Surface Defects Based On Machine Vision	Min, Y., Xiao, B., Dang, J., Yue, B., & Cheng, T.	2018	EURASIP Journal on Image Video Process., vol. 2018, no. 1, 2-11	Apply sufficient light for capturing image	▶ Lighting ▶ Illumination	The lighting process for data acquisition is used to reduce the ambient lighting that creates a negative effect on the SDD other than to prevent shading by giving constant light.
27	Image Recognition Using Convolutional Neural Network Combines with Ensemble Learning Algorithm	Mo, W., Luo, X., Zhong, Y., & Jiang, W.	2019	Journal of Physics: Conference Series, Volume 1237, Issue 2, 1-6	Convolutional Neural Network	▶ Quality monitoring ▶ Accuracy ▶ Algorithm	Convolutional neural network has achieved excellent results due to their network structure ability to extract image of multi-level features. Improvement for this technique is in term of the recognition reliability and target recognition under the premise of increasing parameters number.
28	Image Processing Representation Using Binary Image; Grayscale, Colour Image, and Histogram	Mohan, V., Durga, K., Devathi, S., & Raju, K.	2016	Proceedings of the Second International Conference on Computer and Communication Technologies (pp. 353-361)	Apply sufficient light for capturing image	▶ Colour image ▶ Grayscale image ▶ Binary image	Colour is an important perception and can be expressed in the basic colour components which is red, green, and blue (RGB). Brightness is utilized frequently in order to illustrate apparent strength among psychological intelligence in optical sensitivity in physics realm.
29	Plastic Injection Molding: How Manufacturers Check Part Quality	Mold, M.	2019	Midstate Mold Engineering website	IPQC inspection and procedure	▶ Quality standard	Defective part required to be located, troubleshoot and remove when assuring the quality because the standard and particular needs from client and their industry is

							crucial for different process and practice to meet their standard and quality.
30	Image Processing with MATLAB	Morris	2004	Image Processing with MATLAB. Manchester: Dr. Tim Morris	Image information in MATLAB	▶ Image format ▶ Image pixels ▶ Brightness	Each image has their own format. The image size is usually a rectangular array values or pixels. The coloured image usually represented by the integer of eight bit and give a range of 256 different levels of brightness.
31	A MATLAB GUI: Designed to Perform Basic Image Processing Operations	Nayana, S., Kamala, C., & Vindhya, K.	2016	International Journal of Advanced Technology in Engineering and Science, Vol. No. 4, Issue No. 01 ISNN:2348-7550	Design Graphical User Interface	▶ Components ▶ Figures ▶ Callbacks	GUI in MATLAB is designed to integrate various functions of image processing. In order to generate the interface, callbacks of the component selected need to be used when user trigger or manipulate the components with keystrokes.
32	Automated fabric defect detection—a review	Ngan, H. Y., Pang, G. K., & Yung, N. H.	2011	Image Vision Comput., vol. 29, 442-458	Feature extraction in image processing	▶ Feature extraction ▶ Defect detection	Various methods for feature extraction can be used for defect detection in the SDD process. These methods include statistical, spectral, model-based and learning-based groups.
33	Improvement The Quality of Industrial Products by Applying	Nicolae, R., Nedelcu, A., & Dumitrascu, A.-E.	2015	Review of the Air Force Academy No 3 (30) 2015, 169-172	Pareto analysis	▶ Frequency ▶ Quality ▶ Quantity	This tool is used for data coordination and consolidation to concern the quality, making decisions for the batch size

	the Pareto Chart					production quality based on the analysis sampling collected, and process control to meet high level quality.
34	The Importer's Guide to Managing Product Quality with AQL	Niggl, J.	2017	Asia Quality Focus. Intouch eBook	Acceptable quality level (AQL)	▶ Quantity ▶ Quality	To sort these defects, a classification is required to allow clearer acceptance sampling according to the most product inspection method which is acceptable quality level (AQL).
35	Acoustic data condensation to enhance pipeline leak detection	Oh, S. W., Yoon, D. B., Kim, G. J., Bae, J. H., and Kim, H. S.,	2018	Nuclear Eng. Des., vol. 327	Quality inspection	▶ Quality ▶ Production cost	Products manufactured are prone to defects which cause considerable economic opportunities and wasted resources other than increasing in production cost.
36	Surface Defect Detection and Quantification with Image Processing Methods	Özseven, T.	2018	Theoretical Investigations and Applied Studies in Engineering (p. 63-98). 2019 Ekin Publishing House	Data acquisition in image processing	▶ Extraction data ▶ Interpretation data	Hyperspectral imaging is very common in remote sensing. The need to extract information and interpret content for image processing has become its driving factor for the image processing development.
37	Anisotropic Diffusion Filtering Operation and Limitations – Magnetic Resonance Imaging Evaluation	Palma, C., Cappabianco, F., & Miranda, J.	2014	Proceedings of the 19th World Congress the International Federation of Automatic Control (pp. 3887-3892)	Anisotropic Diffusion Filter	▶ Magnetic Resonance ▶ Edges intensity	ADF technique has been successfully employed and used in several different automated ways in the context of image processing in order to remove noise with high frequency and conserving the existing

							main edges at the same time.
38	Automatic Defect Detection And Classification Technique From Image: A Special Case Uisng Ceramic Tiles	Rahaman, G. M., & Hossain, M. M.	2009	(IJCSIS) International Journal of Computer Science and Information Security, Vol. 1, No. 1, May 2009, 22-30	Machine vision defect detection	▶ Defect detection ▶ Quality ▶ Analog image	There are a lot of development for inspection using vision-based approaches to detect defect on part's surface and image processing is the most increasing approaches in quality control since analog imaging has switched to a digital system these days as the technology advances.
39	Image Enhancement in Spatial Domain: A Comprehensive Study	Rahman, S., Rahman, M. M., Hussain, K., Khaled, S. M., & Shoyaib, M.	2014	17th Int'l Conf. on Computer and Information Technology, 22-23 December 2014 (pp. 368-373)	Increase image contrast using spatial domain	▶ Spatial domain ▶ Image contrast	An issue such as low intensity pixels may be transformed at a high rate and thus create an over-enhancement image. This technique might result in a mean shift where the input image mean brightness may create an undesirable artifact.
40	A Framework for Fast Automatic Image Cropping Based on Deep Saliency Map Detection and Gaussian Filter	Rahman, Z., Pu, Y.-F., Aamir, M., & Ullah, F.	2018	International Journal of Computers and Applications, 2-11.	Cropping image	▶ Colour ▶ Illumination ▶ Viewpoint	Over the year, image cropping has been an essential task to identify and focus on the common and visible object. Properties such as image background colour, illumination condition and viewpoint disparity make the task to be more complex.
41	Wiener Filtering	Rice, U. O	2008	Rice University Information Technology	Filtering image using Wiener	▶ Image pixel ▶ Pixel value	Wiener filtering execute an optimal trade-off between inverse filtering and noise

				website	Filter	▶ Mean square error ▶ Mean square value	smoothing because it able to inverts the blurring and remove the additive noise simultaneously and it minimize the overall mean square error since it is optimal in those terms for the inverse filtering and noise smoothing process.
42	A Review of Image Contrast Enhancement Methods and Techniques	Roomi, M., & Ganesan, G. M.	2015	Research Journal of Applied Sciences, Engineering and Technology 9(5): 309-326, 2015, 1-18	Increase image contrast using HE	▶ Histogram equalization ▶ Image contrast	Histogram equalization (HE) is a technique that is general in image enhancement because it provides a better performance on all images. HE will try to spread the image pixels intensity based on the whole image information to enhance the image.
43	Defect In Plastic Injection Moulding	Rozaimi	2019	UTM lecture notes	Cleaning machine and mould components	▶ Production output ▶ Production profitability	- Defect: black dot - Cause: presence of empty space inside the nozzle and also by grease at the lifter mechanism or at the side pull. - Countermeasure: check the temperature setting of the machine if it is unsuitable.
44	The Effect of Recycled Acrylonitrile Butadiene Styrene (ABS) Mixing Ratio on The Tensile	Salleh, S. N.	2013	Faculty of Manufacturing Engineering UNIVERSITI MALAYSIA PAHANG	Combining monomers	▶ Monomers percentage	The combination of ABS requires 15-35% of Acrylonitrile, 5-30% Butadiene, and 40-60% of Styrene depending on how the different properties can be achieved by blending these monomers.

	Strength of Acrylonitrile Butadiene Styrene Polymer						
45	Troubleshooting Black Specks and Color Streaks in Injection Molded	Spalding, M. A. & Campbell, G.	2012	Conference: SPE ANTEC Tech. Papers Volume: 58, 1-6	Controlling mould temperature	▶ Mould temperature	The metering section of the injection moulding machine must operate as the controlling step rate and should always be verified by the trouble-shooter and one of the solutions for black spot defects is to lower the mould temperature.
46	Morphological: Operations for Image Processing	Srisha, R., & Khan, A	2013	NCVSComs-13 CONFERENCE PROCEEDINGS, (pp. 17-19)	Feature extraction using Morphology technique	▶ Image pixel ▶ Image texture ▶ Thresholding	Morphology signifies a description of structure and shape of the object in the image. Morphological process work on the basis of sets of theory and more relied on pixel relative ordering instead on its numerical value.
47	Graphical User Interface - Layout and Design	Stopper, R.	2012	cartouche. http://www.e-cartouche.ch	Graphical User Interface	▶ User Centred Design	The control of GUI is known as tools that allow user-system interaction and there are four GUI control groups which is the input elements, the output elements, the selection elements and the action elements.

48	Understanding Digital Image Processing	Tyagi, V	2018	A science Publisher Book	Image processing technique	▶ Grayscale level	History behind image processing shows that in 1929 Image coding capability was one of the Initial Bartlane picture system ability which use five levels of grey which is then enhanced to 15 levels of grey. After that, in 1960 an onward, the use of image processing techniques has tremendously grown starting.
49	In Process Quality Control: A Review	Verma, A., & Tangri, P.	2014	International Journal of Industrial Pharmacy and Bio Sciencces, 49-58	IPQC inspection	▶ Quality	IPQC controls the procedure involved in manufacturing to prevent error during processing. Thus, rejected parts collected during the inspection should be controlled under a designed system of quarantine for prevention in production.
50	Using Deep Learning to Detect Defects in Manufacturing: A Comprehensive Survey and Current Challenges	Yang, J., Li, S., Wang, Z., Dong, H., Wang, J., & Tang, S	2020	Materials Multidisciplinary Digital Publishing Institute 13(24):5755, 1-23	Defect detection in image processing	▶ Machine vision ▶ Accuracy	Several methods can be used to detect the surface defect including deep learning, magnetic powder, eddy current testing, ultrasonic testing, and machine vision detection method. Achieved 95.30% of defect detection accuracy by using machine vision-based defect detection.

APPENDIX C

Detection of Defect of An Automotive Part Using Image Processing Approach

UNIVERSITI TEKNIKAL MALAYSIA MELAKA
AFRENA DARWISYAH BINTI AZMAN

Project Start: 15/03/21
Display Week: 1

TASK	ASSIGNED TO	PROGRESS	START	END
Registration				
Confirm title & SV	Afrena	100%	15/03/21	17/03/21
PSM Briefing	Afrena	100%	17/03/21	17/03/21
Revise Title	Afrena	100%	17/03/21	24/03/21
Introduction				
Background Study	Afrena	100%	24/03/21	25/03/21
Problem Statement	Afrena	100%	24/03/21	26/03/21
Objective	Afrena	100%	26/03/21	27/03/21
Scope of Research	Afrena	100%	26/03/21	27/03/21
Significant of Study	Afrena	100%	27/03/21	29/03/21
Organization of Report	Afrena	100%	29/03/21	30/03/21
Summary	Afrena	100%	30/03/21	31/03/21
Literature Review				
Defect	Afrena	100%	01/04/21	05/04/21
Quality Control	Afrena	100%	05/04/21	09/04/21
Image Processing	Afrena	100%	10/04/21	14/04/21
Injection Moulding	Afrena	100%	15/04/21	19/04/21
Acrylonitrile Butadiene Styrene	Afrena	100%	20/04/21	24/04/21
Methodlogy				
Process Flow Chart	Afrena	100%	30/04/21	30/04/21
Gantt Chart	Afrena	100%	01/05/21	06/05/21
Method Selection	Afrena	100%	13/05/21	23/05/21
Video Presentation Preparation	Afrena	100%	31/05/21	06/06/21
Submission FYP 1				
Logbok Submission	Afrena	100%	24/05/21	28/05/21
Video Presentation	Afrena	100%	07/06/21	11/06/21
Report Submission	Afrena	100%	18/06/21	22/06/21

Project Gantt Chart FYP1

APPENDIX D

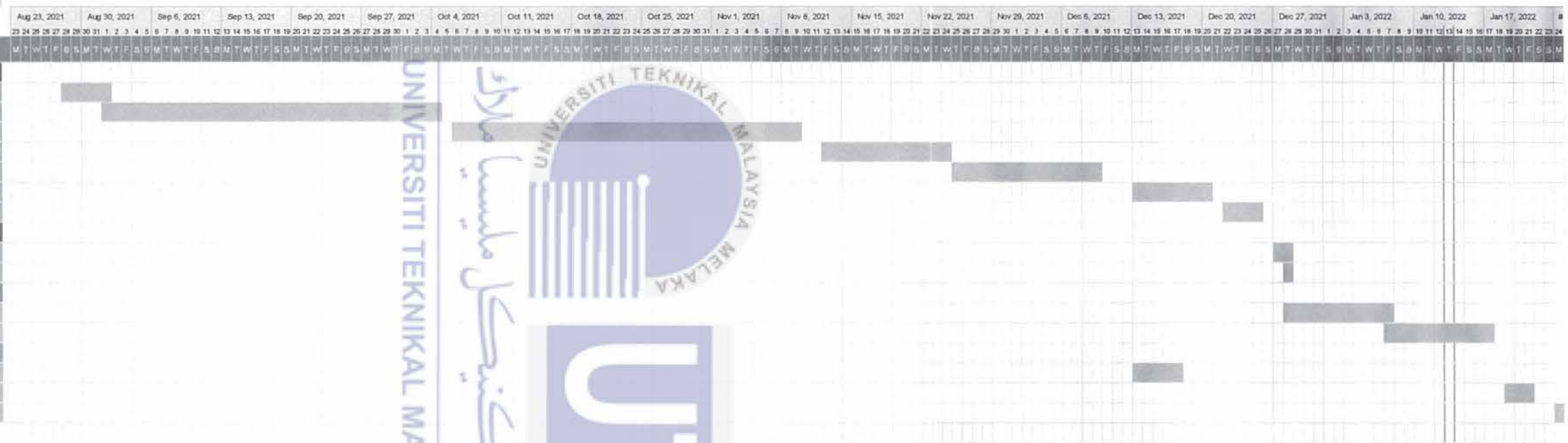
Detection of Defect of An Automotive Part Using Image Processing Approach

UNIVERSITI TEKNIKAL MALAYSIA MELAKA
AFRENA DARWISYAH BINTI AZMAN

Project Start: 28/08/21
Display Week: 1

TASK	ASSIGNED TO	PROGRESS	START	END
Result and Discussion				
Analysis Data	Afrena	100%	28/08/21	01/09/21
Design Algorithm	Afrena	100%	01/09/21	04/10/21
Debugging Program	Afrena	100%	06/10/21	09/11/21
Create GUI	Afrena	100%	12/11/21	24/11/21
GUI analysis	Afrena	100%	25/11/21	09/12/21
Analysis Processing Time	Afrena	100%	13/12/21	20/12/21
Analysis Accuracy	Afrena	100%	22/12/21	25/12/21
Conclusion				
Conclusion	Afrena	100%	27/12/21	28/12/21
Recommendation	Afrena	100%	28/12/21	28/12/21
Report Correction & Improvement				
Improvement (Chapter 4,5 & (	Afrena	100%	28/12/21	07/01/22
Correction (Chapter 1,2 & 3)	Afrena	100%	07/01/22	17/01/22
Submission FYP 2				
Logbok Submission	Afrena	100%	13/12/21	17/12/21
Video Presentation	Afrena	100%	19/01/22	21/01/22
Report Submission	Afrena	100%	24/01/22	24/01/22

Insert new rows ABOVE this one



Project Gantt Chart FYP2

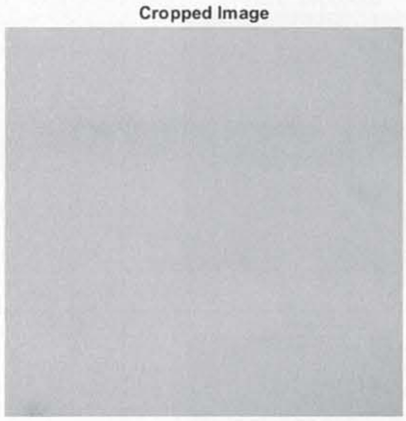
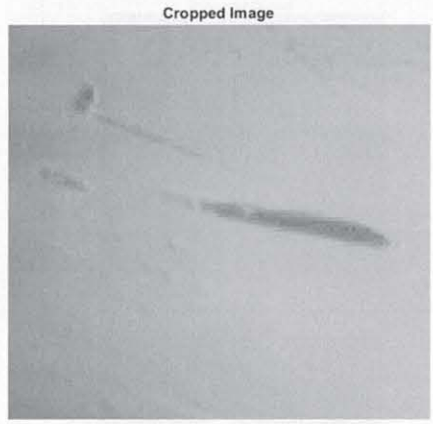
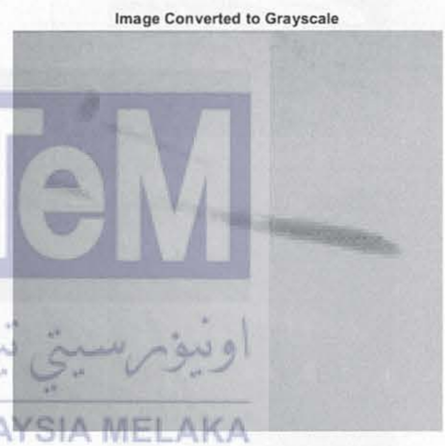
APPENDIX E

Defect Detection Algorithm

```
%Step 1= Data Acquisition

cam = webcam(2); %call webcam 2 {'GL USB2.0 UVC Camera Device'}
tic
preview(cam); %Preview live video
A = snapshot(cam); %Take picture from the video

%Step 2 = Pre-Processing Image

A1 = imcrop(A); %Crop image to focus on defect
A2 = rgb2gray (A1); %Convert Image To Grayscale

%Step 3 = Feature Extraction

[~,threshold] = edge(A2, 'sobel'); %Calculate threshold value for edge
detection
fudgeFactor = 0.5; %Variable to calculate threshold
A3 = edge(A2, 'sobel', threshold * fudgeFactor); %Create binary mask
containing segmentation
se90 = strel('line', 3, 90); %Detect straight line above 3 pixels at 90
degree
se0 = strel('line', 3, 0); %Detect straight line above 3 pixels at 0 degree
A4 = imdilate(A3,[se90 se0]); %Dilate the image
A5 = imfill(A4,'holes'); %Fill interior gap
A6 = imclearborder(A5, 4); %Remove unwanted objects on border
seD = strel('disk',3,4); %Detect object around 3 radius with 4 sructure
elements line
A7 = imerode(A6, seD); %Erode image
figure %Show Image
subplot(1,2,1), imshow (A1), title ('Original image'); %Preview original
image
subplot(1,2,2), imshow (A7), title ('Processed image'); %Preview processed
image

%Step 4 = Defect Detection

total = bwarea (A7); % Calculate Total Area In Image
if any(total > 0)
    disp('NG')
else
    disp('OK')
end
for X = total % Classify Scratch Class According to Range
if any(0<X)&&(X<300)
    disp("class 1 scratch")
elseif any(301<X)&&(X<600)
    disp("class 2 scratch")
elseif any(601<X)&&(X<900)
    disp("class 3 scratch")
elseif any(901<X)&&(X<1200)
    disp("class 4 scratch")
elseif any(1201<X)&&(X<1500)
    disp("class 5 scratch")
end
end
toc
```

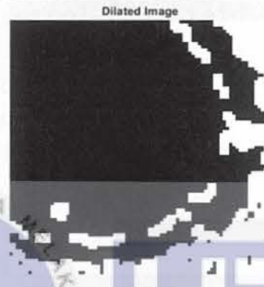
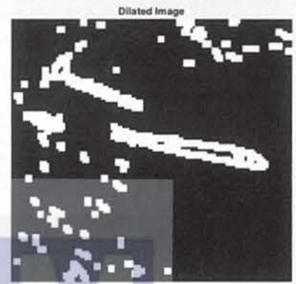
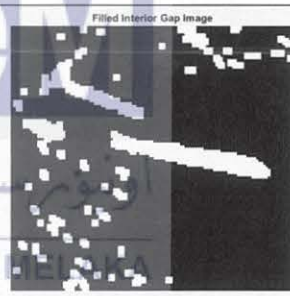
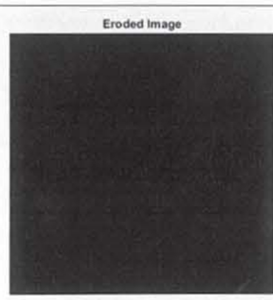
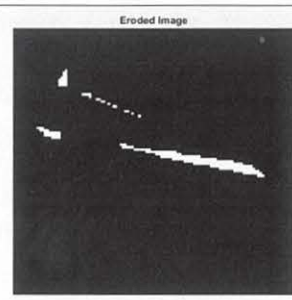
APPENDIX F

Output from Pre-Processing Step

Title	OK	NG
Cropped Image		
Image Converted into Grayscale		

APPENDIX G

Output from Feature Extraction Step

Title	OK	NG
Image in Binary Mask		
Dilated Image		
Fill Interior Gap Image		
Cleared Border Image		
Eroded Image		

APPENDIX H

GUI Algorithm

```
classdef Test1 < matlab.apps.AppBase


% Properties that correspond to app components
properties (Access = public)
UIFigure matlab.ui.Figure
Image2 matlab.ui.control.Image
OriginalIm_2 matlab.ui.control.TextArea
ClassEditField matlab.ui.control.EditField
ClassEditFieldLabel matlab.ui.control.Label
ResultEditField matlab.ui.control.EditField
ResultEditFieldLabel matlab.ui.control.Label
LoadImageButton matlab.ui.control.Button
Image_2 matlab.ui.control.Image
Title matlab.ui.control.TextArea
ProcessedIm matlab.ui.control.TextArea
OriginalIm matlab.ui.control.TextArea
Image matlab.ui.control.Image
OriginalIm_3 matlab.ui.control.TextArea
end


% Callbacks that handle component events
methods (Access = private)


% Button pushed function: LoadImageButton
function LoadImageButtonPushed(app, event)
global im
im = imread('C:\Users\afren\Downloads\K2.12.jpeg');
app.Image.ImageSource=im;
%set(app.Image,'CData',im)
A1 = rgb2gray (im); %Convert Image To Grayscale
[~,threshold] = edge(A1, 'sobel'); %Calculate threshold value for edge
detection
fudgeFactor = 0.5; %Variable to calculate threshold
A2 = edge(A1, 'sobel', threshold * fudgeFactor); %Create binary mask
containing segmentation
se90 = strel('line', 3, 90); %Detect straight line above 3 pixels at 90
degree
se0 = strel('line', 3, 0); %Detect straight line above 3 pixels at 0 degree
A3 = imdilate(A2,[se90 se0]); %Dilate the image
A4 = imfill(A3,'holes'); %Fill interior gap
A5 = imclearborder(A4, 4); %Remove unwanted objects on border
seD = strel('disk',3,4); %Detect object around 3 radius with 4 sructure
elements line
A6 = imerode(A5, seD); %Erode image
grayim=mat2gray(A6);
```

```
app.Image_2.ImageSource=cat(3,grayim,grayim,grayim);
total = bwarea (A6); % Calculate Total Area In Image
if any(total > 0)
disp('NG')
app.ResultEditField.Value='NG';
else
disp('OK')
app.ResultEditField.Value='OK';
end
for X = total
if any(0<X)&&(X<20000)
disp("class 1 scratch")
app.ClassEditField.Value='Class 1 scratch';
elseif any(20001<X)&&(X<40000)
disp("class 2 scratch")
app.ClassEditField.Value='Class 2 scratch';
elseif any(40001<X)&&(X<60000)
disp("class 3 scratch")
app.ClassEditField.Value='Class 3 scratch';
elseif any(60001<X)&&(X<80000)
disp("class 4 scratch")
app.ClassEditField.Value='Class 4 scratch';
elseif any(80001<X)&&(X<100000)
disp("class 5 scratch")
app.ClassEditField.Value='Class 5 scratch';
end
end
end


% Value changed function: ResultEditField
function ResultEditFieldValueChanged(app, event)
string = app.ResultEditField.Value;
total = bwarea (A6); % Calculate Total Area In Image
diary('Result');
diary on
if any(total > 0)
disp('NG')
app.ResultEditField.Value='NG';
else
disp('OK')
app.ResultEditField.Value='OK';
end
diary off;
output = fileread('Result');
set(app.ResultEditField,string,output);
delete('result');
end


% Value changed function: ClassEditField
function ClassEditFieldValueChanged(app, event)
string = app.ClassEditField.Value;
diary('Class');
```

```
diary on
for X = total
if any(0<X)&&(X<300)
disp("class 1 scratch")
app.ClassEditField.Value='Class 1 scratch';
elseif any(301<X)&&(X<600)
disp("class 2 scratch")
app.ClassEditField.Value='Class 2 scratch';
elseif any(601<X)&&(X<900)
disp("class 3 scratch")
app.ClassEditField.Value='Class 3 scratch';
elseif any(901<X)&&(X<1200)
disp("class 4 scratch")
app.ClassEditField.Value='Class 4 scratch';
elseif any(1201<X)&&(X<1500)
disp("class 5 scratch")
app.ClassEditField.Value='Class 5 scratch';
end
end
diary off
output = fileread('Class');
set(app.ClassEditField,string,output);
delete('result');
end
end


% Component initialization
methods (Access = private)


% Create UIFigure and components
function createComponents(app)


% Create UIFigure and hide until all components are created
app.UIFigure = uifigure('Visible', 'off');
app.UIFigure.Color = [0.902 0.902 0.902];
app.UIFigure.Position = [100 100 828 546];
app.UIFigure.Name = 'MATLAB App';


% Create OriginalIm_3
app.OriginalIm_3 = uitextarea(app.UIFigure);
app.OriginalIm_3.HorizontalAlignment = 'center';
app.OriginalIm_3.FontColor = [1 1 1];
app.OriginalIm_3.BackgroundColor = [0.5098 0 0];
app.OriginalIm_3.Position = [2 1 828 76];
app.OriginalIm_3.Value = {''; 'FACULTY OF MANUFACTURING ENGINEERING';
'UNIVERSITI TEKNIKAL MALAYSIA MELAKA'};


% Create Image
app.Image = uiimage(app.UIFigure);
```

```
app.Image.Tag = 'ori';
app.Image.Position = [62 157 363 302];
% Create OriginalIm
app.OriginalIm = uitextarea(app.UIFigure);
app.OriginalIm.HorizontalAlignment = 'center';
app.OriginalIm.FontSize = 20;
app.OriginalIm.BackgroundColor = [0.5922 0.9098 0.6549];
app.OriginalIm.Position = [100 458 286 31];
app.OriginalIm.Value = {'Original Image'};


% Create ProcessedIm
app.ProcessedIm = uitextarea(app.UIFigure);
app.ProcessedIm.HorizontalAlignment = 'center';
app.ProcessedIm.FontSize = 20;
app.ProcessedIm.BackgroundColor = [0.5882 0.9098 0.651];
app.ProcessedIm.Position = [439 458 286 31];
app.ProcessedIm.Value = {'Processed Image'};


% Create Title
app.Title = uitextarea(app.UIFigure);
app.Title.HorizontalAlignment = 'center';
app.Title.FontSize = 30;
app.Title.BackgroundColor = [0.9804 0.8 0.4392];
app.Title.Position = [157 498 517 44];
app.Title.Value = {'PART''S SURFACE INSPECTION'};


% Create Image_2
app.Image_2 = uiimage(app.UIFigure);
app.Image_2.Position = [415 157 334 302];


% Create LoadImageButton
app.LoadImageButton = uibutton(app.UIFigure, 'push');
app.LoadImageButton.ButtonPushedFcn = createCallbackFcn(app,
@LoadImageButtonPushed, true);
app.LoadImageButton.BackgroundColor = [0.0039 0.0039 0.3294];
app.LoadImageButton.FontSize = 20;
app.LoadImageButton.FontColor = [1 1 1];
app.LoadImageButton.Position = [101 91 136 46];
app.LoadImageButton.Text = 'Load Image';


% Create ResultEditFieldLabel
app.ResultEditFieldLabel = uilabel(app.UIFigure);
            app.ResultEditFieldLabel.HorizontalAlignment = 'center';
            app.ResultEditFieldLabel.FontSize = 18;
            app.ResultEditFieldLabel.Position = [248 91 82 43];
            app.ResultEditFieldLabel.Text = 'Result';


            % Create ResultEditField
```

```
            app.ResultEditField = uieditfield(app.UIFigure, 'text');
            app.ResultEditField.ValueChangedFcn = createCallbackFcn(app,
@ResultEditFieldValueChanged, true);
            app.ResultEditField.FontSize = 20;
            app.ResultEditField.FontWeight = 'bold';
            app.ResultEditField.Position = [329 91 131 43];


            % Create ClassEditFieldLabel
            app.ClassEditFieldLabel = uilabel(app.UIFigure);
            app.ClassEditFieldLabel.HorizontalAlignment = 'center';
            app.ClassEditFieldLabel.FontSize = 18;
            app.ClassEditFieldLabel.Position = [490 91 74 42];
            app.ClassEditFieldLabel.Text = 'Class';


            % Create ClassEditField
            app.ClassEditField = uieditfield(app.UIFigure, 'text');
            app.ClassEditField.ValueChangedFcn = createCallbackFcn(app,
@ClassEditFieldValueChanged, true);
            app.ClassEditField.FontSize = 15;
            app.ClassEditField.FontWeight = 'bold';
            app.ClassEditField.Position = [563 91 131 43];


            % Create OriginalIm_2
            app.OriginalIm_2 = uitextarea(app.UIFigure);
            app.OriginalIm_2.FontWeight = 'bold';
            app.OriginalIm_2.BackgroundColor = [0.8 0.8 0.8];
            app.OriginalIm_2.Position = [579 8 244 62];
            app.OriginalIm_2.Value = {'CREATED BY:'; 'AFRENA DARWISYAH BINTI
AZMAN'; 'SUPERVISED BY:'; 'IR. DR. LOKMAN BIN ABDULLAH'};

            % Create Image2
            app.Image2 = uiimage(app.UIFigure);
            app.Image2.Position = [-10 7 153 63];
            app.Image2.ImageSource = 'LogoJawi.png';

            % Show the figure after all components are created
            app.UIFigure.Visible = 'on';
        end
    end

    % App creation and deletion
    methods (Access = public)

        % Construct app
        Function app = Test1

            % Create UIFigure and components
            createComponents(app)

            % Register the app with App Designer
```

```
        registerApp(app, app.UIFigure)

        if nargout == 0
            clear app
        end
    end

    % Code that executes before app deletion
    Function delete(app)

        % Delete UIFigure when app is deleted
        delete(app.UIFigure)
    end
end
end
```

APPENDIX I

Data Collected from Unique Diamond Sdn Bhd (UD)

DATE	PLACE	NO. MP	SORTING RESULT				DEFECT
			QTY	OK	NG	%	
12.03.20	UD 2ND FILTER	1	1620	0	1620	100.00	100% TRIM HAIR LINE
19.06.20	OVC	1	3320	3116	204	6.14	MIX PART
19.06.20	OVC	1	3320	3109	211	6.36	MIX PART 204, **SCRATCHES 7**
24.06.20	UD 2ND FILTER	1	480	436	44	9.17	WELD LINE 21, **DENTED 23**
24.06.20	UD 2ND FILTER	1	480	316	164	34.17	**SCRATCHES 154, DENTED 10**
21.09.20	OVC	1	1620	1608	12	0.74	**BLACK DOT**
23.09.20	OVC	1	540	540	0	0.00	**SCRATCHES**
25.09.20	OVC	1	2683	2671	12	0.45	**SCRATCHES**

APPENDIX J

Processing Time Data

No.	KEYTOP 1		KEYTOP 2	
	Processing time (s)		Processing time (s)	
	Semi-automatic	Manual	Semi-automatic	Manual
1	10.14	14.96	9.12	17.72
2	9.76	20.20	7.29	10.93
3	9.92	21.89	7.68	4.17
4	12.02	15.81	5.43	23.83
5	8.12	32.19	6.36	11.78
6	8.68	20.25	6.73	12.83
7	11.35	17.29	8.60	5.33
8	12.70	11.93	9.33	12.88
9	7.86	22.69	5.33	20.11
10	7.85	26.70	12.14	16.20
11	16.10	15.95	4.92	8.75
12	7.86	23.54	8.08	14.15
13	8.98	7.19	5.81	15.43
14	11.68	14.98	11.23	19.91
15	5.05	2.86	6.96	6.26
16	8.06	17.86	9.86	25.66
17	6.64	18.84	5.55	12.81
18	7.01	14.70	4.89	12.38
19	4.73	12.98	4.00	6.32
20	5.83	11.01	5.55	5.94
21	6.53	18.07	6.86	8.33
22	7.53	19.34	5.00	19.06
23	5.98	5.68	6.11	14.56
24	6.43	7.88	3.95	14.08
25	7.27	2.65	8.75	5.37
26	6.23	3.53	5.56	11.96
27	6.83	8.39	11.22	15.49
28	7.72	9.74	5.00	5.25
29	6.10	6.52	6.81	6.31
30	8.69	5.61	6.89	18.72
31	7.02	23.66	13.67	12.73
32	6.58	5.31	6.20	8.37
33	10.62	10.68	3.99	3.64
34	6.60	9.50	10.36	7.60
35	6.65	19.25	8.85	14.55
36	8.53	7.98	14.48	25.42
37	6.69	3.78	6.23	9.53
38	6.71	7.42	6.84	8.99
39	7.53	17.49	13.45	17.16
40	12.08	4.72	10.43	19.94
41	7.47	8.26	11.05	11.69
42	15.35	13.31	7.80	10.82
43	4.23	6.63	12.44	13.70
44	7.95	10.43	6.72	8.71
45	8.12	4.35	8.49	15.21
46	9.59	19.50	5.19	12.28
47	21.82	14.78	9.23	14.30
48	8.05	4.85	6.48	12.34
49	18.33	14.55	7.27	12.16
50	20.06	8.70	6.61	9.54

APPENDIX K

Accuracy Data

No.	KEYTOP 1		KEYTOP 2	
	True Class	Predicted Class	True Class	Predicted Class
1	P	P	P	P
2	N	N	P	P
3	P	P	P	P
4	P	P	P	P
5	N	N	P	P
6	P	P	P	P
7	P	P	P	P
8	N	N	P	P
9	P	P	N	N
10	P	P	P	P
11	N	N	N	N
12	P	P	P	P
13	P	P	P	P
14	N	N	N	N
15	P	P	P	P
16	N	N	P	P
17	P	P	P	P
18	P	P	P	P
19	P	P	P	P
20	P	P	P	P
21	N	P	P	P
22	P	P	P	P
23	P	P	P	P
24	P	P	P	P
25	P	P	N	P
26	P	P	P	P
27	P	P	P	N
28	P	P	P	P
29	P	P	P	P
30	N	N	P	P
31	P	P	N	N
32	P	P	P	P
33	N	N	P	P
34	P	P	N	P
35	P	P	P	P
36	P	P	N	N
37	P	P	P	P
38	P	P	P	P
39	P	P	P	P
40	N	N	P	P
41	P	P	P	P
42	N	N	P	P
43	P	P	N	N
44	P	P	P	P
45	P	P	P	P
46	P	P	P	P
47	N	N	P	P
48	P	P	P	P
49	N	N	P	P
50	N	N	P	P

APPENDIX L

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

DETECTION OF DEFECT OF AN AUTOMOTIVE PART USING IMAGE PROCESSING APPROACH

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UTeMEX 2021

INTRODUCTION

- An industrial based project.
- To create an inspection method via image processing approach for a plastic injection molding company.
- Selected part:

KEYTOP 1

KEYTOP 2

- Why proposing new method?
  - To avoid defective parts containing defects on the surface.
  - To prevent defective part from reaching out to customers.

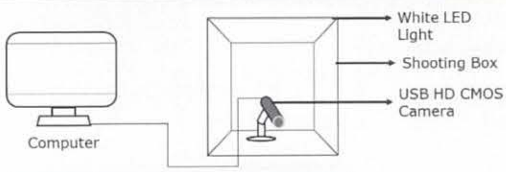
PROBLEM STATEMENT

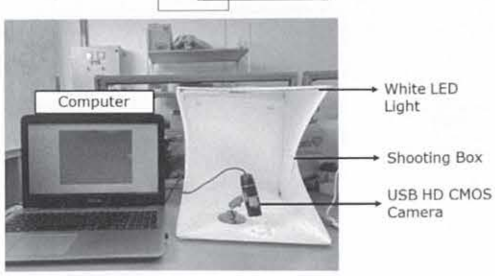
- Ineffective method:
  - Manual Inspection
  - Using Smart Scope
- Defect overlook scenario:
  1. Constant customer complaint.
  2. Interruption of production and delivery planning.
  3. Reduction of manufacturing productivity.
  4. Required cost to send manpower for sorting.
- Over the year 2020:
  - At least 8 times for 100% checking requested.
  - Found 1.80% scratches, 0.34% dented and 0.12% black dot.

OBJECTIVES

1. To identify the frequency of defective injection molded part produce.
2. To formulate an algorithm via image processing technique to detect defective part.
3. To analyze the effectiveness of image processing technique for quality inspection in term of accuracy and processing time.

EQUIPMENT SETUP





RESULT/ANALYSIS

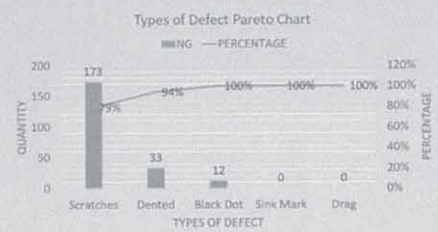


Figure 1: Types of Defect Pareto Chart

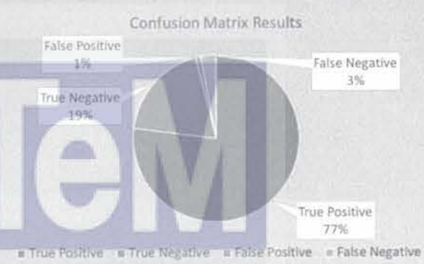


Figure 2: Confusion Matrix Results

$$\text{Accuracy} = \frac{TP + TN}{TP + TN + FP + FN} = \frac{77 + 19}{77 + 19 + 1 + 3} = 0.96 \approx 96\%$$

Table 1: Comparison of Average Processing Time (s)

Part's Name	Method	Processing time (s)
KEYTOP 1	Automatic	8.97
	Manual	12.57
KEYTOP 2	Automatic	7.75
	Manual	12.32

BENEFITS

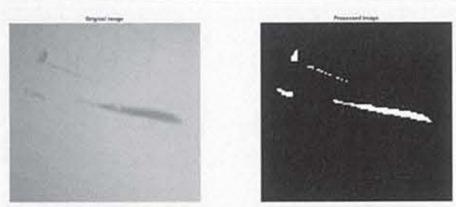


Figure 3: Comparison of Original and Processed Image

- Algorithm formulated is successful to detect 2D defects even on complex shape of plastic parts.
- Results obtained prove that it able to reduce inspection processing time with an accuracy of 96%.
- An alternative for the company to replace current method and avoid customer complaints in future.

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