"I hereby declare that I have read through this report entitled "**Design and Construction of a Simple Bipedal Robot with Obstacle Avoidance System**" and found that it has comply the partial fulfilment for awarding the degree of Bachelor of Mechatronics Engineering.

Signature : .....

Supervisor's Name : Dr. Fariz bin Ali@Ibrahim

Date : .....

DESIGN AND CONSTRUCTION OF A SIMPLE BIPEDAL ROBOT WITH OBSTACLE AVOIDANCE SYSTEM

WONG ZHE MING

A report submitted in partial fulfillment of the requirements for the degree of Bachelor of Mechatronics Engineering

Faculty of Electrical Engineering

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

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I declare that this report entitled "**Design and Construction of a Simple Bipedal Robot with Obstacle Avoidance System**" is the result of my own research except as cited in the references. The report has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature : .....

Name : .....

Date : .....

To my beloved mother and father

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ABSTRACT

The main objective of this project is to design and construct a simple bipedal robot with obstacle avoidance system by using Arduino microcontroller board and Dynamixel AX-12A servo as actuators. The developed bipedal robot consists of 8 Degree of Freedom which capable of walking in three dimensional motions (walking forward, turning left and turning right). The design aspects cover the use of inverse kinematic method to determine the joint parameters of 8 servos for walking algorithm, the simple design of the turning algorithm without using the yaw joint and the code generation of the joint parameters of 8 servos on every time interval. List of experiments is done to design and construct the bipedal robot. The experiments done included developing a half-duplex UART system to interface Arduino board and Dynamixel servo, interfacing obstacle avoidance system with Arduino microcontroller, studying the relationship of roll angle and the stability of the bipedal robot and implement the walking and turning algorithm into the bipedal robot. The results for all the experiments is tabulated and analyze to study the performance of the developed system and the bipedal robot in practical. The trajectory graph and graph of angle variation for every servo of the bipedal robot is analyzed. The study of the performance of the bipedal robot with its obstacle avoidance system also shown in this thesis. The results shown that the off-line walking algorithm for bipedal robot is not sufficient enough to create a smooth walking cycle, the walking pattern is somehow unstable due to limitation of the microcontroller and the servo motor.

ABSTRAK

Objektif utama projek ini adalah untuk mereka bentuk dan membina sebuah robot berkaki dua dengan sistem pengelakkan halangan dengan menggunakan papan mikropengawal Arduino dan Dynamixel AX-12A servo. Robot berkaki dua dibangunkan terdiri daripada 8 darjah kebebasan yang mampu bergerak dalam tiga pegerakan (berjalan ke hadapan, belok ke kiri dan belok ke kanan). Aspek-aspek reka bentuk merangkumi penggunaan kaedah kinematik sonsang untuk menentukan parameter sendi 8 servos untuk algoritma berjalan, reka bentuk yang alternatif untuk algoritma belok tanpa menggunakan "yaw joint" dan generasi kod untuk joint parameter untuk 8 servos pada setiap selang masa. Senarai eksperimen terlah dilakukan untuk mereka bentuk dan membina robot berkaki dua. Eksperimen yang dilakukan termasuk membangunkan sistem UART separuh dupleks untuk berkomunikasi antara papan Arduino dan Dynamixel servo, pengantaramukaan sistem mengelakkan halangan dengan mikropengawal Arduino, mengkaji hubungan sudut "roll" dan kestabilan robot berkaki dua dan melaksanakan algoritma jalan dan algoritma belok pada robot yang berkaki dua. Keputusan bagi semua eksperimen telah dijadualkan dan menganalisis untuk mengkaji prestasi sistem eletronik yang dibangunkan dan robot berkaki dua dalam praktikal. Trajektori graf dan graf variasi sudut untuk setiap servo bagi robot berkaki dua terlah dianalisis. Kajian mengenai prestasi robot berkaki dua dengan sistem mengelakkan halangan yang juga ditunjukkan dalam tesis ini. Keputusan keseluruhan menunjukkan bahawa "off-line" algoritma berjalan untuk robot berkaki dua tidak cukup untuk mewujudkan satu kitaran berjalan yang lancar, corak berjalan kaki tidak stabil oleh sebab had mikropengawal dan motor servo.

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CHAPTER 1

INTRODUCTION

1.1 Motivation

Since the first humanoid robot was made in the seventies, the technology has developed extremely. The number of scientist and researchers study on the humanoid robot are increasing every year. Scientist and engineers around the world are attempting to design and develop different kinds of humanoid robot to meet certain applications and research purpose. Humanoid robots are now being involved in many aspects such as educational, industry and military.

At the beginning of time, humanoid robot it is mostly designed to study and achieve human's locomotion which is the ability to move from one place to another. In recent years, humanoid robot has substitute human being to do some critical task in dangerous environment. In recent years, the number of active nuclear reactor plant operate around the world are increases. As of June 2015, there are 438 power plant installed in 31 countries and 67 nuclear power plant are under construction[1]. Nuclear power plant accidents and incidents are serious disaster may cause millions of dead. In March 2011, a nuclear disaster happen in Fukushima, Japan cause by the tsunami and earthquake. The loss of backup power cause the failure of coolant system and releases of radioactive materials. It is reported that one man died suddenly during the clean-up. The reason people sending human into the disaster workspace because human is suitable and familiar with those environments and able

to handling tools and equipment created for the human. Mobile robot is limited by its structure and not able to work in the environment created for human.

It is necessary to design and develop a human-body structure shape robot which able to handling human equipment to help in those disaster. Humanoid robots developed must capable of working in the environments adapted with humans, side by side with them to speed up of the time of operation or instead of them when the environment is no friendlier for human but robot. In addition, an organization "Centre for Robot-Assisted Search and Rescue" founded on 2001 serves as crisis response and research organization which focus on robot technology have participated in numerous incidents. It has the largest number of deployments of rescue robots in the world[2].

In short, the development of robot to substitute to face the hazardous environment is necessary. A flexible robot which are familiar with the human environment and able to handle human tools and equipment is very crucial in the world.

1.2 Problem Statement

Humanoid robot is designed to substitute human to carry out some critical tasks and reduce labor workforce. The designed robot must capable doing things that human can do. Locomotion (moving to one place to one place) is one of the things a normal human can do.

The greater challenge is design a walking algorithm for the bipedal robot. In terms of hardware used, microcontroller as the brain of the bipedal robot must be able to understand the walking algorithm and give signal for the robot to move. The other components such as the actuator connected all joints must very precise in order to walking just like human. All the components used must able to interface with the main controller. Extra circuitry may add to the system to connect and control all the components used.

One way to design the walking motion of the bipedal robot is using the forward and inverse kinematic method. The problem using the forward kinematic is that the bipedal robot consists of more than 6 servos, this may involve a calculation of a large matrix, the servo used is very precise with smaller resolution, a smaller angle change may have significant change on the matrix. Moreover, the bipedal robot is a moving body, it does not have a fixed base in a fixed position, hence, to move all the part of bipedal robot forward (walking) may involve a lot of calculation.

Inverse kinematic method to design the walking pattern is suitable for this project. The problem faced is how to deal with the angle change on every single moment. Joint parameters along the stride length of bipedal robot is needed to calculated to design a smooth walking pattern. Other method like code generation may use to generated all the joint parameters by feeding inputs and several constant parameter of the bipedal robot.

As a conclusion, this project is started with interfacing all the electronic components used in the project including the microcontroller, the actuator and the obstacle avoidance system. Next, the bipedal walking algorithm is design and developed, several experiment is designed to test the performance of the whole system.

1.3 Objectives

There are few objectives that need to achieve by end of this project. The objectives of this project are stated as below.

1. To design and construct a simple bipedal robot with obstacle avoidance system.
2. To design and analyze the walking algorithm of the bipedal robot.

1.4 Scopes

The scope of the project is stated as below.

1. The bipedal robot is designed and constructed by using Arduino Mega (based on Atmega328P) as a microcontroller and Dynamixel AX12-A servo motor as actuator.
2. The bipedal robot is designed to walk in 3 dimensional motions which are walking forward, turning left and turning right.
3. The design of bipedal robot is simple and consists of 8 degree of freedom which capable of dexterous three dimensional motion.
4. The project covers the design and analysis of the walking algorithm of the bipedal robot which is included the normal walking cycle in a flat surface and in environment with obstacle.
5. The bipedal robot is embedded with SR04 Ultrasonic Module for obstacle avoidance system. The system is implanted to give a feedback to microcontroller and thus choosing the suitable walking algorithm.
6. The obstacle avoidance system of the bipedal robot is limited by the SR04 Ultrasonic sensor to only detect obstacle within range 2cm - 400 cm, with 15 degree of measuring angle.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction to Bipedal Robot

The word "robot" was first introduced in 1921 by a Czech writer, according to Robotics Institute of America (RIA) [3], robot can be defined as:

" A re-programmable multi-functional manipulator designed to move materials, parts, tools, or specialized devices through variable programmed motions for the performance of a variety of task"

Robot is a mechatronic machine which is controlled by a controller equipped with electrical circuitry and mechanical parts to do any task programmed by human. There are many robots such as mobile robot, industrial robot and service robot. Certain robot such as industrial robot and service robot are programmed to work in a limited work space only, while mobile robot is one kind of robot which able to move around to any environment with powered actuator.

Humanoid robot is a robot which build based on the human body structure, humanoid robot have head, two arms and two legs for moving around. Bipedal robot is always defined as a robot with only two legs which emulates human walking motion. At the beginning of bipedal robot history, it is mostly designed to study and achieve human's locomotion which is the ability to move from one place to another. In recent years, bipedal robot is increasingly