ANALYSIS OF SHAPE RECOGNITION USING ROBOTIC FINGERS BY IMAGE PROCESSING TECHNIQUE FOR OBJECT MANIPULATION

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DECLARATION

I declare that this thesis entitled "Analysis of Shape Recognition Using Robotic Fingers by Image Processing Technique For Object Manipulation" 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.

Signature : .....

Name : .....

Date : .....

APPROVAL

I hereby declare that I have checked this report entitled “Analysis of Shape Recognition Using Robotic Fingers by Image Processing Technique For Object Manipulation” and in my opinion, this thesis it complies the partial fulfillment for awarding the award of the degree of Bachelor of Mechatronics Engineering with Honors

Signature : .....

Supervisor Name : .....

Date : .....

DEDICATIONS

To my beloved mother and father

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ABSTRACT

In line with the advancement of technologies, present tactile sensing based gripping technologies have shown improvements in interactive force gripping and identification of object. However, the precision of shape recognition using tactile sensors on gripper is unsatisfied. The main objective for this study is to design and develop a system for identifying the contact points of different object shapes and analyze the angular motion of fingers movement as well as accuracy of object grasped. The design of gripper involves two robotic fingers with two degree of freedom. It implements basic image processing techniques such as gray-scale, threshold and edge detection as the approach to determine the vertices on the object image for recognizing the object's shape. Plus, the contact points on the object surface that will be touched by the gripper's fingers define the orientations of the joints by using inverse kinematic equation. The effectiveness of this vision system required large size of targeted object compared to smaller size. These analyses obtained 2.05 and 2.0 pixels per millimeter which have been converted from pixel coordination to the real coordination for circle object and square object respectively. The accuracy on the orientations calculated in actual value and pixel value were just in slightly different which were 97.54% (Link 1) and 97.4% (Link 2) for grasping circle object while 97.48% (Link 1) and 93.8% (Link 2) for grasping the square object.

ABSTRAK

Sebaris dengan kemajuan teknologi, sensor sentuhan kini yang berasaskan teknologi pencengkam telah menunjuk penambahbaikan bagi daya interaktif mencengkam dan mengenalpasti objek. Objektif utama kajian ini adalah untuk mereka bentuk dan membangunkan suatu sistem untuk mengenal pasti titik hubungan pada bentuk objek yang berbeza dan menganalisis pergerakan jari serta ketepatan objek yang dicengkam. Reka bentuk penggenggam melibatkan dua jari robot dengan dua darjah kebebasan. Kajian ini melaksanakan teknik pemprosesan imej asas seperti skala kelabu, ambang dan pengesanan pinggir sebagai pendekatan untuk menentukan jumlah bucu untuk mengenali bentuk objek. Tambahan pula, titik hubungan pada permukaan objek yang akan disentuh oleh jari-jari penggenggam menentukan orientasi pada sendi dengan menggunakan persamaan kinematic songsang. Keberkesanan sistem penglihatan ini memerlukan saiz yang besar bagi objek yang disasarkan berbanding saiz yang lebih kecil. Analisis ini memperoleh 2.05 dan 2.0 piksel bagi setiap millimeter yang telah ditukarkan daripada koordinasi piksel ke koordinasi sebenar. Ketepatan pada orientasi yang dikira dalam nilai sebenar dan nilai piksel hanya sedikit berbeza iaitu 97.54% (Link 1) dan 97.4% (Link 2) untuk menggenggam objek bulat manakala 97.48% (Link 1) dan 93.8% (Link 2) untuk menggenggam objek segi empat.

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CHAPTER 1

INTRODUCTION

1.1 Overview

This chapter briefly describes about motivation, problem statement, project objectives and limitations of the project. Motivation inspired to current manufacturing industry development. Problem statement in this report written referring to the information gathering after studied the previous researches. As well as objectives and scopes for this project, it was set by identifying the problems.

1.2 Motivation

In this era of globalization, industrial sector plays a main role in developing the country. There are several broad categories of industry, namely genetic industries, extractive industries, manufacturing industries and construction industries. In addition, genetic and extractive industries are generally known as primary industries due to their output of raw materials such as forestry, farming, fishing and mining. Meanwhile, the manufacturing and construction industries are known as secondary industries because of their output of finished products that are converted from raw materials such as goods, electrical equipment, vehicle and building.

In fact, the developing countries and underdeveloped countries are making terrific developments for growth of the manufacturing industries. In the large scale of the manufacturing industry, automation and robotic are implemented. It shown in the Figure 1.1, the statistic represents worldwide sales of industrial robots between 2004 and 2017 announced at Automatica 2018 in Munich by International Federation of Robotic (IFR). It shows that the industrial robots sales increased by 29 percent from about 294,300 units sold in 2016 to around 387,550 units sold in 2017 [1]. It can be observed, that every year for the previous decade is showing increasing sales of industrial robots.

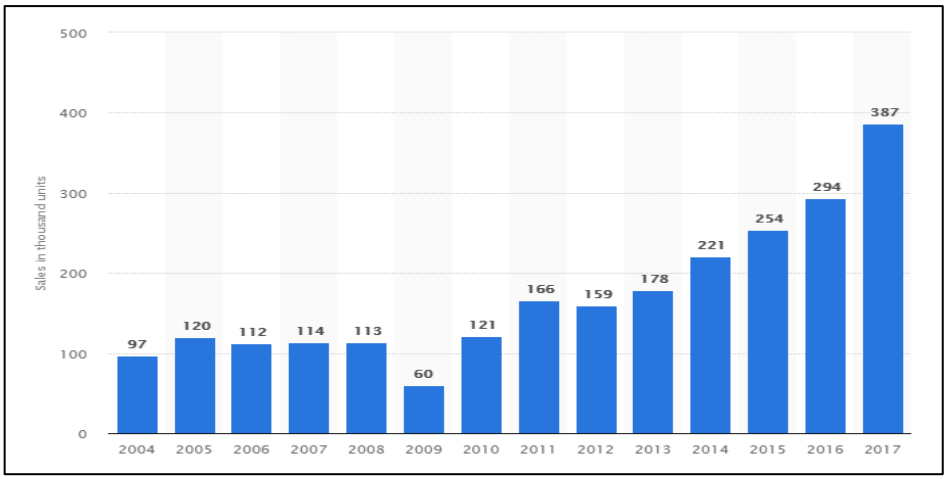

Figure 1.1: Worldwide Sales of Industrial Robots 2004-2017 (in 1,000 Units) [1]

In the robotics industry, mechanical arm is a popular application. However, arm is useless without hand. The robot end-effector is the connection between the robot arm and the environment around it. Generally, the implementation of robotic end-effector is for part handling. In industrial, there are many application of it. Collaboration of other field in engineering such as mission vision, artificial intelligence, control system and others can be made to improve the robotic end-effector. As shown in Figure 1.2, the graph represents the total machine vision financial transactions by North America from 2001 to 2015 stated in Shanghai by Automated Imaging Association (AIA). It shows that the market growth by 13 percent on average since 2010 [2]. It can be determine, machine vision and industrial robot are the technologies that corresponding in speedy developing until now.

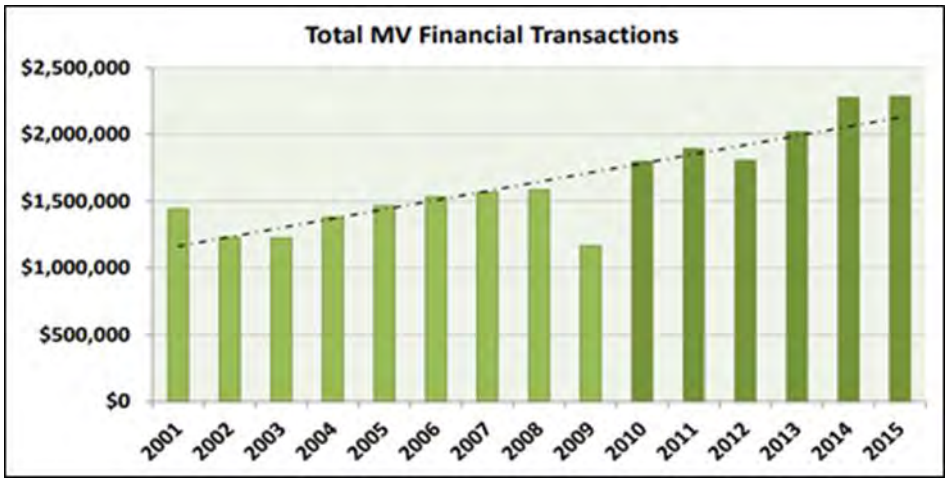

Figure 1.2: North America Total Machine Vision Financial Transaction from 2001 to 2015 (in USD) [2]

In conclusion, the substitution of vision sensor as human eyes to provide visual system for the machine is popular nowadays. It is applied for inspection, measurement, recognition and also determines location. So that, it is important to provide a study related to the collaboration of machine vision and robotic gripper. It recognizes the targeted objects first and then does the gripping mechanism. This kind of study may help to initialize the steps before grasping, prevent the insecurities of the object and give massive other benefit in future.

1.3 Problem Statement

This section elaborates on common problems faced by the user of robotic hand or gripper. There is numerous problems state in the use of gripper. Then, there are various ways to improve the use of gripper in the industry. First of all, the gripper has no common design suitable for all uses. It has a wide range of designs applied in the industry. Each of the design has its own use. It is for specific tasks and do not has diversity in its application. Most of the wide-ranging design in the industry has a simple and modifiable design.

However, there are few studies that involve the use of gripper other than the purpose of grasping. In instance, the gripper can be used to define the position and the shape of grasped object. The collaboration along with other fields such as machine learning, machine vision, sensors and etc. can be made to create a multifunctional gripper. As we know that the complex design and functional gripper is the end-effector that attached to robot manipulator or robotic arm. Most of previous researches were made for the purpose of studied for identifying the positions of the object involving robotic arm. There is relationship has been discovered to determine the effectiveness of usage of robot manipulator which is the amount of degree-of-freedom attached to the robot. It costs a lot, difficult to get and using complex processes.

Finally, the basic gripper is an open loop system and simple. Unless, it involves the measurement acts as feedback such a haptic feedback then it will be a closed loop system. Gripper that applied haptic feedback touch the object first and then it measure variables needed such as force, shape and position parameter. In this case, the haptic feedback is substitute by the vision system. Undeniably, layout of the processes in the field of computer vision is difficult to match with the gripping mechanism. Moreover, this kind of system applied is inversely to the haptic feedback. It measures the contact points needed before it touches the targeted object.

1.4 Objective

The main purposes of this project are to:

1. Design and develop a planar gripper using two robotic fingers arrangement.

2. Develop machine vision system for identifying the contact points of the object that will be grasped by the robotic fingers.

3. Analyze angular motion of gripper to grip object and determine accuracy of object grip using repeatability test.

1.5 Scope

The limitations of this project are:

1. Shape recognition by using two moveable fingers of robotic gripper applied with a webcam as imaging device.

2. It applied two degree-of-freedom of robotic fingers and location of a webcam is on top of the workspace.

3. 420 mm x 594 mm (A3 size) of grid paper is the area cover of the workspace.

4. Light intensity never set because it used the default light in lab environment and the position of imaging device is fixed.

5. Consider only two shapes of the objects which are circular and square.

6. Approximately 50.27cm^2, 28.27cm^2 and 12.57cm^2 size of circular and 64 cm^2 size of square for target objects.

7. Implementation of OpenCV-Python as an image processing platform and Arduino as a controller for gripping mechanism.

8. Two moveable fingers of gripper will be in initial position before the program start.

9. Two moveable fingers of gripper move in determined angular after the program recognized the shape of the object.

CHAPTER 2

LITERATURE REVIEW

2.1 Overview

Robotic end-effector and machine vision are the technology that is empowered to this day. Both are widely used in manufacturing industry. The collaboration between these two technologies involved in inventing a gripper that is able to identify the shape of an object. The project approach is to substitute the human gripping and visioning functions. Further information is divided into two parts, the techniques used to identify the visual features and exactly how to grip the targeted object.

2.2 Mechanical Gripper

Generally, implementation of robotic end-effector is for part handling. There are numerous of end-effector in designs such as hook, vacuum, mechanical gripper, clamp, scoop, magnetic and etc. Most popular end-effector used in manufacturing industry is mechanical gripper. In addition, there are several things that need to be emphasized on the use of it which are design and external factors. The designed involves the amount of finger usage, degree of freedom, mechanism, force applied and drive method; electric, pneumatic or hydraulic. Moreover, external factors such as slippage, friction, compliance and dynamic also affect the use of it.

2.2.1 Design

There are a few things that need to be considered in the implementation of robotic hand. First of all, most priority refers to the drive method applied for it. In engineering there are three drive methods which are electric, pneumatic and hydraulic. All of previous studies [1]–[15] used electrical drive except [16] which

uses pneumatic drive. In instance, research [10] used dc motor and research [11], [17] used servomotors as their drive.

Secondly, the thing that needs to be considered for the selection of gripper is the amount of fingers use. Frankly, at least two fingers used for gripping purpose. Most previous researches implemented two fingers in their cases [3], [7]–[9], [11], [17]. There are many designs for two fingers gripper such as four-bar link gripper [11], jaw gripper [3], [7], parallel gripper [8], and clamp gripper [7], [17].

Next, researchers for articles [5], [12], [14] have three fingers implemented for their gripper. It is also known as Barrett hand. In articles [12], [14], the researchers stated that they used two movable fingers oppose to the fixed thumb and all fingers are attached to the palm. The grasping system is even more complex if it applies more than two fingers. It illustrates in Figure 2.1, the Barrett hand is used in the previous research [14]. Then, the studies used four fingers called dexterous hand for the gripper design [6], [16]. It mostly designs same like human hand but with four fingers. Meanwhile, a few studies are using an anthropomorphic design which includes five fingers and a palm [10], [13]. It is a complex design that is exactly same like human hand.

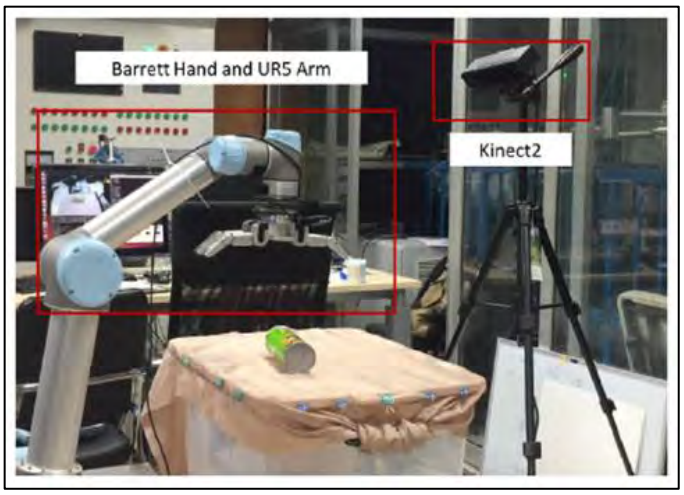

Figure 2.1: The Experimental Setup Involved Barrett Hand [14]

2.2.2 Degree of Freedom

Another important thing that needs to be considered for gripper selection is the degree of freedom (DOF) implemented by each finger used. Most of the jaw, parallel or clamp gripper designs are 1 DOF [3], [7], [11], [14], [17]. It used only a basic mechanism such as close and open to perform grasped. It only controls the rotation of the motor by rotate it clockwise and anticlockwise rotation. Meanwhile, there are grippers that implemented the robotic fingers with more than 1 DOF. Most of the previous studies used 2 DOF for their robotic fingers [5], [8]–[10], [16]. Other than that, the dexterous hand and anthropomorphic are use 3 or 4 DOF [6], [12], [13]. In fact, the hypothesis stated the more usage of degree of freedom for the robots then the more accurate and precise the task performed. Thus, the mechanism and mathematical derivation applied will be more complicated.

The degree of freedom applied in each link needs to be considered about the mechanism used. Basically, the kinematic equation derived for the robotic fingers that fulfilled by more than 1 DOF. The kinematic is the study of motion that involves position, velocity or acceleration. The previous studies applied the forward kinematic in their research for mapping from Joint space to Cartesian space [3], [6], [9], [12]. In easiest way for understanding, it is the derivation of finding the position of the end of link by given the orientation of the joint of links. Whereas, the previous studies were involved the inverse kinematic in their research are mapping the Cartesian space to Joint space [13], [17]. It stated that the progression of finding the desire orientations by using the reference position. Different with the article [10], it is studied about the kinematic redundancy. It is the study about the needed of additional degree of freedom by adding the extra joints and links to the mechanism.

2.3 Machine Vision

Machine vision is also called as robotic vision or computer vision. It has countless techniques and implementations made for inspection, identification and navigation purposes. Most of the applications in industrial are inspection while in research and learning is more focused on identification. As shown in Figure 2.2, the techniques involved in machine vision systems can be classified in three, namely image acquisition, image processing and image analysis [18]. Each class has its specific important role to be explained in the next subdivision.

Figure 2.2: Machine Vision Block Diagram [18]

2.3.1 Image Acquisition

The first stage in machine vision is called image acquisition or image formation. This process known as low level process in machine vision system that determined input and output of this process are in image form. Image acquisition is the sequential process of image sensing, image digitizing and image preprocessing. Figure 2.2 shows the basic elements in the low level process [19]. The visual information that can be determined by image is color, geometry (shape, position, dimension, density and texture) and movement (dynamic process). Theoretically, determinant of contrast and sharpness are the keys in image sensing. So that, illumination technique used and imaging device selection play an important role. Most illumination techniques used to provide good contrast in previous researches are front light and clear background to differentiate and focus on targeted object. Front light is an external light source provided by other device such as LED spot light, LED ring light or fluorescence lamp to help in improves the enlightenment.