Development of Product Flaw Detection Algorithm Based on Deep Learning

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DECLARATION

I declare that this thesis entitled “Development of Product Flaw Detection Algorithm Based on Deep Learning” is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

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APPROVAL

I hereby declare that I have checked this report entitled "Development of Product Flaw Detection Algorithm Based on Deep Learning" and in my opinion, this thesis it complies the partial fulfillment for awarding the award of the degree of Bachelor of Mechatronics Engineering with Honours

Signature :

Supervisor Name : DR. SAIFULZA BIN ALWI @ SUHAIMI

Date : 5 JULY 2021

DEDICATIONS

To my beloved lecturers, classmates, friends and family members. Thank you for all the help, encouragement and support in preparing this report.

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ABSTRACT

In recent years, technology is involving rapidly and PCBs are very crucial component in most electronic devices, thus, demands of PCBs are gradually increasing days by days. Therefore, PCBs inspection processes have to continually improve to meet the increasing demand of PCBs. Besides that, PCBs are now having more and more complex designs and tinier components, therefore, human inspection system is not suitable to meet the high accuracy and high-speed inspection. So, industries have attempted to achieve nearly 100% quality inspection system by using machine vision to ensure the quality of all PCBs with also the help of new era of inspection method which is deep learning algorithm. However, inspection method with deep learning algorithm has not been widely implemented yet. In this project, the focus is on the design and development of a product flaw detection using deep learning algorithm. This is used to detect components missing and distance detection on the PCBs. The hardware components are built by a Sony XZs smartphone camera, LED system and laptop with GPU processor. The software is using Python language, PyCharm IDE, OpenCV library, different types of YOLO deep learning algorithm. The YOLO deep learning object detection networks are trained using Google Colab GPU. Experiments have been conducted to compare the accuracy between all four type of YOLO algorithms with different lighting conditions.

ABSTRAK

Dalam beberapa tahun yang dekat, teknologi telah bermaju dengan maju dan PCB telah menjadi komponen yang amat penting dalam barang elektronik. Sehubungan dengan itu, keperluan PCB telah meningkat dari sehari ke sehari. Sebab itu, proses pemeriksaan PCB perlu sentiasa maju supaya dapat memenuhi permintaan PCB yang semakin meningkat. Selain itu, PCB sekarang semakin kompleks dalam rekaan dan komponen juga semakin kecil. Oleh itu, pemeriksaan manusia sudah tidak sesuai untuk mencapai ketepatan pemeriksaan yang tinggi dan cepat. Jadi, kilang-kilang telah membuat cubaan untuk mencapai 100% kualiti pemeriksaan dengan menggunakan penglihatan mesin dan pemelajaran struktural mendalam. Namun begitu, penglihatan mesin dengan menggunakan pemelajaran struktural mendalam tidak biasa lagi dilaksanakan dan digunakan. Dalam projek ini, fokus adalah pada rekaan dan pembangunan pengesanan kecacatan produk dengan menggunakan algoritma pemelajaran struktural mendalam. Ia digunakan untuk pemeriksaan komponen yang hilang di atas PCB dan juga jarak antara komponen LED dan butang. Hardware yang digunakan adalah kamera telefon pintar Sony XZs, pencahayaan menggunakan LED dan pemproses GPU. Software yang digunakan adalah bahasa komputer Python, PyCharm IDE, OpenCV library dan empat jenis YOLO algoritma pemelajaran structural. Eksperimen telah dijalankan untuk membanding ketepatan antara empat algoritma YOLO dalam pelbagai keadaan pencahayaan

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LIST OF SYMBOLS AND ABBREVIATIONS

2-D	-	2-Dimentional
3-D	-	3-Dimentional
FYP	-	Final Year Project
CCD	-	Charge Coupled Device
CMOS	-	Complementary Metal Oxide Semiconductor
PCB	-	Printed Circuit Board
CPU	-	Central Processing Unit
GPU	-	Graphic Processing Unit
LED	-	Light Emitting Diode
IC	-	Integrated Chip
CNN	-	Convolutional Neural Network
R-CNN	-	Region-Convolutional Neural Network
SSD	-	Single-Shot Detector
YOLO	-	You Only Look Once
GAN	-	Generative Adversarial Network

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CHAPTER 1

INTRODUCTION

In this chapter, a brief introduction and motivation related to the project's topic will be discussed. The problem statements, objectives and scopes will also be listed.

1.1 Introduction

During manufacturing processes such as embossing, punching, blanking, press or pull working, and many more, products might undergo deformation and sometime defection such as cracking, necking and marking line might occur. Thus, defect detection during manufacturing process is very important for ensuring quality and safety control of the products. Conventional visual inspection is using human visual and it is very subjective and often inaccurate. Therefore, defect detection system for automated and high accuracy is required such as image-based processes [19].

Nowadays, smart manufacturing refers to new manufacturing paradigm. Manufacturing machines are now monitored by sensors, connected to network, controlled by intelligent computer, high quality and quantity products output and low breakdown. The high-quality controlling system are made with the help of powerful machine vision-based system [20]. Machine vision is the technology and science of machines that enable the machines to "see" and with the help of computer programming, machines can help the computers to process and understand images and videos [25]. A good vision system is able to prevent low quality or defected products to reach markets and also can cut down labour investments. Generally, an inspection system consists of four main modules which are image acquisition, image processing, feature extraction and decision making. Figure 1.1 shows the main flow of machine vision system. Advanced image processing algorithm can help to extract properties of product such as colour, shape and texture from the image [20].

Object recognition is task that to identify objects and label objects in the digital photograph or image. Deep learning such as convolution neural network (CNN) is one of the techniques used to locate and recognize objects in the digital image [22]. Deep learning uses cascade of multi layers of nonlinear processing units to extract features. Each layer takes regard of the previous output as input. Therefore, it is able to integrate feature extraction and classification into one framework. The final layer is used to output the desired label [20]. Todays, Faster R-CNN, YOLO, and SSD are currently most popular deep learning methods for machine vision object detection.

In conclusion, machine vision is crucial in modern manufacturing production for flaw detection. Image processing and computer vision technologies are becoming indispensable tools for automated manufacturing system. It is significantly reducing inspection time, avoidance of human errors, cutting down labour costs and improving product quality[8].

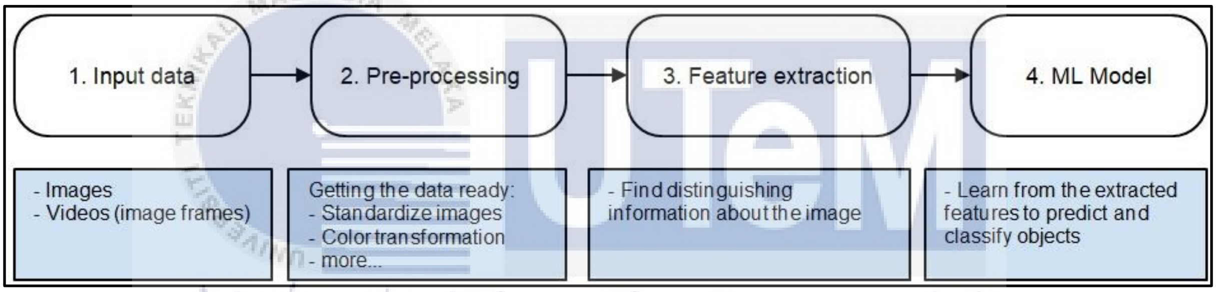

Figure 1.1: Main flow of machine vision system.

1.2 Motivation

Products that produced and inspected by machine vision-based inspection methods are being widely investigated to improve product quality, increase productivity and reduce labour costs. Recently, with the aid of deep learning, machine vision-based inspection is becoming more robust and accurate [20].

Besides that, today's manufacturing process is becoming more advance with the help of increasing internet speed, more accurate and sensitive sensors, and now with help of artificial intelligent and also deep learning vision inspection. The quality of life of human can be improved with all these technologies. Machines vision inspection plays important role in hitting 100% inspection of the product and reaching zero defect products flow into marketing. Almost all the defect and flaw products can be detected and prevent them to go into customer. This can improve the income of a company if less customer complains about for receiving new product but with defect [4]. Vision inspection system can also be used for civil inspection for cracking and help human to repair them before it become a tragedy [19].

In recent years, technology is involving rapidly and PCBs are very crucial component in most electronic devices, thus, demands of PCBs are gradually increasing days by days. Therefore, PCBs inspection processes have to continually improve to meet the increasing demand of PCBs. Besides that, PCBs are now having more and more complex designs and tinier components, therefore, human inspection system is not suitable to meet the high accuracy and high-speed inspection. So, industries have attempted to achieve nearly 100% quality inspection system by using machine vision to ensure the quality of all PCBs with also the help of new era of inspection method which is deep learning algorithm [24].

In a nutshell, vision-based flaw inspection system with deep learning algorithm can gradually increase the quality of products, and thus quality life of consumers can also be increased. It improves the manufacturing level of automated production.

1.3 Problem Statements

Construction of machine vision inspection is very advance and producing high inspection accuracy and thus high-quality product. But construction of deep learning model is typically not easy to achieve high accuracy and quick inspection together. In order to achieve high accuracy, the deep convolutional networks have been made deeper, thus sacrifice the size of data and speed of analysis on the way. The bigger the data size, the slower the speed of analysis. Therefore, a high accuracy and suitable analysis speed must be investigated using a suitable deep learning algorithm and a suitable data size.

Besides that, there is a big problem that machines learning faced is lack of good database when doing algorithms. Good data quality is very essential for the algorithms to function as desired. Noisy data, incomplete data or dirty data may affect the quality of the inspection or output. Therefore, the equipment and technique to capture the image of the desired object to be inspected are also very important. Low quality or wrong technique applied may result low quality output such as image acquisition and image filtering or enhancement. The illuminate system for image acquisition can be very crucial. A bad lighting may result in bad solution image and work to reduce the noise might be hard.

In conclusion, correct equipment and technique selected for constructing a high accuracy machine vision inspection system is very important. In this research, a suitable algorithm and vision system is to be designed and develop throughout the study.

1.4 Objectives

The objectives of this project are as below:

1. To develop image acquisition, image processing and illuminating system that suitable for flaw detection.
2. To program a suitable YOLO deep learning algorithm for product flaw detection.
3. To analyse the accuracy and performance of the system in detecting flaw objects orientation and distance.

1.5 Scopes

This project will focus on following process:

1. A suitable image acquisition system for product flaw detection is developed by using 2D camera and lighting material such as LED.
2. A program code for machine vision is written using Python OpenCV software for image processing.
3. A suitable YOLO deep learning algorithm is developed to categorize and detect product flaw using Python.
4. A lab experiment will be carried out by inspecting the defected products to test the functionality of developed system.
5. The accuracy of the flaw detection will be tested with different lighting system, and deep learning methods.

1.6 Organisation of Thesis

Chapter 1 of this report is introduction of the project, a brief introduction and motivation related to the project's topic will be discussed. The problem statements, objectives and scopes will also be listed.

Chapter 2 of this report is literature review. This chapter will discuss and review about the literatures of the fundamental and theory that involved in this project such as machine vision or computer vision, image acquisition, digital image processing, object detection or recognition, and deep learning. The related previous works or processes for the flaws detection vision system will also be discussed. Some comparison of different methods in doing machine vision are also compared and discussed.

Chapter 3 of this report is methodology. The steps, procedures and methods of developing this project will be developed and described. The flow of the project and timeline will also be listed.

Chapter 4 is the results and discussion. This chapter will show the experiment outcomes of the project. The data obtained will be analysed and discussed.

Chapter 5 is the conclusion of the project. Suggestion of improvements for future works is mentioned in this chapter. The overall process and final results are discussed.

CHAPTER 2

LITERATURE REVIEW

In this chapter, we will discuss and review about the literatures of the fundamental and theory that involved in this project such as machine vision or computer vision, image acquisition, digital image processing, object detection or recognition, and deep learning. The related previous works or processes for the flaws detection vision system will also be discussed. Some comparison of different methods in doing machine vision are also compared and discussed.

2.1 Machine Vision or Computer Vision

Nowadays manufacturing operations with the aid of industrial robots are gradually increasing. These robots are evolving from traditionally just blind motion playback machines into now can adapt to the changes in their surroundings with the help of intelligent sensor-based software. Machine vision is a field of computer science that enabling machines to see, identify and process images as same as human eyes. A vision guided robotic system analyses images from one or more cameras. Early implementations of vision guided robots have provided only limited part pose information, primarily in the two-dimensional space and movement of parts are only constrained to a planar surface. However, many robotic applications require the robot to locate and manipulate products or workpiece in three dimensions. This finally sparked various three-dimensional guidance capabilities. Three-dimensional guidance involved stereo configuration which has involved two or more cameras that view overlapping regions of the same object. [1]

Machine visions are designed to eliminate human element from manufacturing and inspection processes which are not difficult but boring processes. The boredom of processes leads to the unfocused of human during operation and thus this condition mays lead to the defect in the products. Traditionally, vision system used monochrome or grey scale system to capture the image of objects by using video camera. These monochrome systems may provide feedback during manufacturing process or during offline as inspection devices or manufacturing aides. The scale of grey may be appropriate for determining the size, shape or colour differences of the objects. But, if the degrees of differentiation between an object are only slightly different, a colour recognition system may be required. Colour recognition systems are used for more complex tasks. All of these systems are relied on sensory input devices especially camera, lighting device and processor. Lighting is a vital part of both the grey scale and colour systems. The system will slow down, give false indications or completely fail to operate if the lighting does not provide the proper contrast. [2]

In conclusion, machine vision is the knowledge and approaches used to provide image-based automatic examination for quality control, process control, and robot guidance. According to the Automated Imaging Association (AIA), machine vision encompasses all industrial and non-industrial applications such as optical gauging, object measurement, sorting, quality assurance, part assembly inspection, building crack inspection, medical imaging, autonomous vehicle system, product flaw detection and many more [3, 4, 7, 8]. Table 2.1 shows how the machine vision application helps meet strategic goals for industrial manufacturing.

Table 2.1: Machine vision application helps meet strategic goals.

Strategic Goal	**Machine Vision Applications**
Higher quality	Inspection, measurement, gauging, and assembly verification
Increased productivity	Manually and repetitive tasks formerly done by human are now replaced or aided with Machine Vision System
Production flexibility	Measurement and gauging / Robot guidance / Prior operation verification
Less machine downtime and reduced setup time	Changeovers programmed in advance, early detection
More complete information and tighter process control	Manual tasks are now can provide data feedback to computer
Lower capital equipment costs	Machine vision can improve performance and avoids obsolescence
Lower production costs	One vision system can replace many people / Detections of flaws early in the process
Scrap rate reduction	Inspection, measurement, and gauging
Inventory control	Optical Character Recognition and identification
Reduced floorspace	A vision system replacing operators

2.2 Image Acquisition

Machine vision process starts with acquisition of an image using appropriate image sensors, optics or lenses and lighting. Figure 2.1 shows the basic machine vision concept.

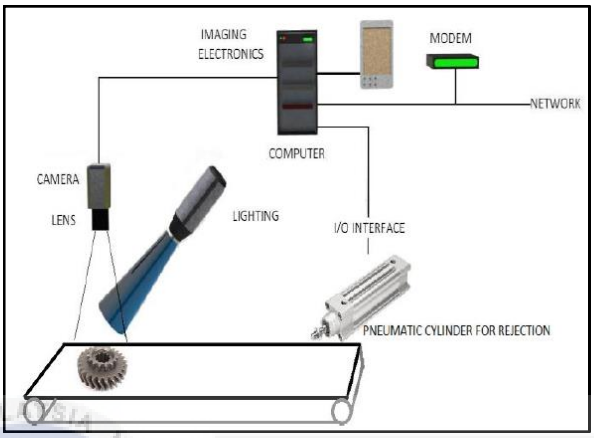

Figure 2.1: Machine vision concept.

2.2.1 Image Sensors

A camera that able to capture a correctly illuminated image of an object is not only depend on the lens but also the image sensor in the camera. An image sensor typically uses a charge coupled device (CCD) or complementary metal oxide semiconductor (CMOS) technology to convert light (photons) to electrical signals (electrons). CCD sensors create high-quality, low-noise images. CMOS sensors are generally more susceptible to noise. Figure 2.2 shows the CMOS sensor and CCD sensor. There is also another cheaper imaging array technology compared to CCD sensor which is contact image sensor (CIS) but it does not provide same level of quality and resolution found in most CCD scanners. [5]

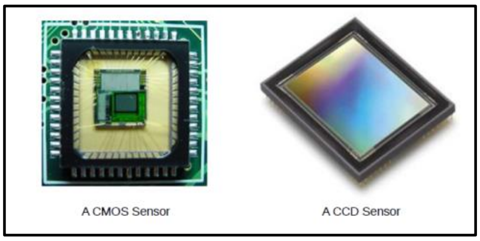

Figure 2.2: CMOS sensor and CCD sensor.