ROBOTIC HUMANOID DEVELOPMENT

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This report is submitted in partial fulfillment of requirements for the award of Bachelor of Electronic Engineering (Computer Engineering) with honours.

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ABSTRACT

Even though in recent years research and development of humanoid robots has increased, the major topics of research generally focus on how to make a robot perform specific human motions such as walking. However, walking is only one of the complicated motions humans can perform. This project describes humanoid robot implementation using hardware and software for mechanical design, behavior control, and communication. This project utilized LEGO ® Mindstorm as its main components and programmed by NQC program. The humanoid has 4 DoFs in total that allows it to imitate human-like walking motions. An Electric Technic Mini-Motor was used as the sub-controller, whereas touch sensors were used in the sensory system. The main controller, Robots-RCX Processor, attached on the top of humanoid communicates with Mindstorms IR tower. The humanoid robot will initiate human walking movement like in moving forward and backward. This robot design incorporate weight-balancing technique during movement and robot-stabilizing design to ensure the robot would not fall down when walking. The advantages of this project are low power consumption and less complex structure.

ABSTRAK

Laporan ini memberikan gambaran tentang Pembangunan Robot Manusia untuk Projek Tahun Akhir 1, Ijazah Sarjana Muda Kejuruteraan Elektronik dan Kejuruteraan Komputer. Ini termasuk gambaran tentang perkakasan dan perisisan yang digunakan untuk rekacipta mekanikal, kawalan gerakan dan komunikasi robot. Projek ini akan menggunakan LEGO ® Mindstorm sebagai komponen utama dan akan dikawal menggunakan bahasa perisian NQC. Robot manusia isi akan mempunyai 4 sambungan keseluruhannya yang membenarkan robot untuk meniru pergerakan berjalan seperti manusia. Motor elektrik Technic digunakan sebagai pengawal dan pengesan sesentuh digunakan dalam sistem pengesan. Kawalan utama, RCX diletakkan di bahagian atas robot akan berkomunikasi dengan IR Mindstorm. Robot manusia ini akan meniru pergerakan berjalan manusia seperti bergerak ke hadapan dan belakang. Rekabentuk robot akan mengaplikasikan teknik menyeimbang berat semasa pergerakan dan rekabentuk yang stabil untuk memastikan robot tidak jatuh semasa berjalan. Kelebihan projek ini ialah ia hanya memerlukan jumlah bekalan kuasa yang rendah dan struktur yang kurang kompleks.

TABLE OF CONTENTS

PROJECT TITLE	**i**
DECLARATION OF THE REPORT STATUS	**ii**
DECLARATION	**iii**
SUPERVISOR APPROVAL	**iv**
DEDICATION	**v**
ABSTRACT	**vi**
ABSTRAK	**vii**
TABLE OF CONTENTS	**viii**
LIST OF TABLES	**xi**
LIST OF FIGURES	**xii**
LIST OF ABBREVIATION	**xiv**
LIST OF APPENDIX	**xv**
CHAPTER 1	**1**
1.1 INTRODUCTION	1
1.2 PROBLEM STATEMENT	2
1.3 OBJECTIVES	2
1.4 SCOPES OF WORK	3
1.5 THESIS LAYOUT	3
CHAPTER 2	**4**
2.1 BACKGROUND STUDY	4
2.2 REVIEW OF PREVIOUS STUDIES	4
2.2.1 Design of Autonomous Humanoid Robot [1]	4
2.2.2 Intelligent Real-Time Flexible Walking, New ASIMO Walking Technology [2]	5
2.2.3 System Design and Dynamic Walking of Humanoid Robot KHR-2 [3]	6
2.2.4 Lego walking robot [4]	7

2.2.5 Comparison 8

2.3 HARDWARE OVERVIEW 9

2.3.1 Lego Mindstorm 9

2.3.2 Fischertechnik 10

2.3.3 NQC-Programming Language 10

2.3.4 Bricx Command Center - Compiler 11

2.3.5 Robolab 11

CHAPTER 3 **13**

3.1 INTRODUCTION 13

3.2 HUMANOID ROBOT DESIGN 13

3.3 SYSTEM IMPLEMENTATION 15

3.4 CONCEPTUAL DESIGN 16

3.4.1 Human like movement 16

3.4.2 Negligible uncertainty of actuators 16

3.4.3 Simple kinematics 16

3.5 GAIT ANALYSIS 17

3.6 KINEMATICS ANALYSIS 17

3.7 HARDWARE DEVELOPMENT 20

3.7.1 Structure design 21

3.7.2 Hardware Properties 22

3.7.3 Mechanical structure 30

3.7.4 CAD Drawing 33

3.8 SOFTWARE DEVELOPMENT 36

3.8.1 Block Diagram 36

CHAPTER 4 **37**

4.1 INTRODUCTION 37

4.2 OVERVIEW PICTURES 38

4.3 DISCUSSION 46

4.3.1 WALKING PATTERN 46

4.3.2 Measurement of Humanoid Structure 54

4.3.3 The relationship of velocity, acceleration and degrees of freedom as an important mechanical structure 55

4.3.4 Center of Mass 57

4.3.5 Leg design 58
4.3.6 Knee design 59
4.3.7 Ankle design 60
4.3.8 Foot design 60
4.3.9 Software Implementation 61
4.3.10 Problem analysis 62

CHAPTER 5 **64**
5.1 CONCLUSION 64
5.2 FUTURE IMPROVEMENT 65

LIST OF TABLES

Table 2.1- Comparison between robots 8

Table 3.1- Main components involve in Humanoid Robot development 21

Table 3.2- RCX Specifications 23

Table 3.3- Lego Motor Specifications 24

Table 3.4- IR Transmitter Specifications 25

Table 4.1- Measurement of Humanoid robot 54

LIST OF FIGURES

Figure 2.1: GuRoo 4
Figure 2.2: ASIMO 5
Figure 2.3: The KHR-2 Humanoid 6
Figure 2.4: Two legged Lego walking robot 7
Figure 2.5: Robotic Invention System Logo 9
Figure 2.6 : NQC Logo 11
Figure 2.7: Brixcc Logo 11
Figure 2.8: Robolab Logo 12
Figure 3.1 Design of the Humanoid Robot 14
Figure 3.2: System Block Diagram 15
Figure 3.3: Gait Analysis 17
Figure 3.4: The body center of mass (CoM) 18
Figure 3.5: Hardware Development Block Diagram 20
Figure 3.6: The RCX Programmable Brick 22
Figure 3.7: 9 Volt Geared Motor 24
Figure 3.8: IR Transmitter 25
Figure 3.9: Touch Sensor 26
Figure 3.10: Lego Spur Gears 27
Figure 3.11: Gear Increasing Speed 27
Figure 3.12: Gear Decreasing Speed 28
Figure 3.13: Gearbox and Worm gear 28
Figure 3.14: Rack gear 29
Figure 3.15: 3D overview of humanoid robot 30
Figure 3.16: 2 ankle motor 31
Figure 3.17: Knees via Znap flexible axles 31
Figure 3.18: Knee connected to ankle via Technic Gear 24 tooth 32
Figure 3.19: Motor on each ankle 33
Figure 3.20: MLCad overview 34
Figure 3.21: MLCad Interface 34

Figure 3.22: CAD drawing of humanoid robot 35
Figure 3.23: Software Development Block Diagram 36
Figure 4.1: Full View 38
Figure 4.2: Front View 39
Figure 4.3: Rear View 40
Figure 4.4: Side View 41
Figure 4.5: Top View 42
Figure 4.6: Sensors Placement 43
Figure 4.7: Left Touch Sensor 43
Figure 4.8: Right Touch Sensor 43
Figure 4.9: Motor B (To Move Ankle) 44
Figure 4.10: Motor A and C (To Turn CoM) 45
Figure 4.11: Transition, Phase 1 47
Figure 4.12: Transition, Phase 2 48
Figure 4.13: Transition, Phase 2 to Phase 3 49
Figure 4.14: Transition, Phase 3 50
Figure 4.15: Transition, Phase 4 51
Figure 4.16: Transition, Phase 4 to Phase 5 52
Figure 4.17: Transition, Phase 1 53
Figure 4.18: Board specification 55
Figure 4.19: Robot at starting grid 56
Figure 4.20: Robot reach finishing grid 56
Figure 4.21: Connection through the Znap flexible axles 58
Figure 4.22: Knees turned to the right to lift left leg 59
Figure 4.23: Knees turned to the left to lift right leg 60

LIST OF ABBREVIATION

CoM	- Center of Mass
NQC	- Not Quite C
DoF	- Degree of Freedom
PC	- Personal Computer
ROM	- Read-Only Memory
CPU	- Central Processing Unit
I/O	- Input/Output
USB	- Universal Serial Bus

LIST OF APPENDIX

APPENDIX A 84

APPENDIX B 85

CHAPTER 1

INTRODUCTION

1.1 INTRODUCTION

The research of humanoid robot is diverging into the various categories such as the artificial intelligence, robot hardware development, realization of biped locomotion and human-robot interaction. In the past, robots were confined to the factory as manipulators that were used for tasks such as welding and parts-assembly in automobiles and electronic devices. Their objectives, specification and design parameters were well defined within a framework based on economics, productivity and efficiency. Now the desired functions of robots have changed, and continue to change. Robots are expected to perform various functions such as walking, speaking, recognizing, etc.

Since recently, many researches have been working on developing of humanoid biped robot, which is similar to a human being. This project primarily involves the combination of hardware and software architecture to control the mechanisms. This project describes the control of balance with human-like geometry and motion capabilities. The humanoid is intended to be an autonomous robot. This project will utilize Mindstorm Kit as its main components and controlled by NQC program. Even though the human locomotion approach is taken as the ultimate reference, manner of walking can be developed using less sophisticated methods. The ultimate aim is to maintain an upright torso while advancing one leg in front of the other continuously. A combination of factors such as weight of each leg mechanism, and its appropriate dynamics such as torque, acceleration, and degrees of freedom need to be considered as an important mechanical structure.

1.2 PROBLEM STATEMENT

The weight of the system imposes physical limits. Additional weight deteriorates the walking performance, as a higher mass has to be accelerated; the maximum achievable joint acceleration decreases with rising weight. Power consumptions, the power support by RCX only 9V, increased weight of hardware structure usually also consume more power. The entire weight of the robot must be completely supported by the robot's legs, which is the robot leg need to be physically strong to support of the upper structure.

1.3 OBJECTIVES

The objectives of this project are:

i) To implement a two legged humanoid walking robot

ii) To apply programming using NQC software with Mindstorm Kit

iii) To study the relationship of velocity, acceleration and degrees of freedom as an important mechanical structure

iv) To develop a walking pattern to control and walk in a human-like manner.

1.4 SCOPES OF WORK

The scopes of works in this project are:

(i) The implemented humanoid walking robot will consists of totally 4 Degree of Freedoms, 2 for each leg (1 DoF for the hip joint and 1 for the knee joint).

(ii) The design of this humanoid robot is to minimal the complexity that is necessary to achieve the mechanical properties and control for specific behaviors.

1.5 THESIS LAYOUT

The overall summary of this project is explained and divided into five main chapters. A brief description of the contents in each chapter is as below.

Chapter 1 is preview the background, project outline, aims and objective for the development of the project. The second chapter that is the literature review about the project title. In literature review, it includes some research on the existing implementation of the humanoid robot. The project methodology is elaborate in chapter 3. In this chapter, the method and the project block diagram has been explained in clearly.

Chapters 4 are discuss about the result of the project. The functional of each part of the project will explain briefly in this chapter. The last chapter is the conclusion for the whole project. From this chapter, it includes the conclusion and also the further improvement that can be made in future.

CHAPTER 2

LITERARUTE REVIEW

2.1 BACKGROUND STUDY

Hardware development is very important towards the success of integrating both software and hardware. The hardware part consists of a microcontroller and robot mechanical structure. The application program is debugged and modified to ensure that it runs accordingly to the program algorithm. Integrating both hardware and software developed the complete system.

2.2 REVIEW OF PREVIOUS STUDIES

2.2.1 Design of Autonomous Humanoid Robot [1]

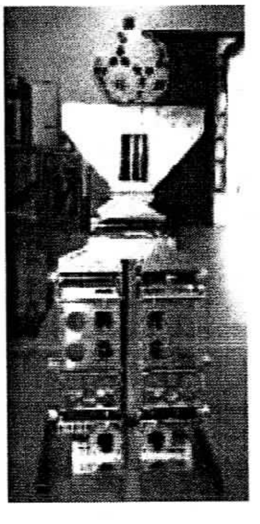

Figure 2.1: GuRoo

GuRoo is a humanoid robot platform, developed at the University of Queensland, Department of Information Technology and Electrical Engineering. It stands 1.2m high with limb propotions based heavily on anthropomorphic data.

A system of 6 motor controller boards all running DSP micro-controllers, provide local control and monitoring of each DoF. A Compaq IPAQ handheld PC provides the gait generation pattern and user interface. Vision processing is provided via a CMOS camera connected to a dedicated Hitachi SH4 board.

SolidEdge, a solid modeling package, was used to design the mechanical structure of the GuRoo. By allocating material properties to each component, it was possible to achieve a mathematical representation of the mass distribution through inertia tensors. These tensors, along with link lengths, motor characteristics and environmental constraints, were modeled in DynaMechs, a high fidelity dynamic simulator. Through this simulator various humanoid gaits and movements can be analysed before operation on the actual robot.

2.2.2 Intelligent Real-Time Flexible Walking, New ASIMO Walking Technology [2]

Figure 2.2: ASIMO

In studying the fundamental principles of two-legged walking, Honda researched both human and other forms of walking, performed numerous experiments and collected an immense amount of data. Based on this research, Honda established fast-walking technology just like a human's.

The human skeleton was used for reference when locating the leg joints. Regarding the toes' influence on the walking function, it became clear that the location where the toes were attached and the where the heel joint was positioned were very important in determining how the robot's weight was supported. Contact sensations from the surface come from the foot joints. Because the foot joints turn from front to back, and left to right, there is stability in the longitudinal direction during normal walking, and feel for surface variations in the lateral direction is enhanced when traversing a slope at an angle. The knee joint and hip joint are needed for climbing and descending stairs, as well as for straddling. The robot system was given many joint functions such as hip joints, knee joints and foot joints. Human beings have structural elements such as soft skin and heels, as well as arch structures consisting of toe joints. These combine with moveable parts which absorb bending impacts to the joints when the foot contacts the ground, softening the impact force.

2.2.3 System Design and Dynamic Walking of Humanoid Robot KHR-2 [3]

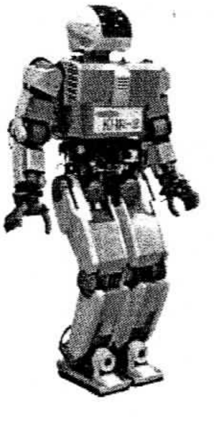

Figure 2.3: The KHR-2 Humanoid

KHR-2 has 41 DoFs and its height and weight are 120 cm and 54 Kg, respectively. Its body was mostly made of aluminum. The distributed control framework has been adopted in order to control all joints and sensors efficiently. A single board computer that assures such features as fast computational speed, low power consumption, compact size and good expansion interface was used as the main controller. RTX HAL extension commercial program was used to realize the real-time capability on Windows OS environment.

The developer also developed joint motor controllers, 3-axis force/torque sensors and inertia sensors. The CAN protocol, which assures adequate speed was used for the serial communion between the main computer and sub controllers, as well as for real-time control. The motion control method and walking stages were defined. In each stage, several online controls were introduced briefly. Also overall dynamic walking control algorithm was shown. In this manner, the performance of KHR-2 has been verified by walking on a not-perfectly flat floor. This project used Windows XP as the OS, which is the most familiar OS to design, implement, and maintain those theories easily.

2.2.4 Lego walking robot [4]

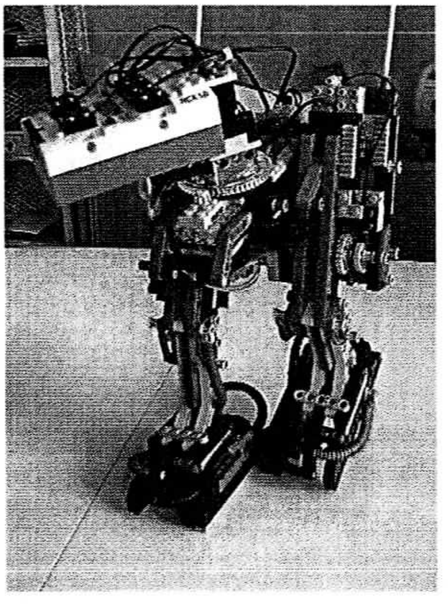

Figure 2.4: Two legged Lego walking robot

This robot does the real two legged walk without using special inwards pointing toes or dragging the feets. This machine will lift one foot after the other completely OFF the ground and uses the RCX to balance the weight while standing on one foot, by turning the RCX from side to side. The machine was built in two weeks time and contains a somewhat complicated transmission with one motor in each leg. The frame is built very steady with a number of beam elements. The head and shoulders itself can be rise and lowered as well with help of pneumatics. This enables the robot to go down in a crouching position before powered down. Almost every piece from the invention system 1.5 and the ultimate builders set was used.

2.2.5 Comparison

Table 2.1 - Comparison between robots

Characteristics	GuRoo	ASIMO	KHR-2	Lego
DoF	23 joints	25 joints	41 joints	4 joint
Power	NiCd batteries	AC100-120V 8A, AC200-240V 4A	Ni-MH (24V/6.6AH, 12V/9.9AH)	9V AA batteries
Motor	DC motor	DC motor	DC motor	DC motor
Controller	iPAQ pocket pc	SH2(HD64F7050 20MHz) CPLD	single board computer (PCM-9575, Advantech Co.)	RCX
Cost	Moderate	Expensive	Expensive	Low cost
Software	Windows CE	RedHat Linux6.2 Kernel 2.2.14-5.0 RT-Linux2.2	RTX HAL Windows XP	NQC Brixcc
Advantages	Small size, lower cost power devices and less heatsinking	A smooth movement	Low power for advance technology	Simple structure

2.3 HARDWARE OVERVIEW

2.3.1 Lego Mindstorm

Lego Mindstorms is a line of Lego Group robot kits combining programmable bricks with electric motors, sensors, Lego bricks, and Lego Technic pieces (such as gears, axles, beams, and pneumatic parts) to build robots and other automated or interactive systems.

Lego Mindstorms is marketed commercially as the Robotics Invention System (RIS). It is also sold and used as an educational tool, originally through a partnership between Lego and the MIT Media Laboratory. The educational version of the products is called *Lego Mindstorms for Schools*, and comes with the ROBOLAB GUI-based programming software.

Lego Mindstorms is used to build a model of an embedded system with computer-controlled electromechanical parts. Almost all kinds of real-life embedded systems, from elevator controllers to industrial robots, may be modelled using Mindstorms. There is a strong community of professionals and hobbyists of all ages involved in the sharing of designs, programming techniques, and other ideas associated with Lego Mindstorms.

The original Mindstorms RIS was released in 1998. In 2006, Lego announced a next-generation Mindstorms system called NXT, centered around a new programmable brick.

Figure 2.5: Robotic Invention System Logo

2.3.2 Fischertechnik

fischertechnik® (the lowercase is deliberately used in the trademarked name) is a brand of construction toy. It was invented by Artur Fischer and is produced by **Artur Fischer GmbH & Co.KG (fischerwerke)**, at Waldachtal, Germany. Fans often refer to fischertechnik as FT or ft. It is used in education for teaching about simple machines, as well as motorization and mechanisms. The company also offers computer interface technology which can be used to teach the theory of automation and robotics.

The basic building blocks were of channel-and-groove design, manufactured of hard nylon. Basic blocks came in 15x15x15 and 15x15x30 millimeter sizes. A peg on one side of each block could be attached into a channel on any of the other five sides of a similar block, producing a tightly-fitting assembly that could assume almost any shape.

The original blocks were characteristically gray with red accessories such as wheels and angled blocks. Electric motors, power sources, and gears were soon added to mobilize models. Additional building pieces such as struts were added in "statics" sets, allowing the construction of realistic-looking bridges and tower cranes. To teach the physics of such models, some sets included measuring devices so that trigonometric vectors could be calculated and tested.

2.3.3 NQC- Programming Language

Not Quite C (NQC) is a programming language, API and native byte-code compiler toolkit for the Lego Mindstorms, Cybermaster and Spybotics systems. It is based primarily on the C programming language but has specific limitations, such as the maximum number of subroutines and variables allowed, which differ depending on the version of firmware the RCX has. The language was invented by David Baum.

NQC Integrated Development Environments are available for many platforms including Microsoft Windows, Mac OS X, Linux, BeOS and DOS.