REAL-TIME HUMAN MACHINE INTERACTION FOR ROBOTIC ARM

MOHAMAD NIDHZAM FARIS BIN MOHAMED ISHACK

This Report Is Submitted In Partial Fulfillment Of Requirements For The

Bachelor Degree Of Electronic Engineering (Computer Engineering)

Fakulti Kejuruteraan Elektronik dan Kejuruteraan Komputer

Universiti Teknikal Malaysia Melaka

June 2017

DECLARATION

"I hereby declare that the work in this project is my own except for summaries and quotations which have been duly acknowledge."

Signature : ....

Author : MOHAMAD NIDHZAM FARIS BIN MOHAMED ISHACK

Date : 2/6/2017

SUPERVISOR DECLARATION

"I acknowledge that I have read this report and in my opinion this report is sufficient in term of scope and quality for the award of Bachelor of Electronic Engineering (Computer Engineering) with Honours."

Signature : ....

Supervisor's Name : DR. KHAIRUDDIN BIN OSMAN

Date : 2/6/2017

DEDICATION

Specially dedicated to,

My beloved parents Mohamed Ishack Bin Sulthan and Normala Binti Abdullah,

Gani mama, Sarj mama, Noraini cinma,

Cousins and Friends,

Supervisor Dr Khairuddin Bin Osman and En Nazreen Bin Abdullasim

&

In loving memory of my grandfather Haji Sulthan, Abdullah and grandmother Aminah

ACKNOWLEDGEMENT

Praise to Allah S.W.T who made all possible

First and foremost, I would like to express my gratitude to both of my supervisors, Dr. Khairuddin Bin Osman and En Nazreen Bin Abdullasim for their abundant advice, valuable guidance and wise suggestions. They have helped me tremendously by keeping me on the right track and keep on motivating me to the highest level that I could possibly achieve. I would like express my deepest appreciation to my family members for their support and encouragement. Lastly, I would like to thank all my colleagues and friends who has helped me throughout my project. Thank You.

ABSTRACT

In today's modern world, robotic technology has been used widely as a mean to ease both repeated and complicated task. The technology is in demand by industries as it can execute any task with precision. However, to create a robotic machine requires extensive knowledge in programming to make it specific for everyone to operate it. The project is focusing on controlling a robotic arm by using human's hand gesture. Therefore, by using Kinect technology, the robotic arm will be easy to be handled by everyone as it requires no programming to operate. Real-Time Human-Machine Interaction For Robotic Arm is designed by applying the Kinect v1 technology which implements Natural User Interface (NUI). The Kinect sensor is connected to a computer, as a platform to monitor the hand gesture captured by the sensor. The robotic arm will imitate the user's arm movements by using the depth algorithm created in Processing 3 software. In this project, Processing 3 is used as the main programming tools as it compatible with Kinect sensor and at the same time can be linked to Arduino microcontroller. Experimental work were conducted to validate the communication between software and hardware.

ABSTRAK

Dalam dunia moden hari ini, teknologi robotik telah digunakan secara meluas sebagai cara untuk mengurangkan kedua-dua tugas yang berulang-ulang dan rumit. Teknologi ini adalah permintaan dari industri kerana ia boleh melaksanakan apa-apa tugas dengan tepat. Walau bagaimanapun, untuk mencipta mesin robot memerlukan pengetahuan yang luas dalam pengaturcaraan untuk membuat ia khusus untuk semua orang untuk mengendalikannya. Projek ini memberi tumpuan kepada mengawal lengan robot dengan menggunakan isyarat tangan manusia. Oleh itu, dengan menggunakan teknologi Kinect, lengan robot akan mudah untuk dikendalikan oleh semua orang kerana ia tidak memerlukan pengaturcaraan untuk beroperasi. Masa Nyata Manusia-Mesin Robotic Arm direka dengan menggunakan teknologi v1 Kinect yang melaksanakan Antara Muka Pengguna Natural (NUI). Sensor Kinect dihubungkan dengan komputer, yang merupakan platform untuk memantau isyarat tangan yang ditangkap oleh sensor. Selain itu, lengan robot akan meniru pergerakan lengan pengguna. Dalam projek ini, Pemprosesan 3 digunakan sebagai alat pengaturcaraan utama kerana ia serasi dengan sensor Kinect dan boleh dikaitkan dengan Arduino mikropengawal pada masa yang sama. Eksperimen di antara perisian dan perkakasan telah dijalankan untuk mengesahkan pergerakan lengan robot

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

PWM	-	Pulse Width Modulation
DOF	-	Degree Of Freedom
AC	-	Alternating Current
ALU	-	Arithmetic Logic Unit
UART	-	Universal Asynchronous Receiver/Transmitter
I/O	-	Input / Output
IDE	-	Integrated Development Environment
RX	-	Receiver Signal
TX	-	Transmit Signal
COM	-	Component Object Model
USB	-	Universal Serial Bus
TTL	-	Transistor-transistor logic
GND	-	Ground
VIN	-	Voltage input
AT	-	Command Mode

CHAPTER I

INTRODUCTION

1.1 Project Overview

Robots are a machine that capable of carrying out a complex series of action automatically, especially the one programmable by a computer. Robots are designed to perform working tasks to replace humans especially to perform the repetitive task[1]. A robotic arm is a robot built by using electronic devices such as, servo motor, stepper motor and gripper to look alike human arm. The links manipulator are connected by joints that can perform rotational motion (articulated robot) or translational (linear) displacement.The ability of a robotic system is to follow the lead of human. However there are many compelling application exist to provide elements that human cannot directly done without the help of robots.[2]

Robotic arm is an autonomous robot which allows a direct mapping from a human machine. This system was designed with combination of robotic arm and Kinect sensor. Besides, the system enables users to control and interact with their computer without the need of a controller, through a natural user interface using gestures. The human body is detected by Kinect® sensor by using depth sensor of the user, then sent the data to other port that contain controllerover a serial port correction. Arduino® programming is used as the processing device between human arm and robotic arm. The invented robotic arm is based on the study of five Degree of Freedom behaviour.

With the growth of interest towards humanoid robots, several robotic arm have been developed as the goals of each project were different. Generally, research on a real time robotic arm is very useful for maintenance work in hazardous environment. Surely human life is priceless compared to high intelligence machine. However, the control system of the humanoid robot becomes more complicated if more degree of freedom (D.O.F) are added for robotic arm design.

1.2 Problem Statement

The problem statement of this study can be expressed as follows:
The automated robotic arm with a conventional controller is difficult to control as it requires detailed data from user to control. The system is non-instinctive, complex, and obliges preparing to control the arm complicatedly. The degree of flexibility is hard to control at the same time, the arm cannot be utilized to perform smooth motion as human arm due to its complexity and delay.

In modern wold, robotic technology has been widely implemented to reduce direct human involvement.This technology is in demand by industries as the system can execute any task with precision.However, operating a robotic arm requires extensive knowledge in programming to make it specific for certain individual to operate it. Therefore, by using Kinect® technology, the robotic arm will be easy to be handled by everyone as it requires less programming skills to operate by motion.

1.3 Research Objectives

The aim of this project is:

i. To develop a user friendly robotic arm system, as it can easily be operated by users that have least knowledge in programming.
ii. To design a robotic system that can perform any tasks in any kind of environment.
iii. To analyse the performance for servo control signal.

1.4 Scope of Work

The followings are the scope of the project:

i. Design the prototype of robotic arm with 5 Degree of Freedom (DOF).
ii. Construct processing coding based on understanding of Kinect on hand movement of user.
iii. Analyse the performance delay for servo motor signal by using oscilloscope.

1.5 Contribution of the Work

There are significant outstanding issues related to the identification and control of real time system that need to be investigated. From the research as discussed previously for the problem statements and the importance, several contributions can be made in the vicinity of identification, control strategy and application. These are also reflected in several journal and conference papers arising from this research study. The main research contributions of this study are as follows:

i. A design of prototype for robotic arm.

ii. A robotic arm system with the real time physical human controller by applying the Kinect sensor.
iii. Analysis of servo control signal to find the reaction time between each part of hand.

1.6 Structure of the Thesis

Chapter 2 present the literature review on robotic arm system, technology, research and development. The discussion is based on human interface for the robotic arm and the real time reaction. The review is discussed in detail on chapter 3.

The methodology to build robotic arm for real time by applyingKinect application is presented in Chapter3. This chapter deal with the modelling and control strategies of robotic arm. Firstly, the hardware that used in this project is identified to build this project. Then, the type of programming neededto construct the coding as the software for this project is studied.Thirdly, the power supply for every D.O.F is identified to prevent power shortage.

Chapter 4 presents the result and discussion of this project on how the robotic arm functions by using Processing 3 programming as the coding platform. This chapter will also discuss the results obtained in detailed manner.

Conclusion and future research presented in Chapter 5 discuss the advantages and the weakness of this project that can be developed in future to make this robotic arm more useful.

CHAPTER II

LITERATURE REVIEW

2.1 Introduction

This chapter will discuss and analyse different kind of robotic arms, Kinect applied projects in the field of robotic industry, specifically focused on humanoid real time robotic arm which requires human interface as the input. In addition, the theory of real time robotic arm will be discussed in this chapter. The analysis is used to determine an exact design and understanding the requirement for the development of this project.

2.2 Robotic Arm System

In the most recent decade, robots go with individuals in ordinary life and assume control over their everyday routine.Robot has become a very beneficial technology in humans Life[3]. Robot has some characteristics which are very useful in assisting human or even replacing them to do a job for both physical activity or decision making[3]. Robots were additionally designed as straight forward activity performer as well as combination of other electronic devices to make it perfect. Mechanical controller is equipped in every degreeof freedom (DOF) and at diverse headings (base, shoulder, elbow, yaw, pitch and bearings)[4].Robot is a digital technology which has an exact accuracy and precision in work done[3]. Robot has been developed for a dangerous task which risks a human life and as a replacement for human, or any task in an inaccessible area for human, such as defusing bomb and underwater or space exploration[3].

Analogue sensor was used in past research to control the robotic arm [4]. A glove with flex sensors contains potentiometer and accelerometer are attached to the haptic glove with ADC position feedback[4]. Haptic technology is applied by touching sensation and control for interaction with virtual or physical applications[4]. To create virtual environment, haptic system is used in robotic field[4].Robots can be programmed with a very advanced artificial intelligent to work automatically for decision making aspects[3]. By having an artificial intelligent implementation, the new robots can learn and adapt in a new environment[3]. Corner feature and Lucas-Kanade Algorithm is used for hand tracking to track the hand gesture to interact with robot[3].

Vision system is used to watch a human perform assembly tasks. The analysed human action sequenced and generated a symbolic-level task plan to program a robot to execute the assembly task[5]. The discrepancies occurs between a human and a humanoid robot can be solved by focused on the trajectory of the end-effector of a human[5].However, the end-effector trajectory imitation results in the ill-posed problem, which means that the pose of the robot may differ from human[5]. To overcome the ill-posed problem, the joint angles of a human must be observed properly and implement to the robot with the specific angle.Most humanoid robots not able to perform every human arm posture due to lacked degree of freedom in the robotic arm shoulder. Thus, the similar posture of a human arm and a robot arm should be designed[5].

Cartesian impedance is used to command the dual robotic arms tracking. The main point here is to select a set of control points on the robot (DOF) and these control points are virtually connected to corresponding command points via virtual springs and damping elements in XYZ directions respectively[6].Figure2.1 show the kinematic model of the human robotic arm and Degree Of Freedom (DOF). When the command points move in space, the robotic arm will be guided by the forces generated from these springs[6]. In this way, robot can follow the human motion without the need of complexity inverse kinematics[6]. To ensure the robotic arm move stable and safe, the increasing rate and imposing upper bound of the output force are required[6].

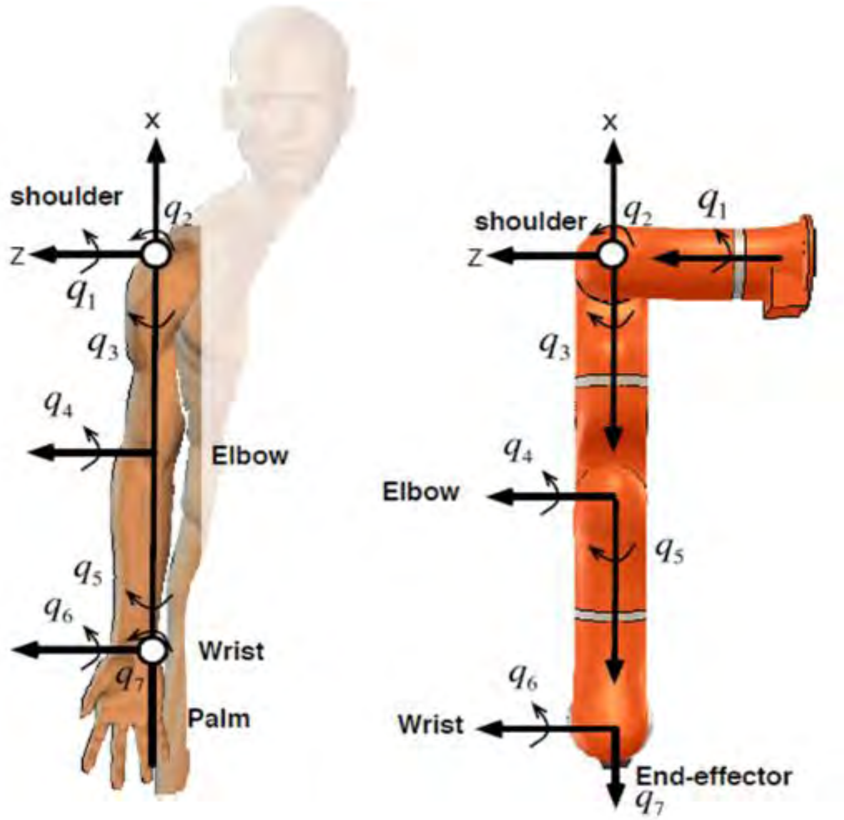

Figure 2.1: Kinematic model of the Human and Robotic arm and (DOF)

2.3 Kinect Sensor

The invention of Kinect sensor by Microsoft is a result for applications based on 3D reconstruction,motion tracking,skeleton tracking and object tracking[7]. Figure 2.2 shows Kinect version 1 sensor component where the sensor has a wide implementation in robotics, gaming and 3D reconstruction in biomedical applications.One of the important parameter in Kinect sensor isdepth data, as it is used in many applications[7]. The colour and depth video streams can be accessed at a time when depth video stream of Kinect is enable[7]. The depth frames can be captured from the depth video stream. In the captured frame of depth video, each pixel of an unsigned 16-bit value of depth data is shown instead of showing each pixel value which represents the distance of each pixel from the camera plane[7]. Depth of Focus is a “comfort zone” that reflects the range of disparities to enable a comfortable view[8]. The Depth of Focus in the Kinect sensor makes the depth data more accurate due to its wide range of focus.

Two cameras in Kinect sensor are Infrared camera and RGB camera and one Infrared projector/Emitter[7]. Infrared Projector and Infrared camera are utilizes as 3D depth sensor. Kinect Sensor also has a tilt motorto rotate the camera in different angle within its line of sight [7]. Kinect

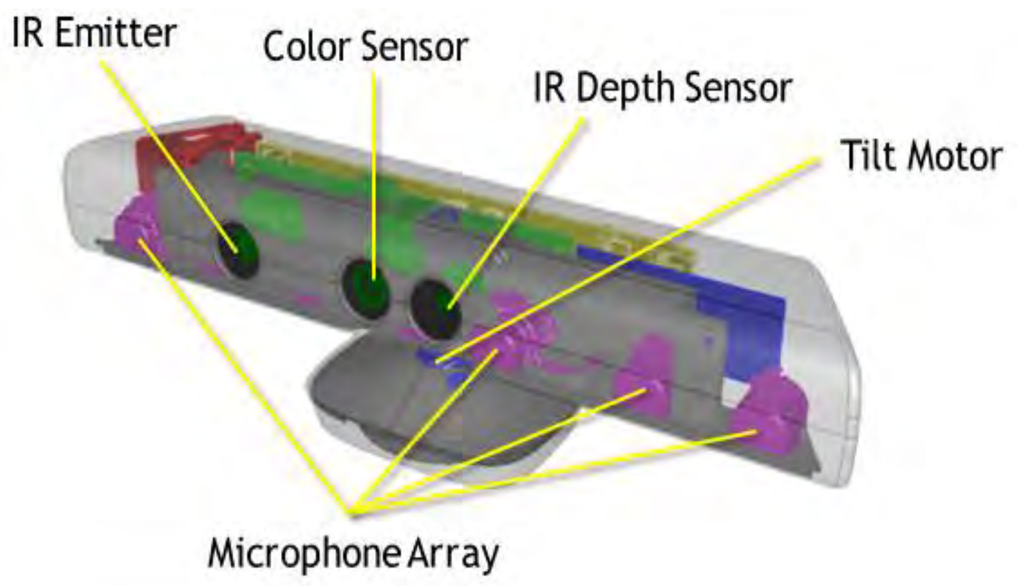

Figure 2:2: Kinect V1 Sensor Component [7]

The technologies that allows the capturing of depth maps in RGB-D sequences, is structured light[9]. The negative part of this technology is the noise introduced during the acquisition process and the lost values for most pixels in the depth map[9].The Kinect v1 measures depth by projecting a known light pattern onto a scene and inferring depth from the deformation of that pattern[9].Kinect V 2.0 uses time-of-flight (ToF) aspect which arrange the distance to an object by measuring the travelling time of a light pulse from a source into the 3D scene and back[9].The 3D information from the depth data is manipulated to do more challenging tasks such as body part recognition or motion recognition, people segmentation and tracking and motion estimation[10].However, the depth data have a serious impact towards the performance of Kinect sensor due to its missing and untrusted depth values[11]. Table 2.1 shows the difference in term of RGB-D sensors between Kinect v1 and Kinect v2.

ToF and structured light are distracted by the sun rays and the depth cannot be measured on reflective surfaces such as windows or computer monitors[9]. The objects located in front of the RGB-D camera is referred as shadows on the background, regions where the depth information is missing[9].

Table 2.1: Characteristics of RGB-D sensors of Kinect v1 and Kinect v2[10]

Feature	Kinect v1	Kinect v2
Depth sensing technology	Structured light	Time of flight
RGB image resolution	640x480 @ 15/30 fps 1280x960 @ 12 fps	1920x1080 @ 30 fps (15 fps with low light)
IR image resolution	640x480 @ 30 fps	512x424 @ 30 fps
Depth sensing resolution	640x480 @ 30 fps 320x240 @ 30 fps 80x60 @ 30 fps	512x424 @ 30 fps
Depth sensing range	0.4-3 m (near mode)	0.5-4.5 m
	0.8-4 m (normal mode)	
Field of View	57° horizontal, 43° vertical	70° horizontal, 60° vertical
Skeleton tracking	Skeleton with 20 joints Up to 2 subjects	Skeleton with 25 joints Up to 6 subjects
Audio	multi-array microphone	multi-array microphone

2.4 Microcontroller

Controller is an electronic device designed to control a technical process automatically by given instruction according to the algorithm created[12]. Programmable controllers contain a processor, memory (holds the operating system kernel,utilities, object control software application and others). However, the hardware module is the one implement the data exchange information and control the working network of the system[12]. Microcontrollers are widely used in the modern automation systems. Microcontrollers are programmable controller produces as a single VLSI (integrates on a single chip processor, memory, input-output devices, and others)[12]. There are various type of microcontrollers such as Raspberry Pi, Arduino, Wemos and PIC(programmable integrated circuit).

2.4.1 Raspberry Pi

Operating system of Linux is used in Raspberry Pi (Raspbian OS), and GNU Octave, Python and Arduino IDE are available for user to use and develop[13].Image processing feature is basically derived from signal processing, where the input is an image which is analysed to obtain some critical values, parameters or the set of characteristics related to that particular images[13]. Raspberry Pi is a small device, an open source and flexible platform for research and experimental development. Due to its open source environment, manipulation can be made easily when required. The Linux based board can be installed with various different free software for vivid purposes[13].

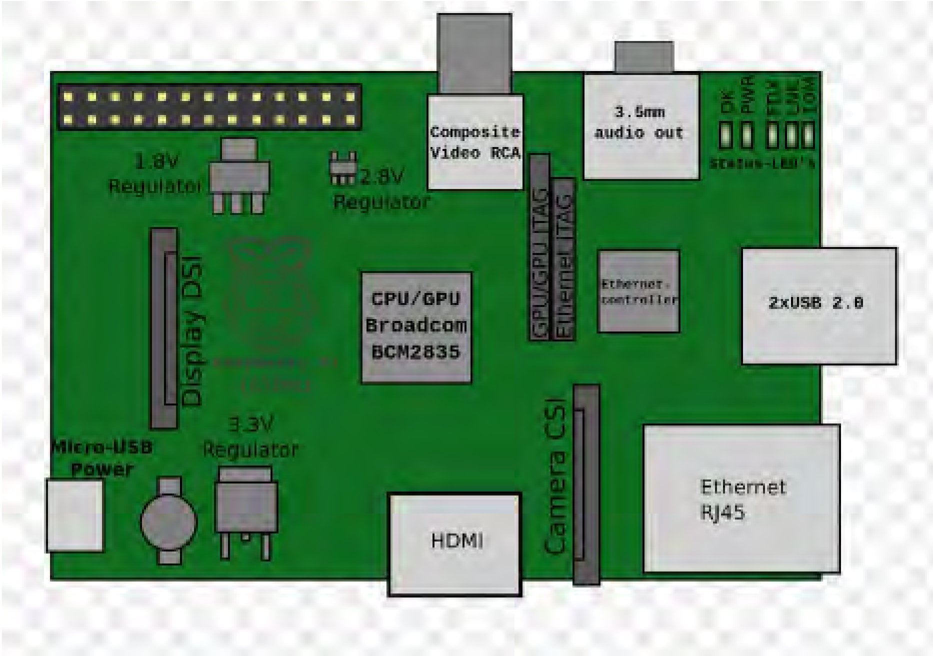

Figure 2.3: Overview of Raspberry pi[13]

Figure 2.3 represent the overview of Raspberry pi. The board has Broadcom BCM2835 on chip contain an ARM1176JZF-S. This chip is 32 bit, 700 MHz System on a Chip built on the ARM11 architecture[13]. It has Video Core IV GPU, and was originally shipped with 256 megabytes of RAM. The SD card is used for booting andlong term storage capability[13]. The Raspberry Pi operatesby using Raspbian OS and programmed by using GNU Octave version 3.6.4 and Python 2.7.6[13].

The microcontroller Atmega328 in the Arduino board is a high-performance Atmel 8-bit AVR RISC-based microcontroller. It combines 32KB ISP flash memory with read-while-write capabilities, 1KB EEPROM, 2KB SRAM, 23 general purpose I/O lines, 32 general purpose working registers, three flexible timer/counters with compare modes, internal and external interrupts, serial programmable USART, a byte-oriented 2-wire serial interface, SPI serial port, 6-channel 10-bit A/D converter, programmable watchdog timer with internal oscillator, and five software selectable power saving modes. The device operates between 1.8-5.5 volts[13].