DESIGN AND CONSTRUCTION OF A 4-LEGGED ROBOT IN VARIOUS SURFACE ENVIRONMENT

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2019

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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

2019

DECLARATION

I declare that this thesis entitled “DESIGN AND CONSTRUCTION OF A 4-LEGGED ROBOT IN VARIOUS SURFACE ENVIRONMENT 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	:	
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APPROVAL

I hereby declare that I have checked this report entitled "DESIGN AND CONSTRUCTION OF A 4-LEGGED ROBOT IN VARIOUS SURFACE ENVIRONMENT" 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 : ....

Date : ....

DEDICATIONS

To my beloved mother and father

ACKNOWLEDGEMENTS

In this section, I would like to express my very great appreciation to my dedicate supervisor, Dr Fariz bin Ali @Ibrahim, who was given me support and guidance throughout the project. Without any guidance and support from him, this project would be difficult to complete.

I would like to show my gratitude to my family, especially my parents, Ooi Aik Piew and Lau Yam Keng for their love and support. They provide a lot morale support and encouragement when I was doing this project. I thank them for believing in me and for helping me to keep my spirits high.

I also want to thank to my friends especially my course mates for assisting me when I need help. They provide a lot of technical advice and mentally support during the journey to accomplish this project. They made a lot of valuable comments suggestions on my paper which gave me an inspiration to improve the quality of the project.

ABSTRACT

This paper presents a study about a 4-legged robot walk in various surface environment with different walking pattern. The main objectives of this paper are designing and constructing a 4-legged walking robot, perform lateral-type and sprawling-type walking pattern on different surface environment. The problems need to solve in this project is to solve the design of the robot that can able to perform both walking pattern. In order to solve this problem, a stable walking algorithm need to be constructed. The first part of this report will be the introduction of the report. In that chapter, the detail of motivation and problem statement will be explained clearly, and the objectives and scope will be stated clearly. Literature review has been done base on previous and latest research which similar to this project. Some of the components had been studied in this part such as the walking pattern of quadruped robot and the degree of freedom (DOF). The third part of this paper will be the methodology which discuss the method used to solve the problem in this project. The software and hardware used in this project will explain in detail. For example, the software used to draw the design of the robot is SolidWorks, and the quadruped robot is programmed by using Arduino IDE. Besides, some of the experiments are carried out to test the accuracy of the robot. Next part of the report will be the result and discussion part. The results from the experiment are discussed in this part to show that the objectives of the research were achieved. The last part of this paper will be the conclusion and recommendation.

ABSTRAK

Makalah ini membentangkan kajian tentang berjalan kaki robot berkaki empat di pelbagai persekitaran permukaan dengan corak berjalan yang berbeza. Objektif utama makalah ini adalah mereka bentuk dan membina robot berkaki empat, melaksanakan corak jenis dan corak jenis lantang pada persekitaran permukaan yang berlainan. Masalah yang perlu diselesaikan dalam projek ini adalah untuk menyelesaikan reka bentuk robot yang mampu melakukan kedua-dua corak berjalan. Untuk menyelesaikan masalah ini, algoritma berjalan yang stabil perlu dibina. Bahagian pertama laporan ini adalah pengenalan laporan. Dalam bab itu, perincian motivasi dan pernyataan masalah akan dijelaskan dengan jelas, dan objektif dan skop akan dinyatakan dengan jelas. Kajian literatur telah dilakukan berdasarkan penyelidikan sebelumnya dan terkini yang serupa dengan projek ini. Beberapa komponen telah dipelajari di bahagian ini seperti pola berjalan robot empat hulu dan tahap kebebasan (DOF). Bahagian ketiga makalah ini akan menjadi metodologi yang membincangkan kaedah yang digunakan untuk menyelesaikan masalah dalam projek ini. Perisian dan perkakasan yang digunakan dalam projek ini akan menerangkan secara terperinci. Sebagai contoh, perisian yang digunakan untuk menarik reka bentuk robot adalah SolidWorks, dan robot empat kali diprogramkan menggunakan Arduino IDE. Selain itu, beberapa eksperimen dijalankan untuk menguji ketepatan robot. Bahagian seterusnya laporan akan menjadi hasil dan perbincangan. Hasil daripada eksperimen dibincangkan di bahagian ini untuk menunjukkan bahawa objektif penyelidikan telah dicapai. Bahagian terakhir dari kertas ini akan menjadi kesimpulan dan cadangan.

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CHAPTER 1

INTRODUCTION

1.1 Motivation

Robot is an actuated mechanism programmable in two or more axes with a degree of autonomy, moving within its environment, to perform intended tasks. Autonomy in this context means the ability to perform intended tasks based on current state and sensing, without human intervention.

Robot can be categorized into 2 main types which are “industrial robot” and “service robot”. A service robot is a robot that perform tasks for humans or equipment excluding industrial automation application. Mobile robot can be defined as an automatic machine that is capable to move around in its environment and is not fixed to one physical location.

A quadruped robot can be categorized as a mobile service robot since it can move around in its environment and help human to complete the task given. A quadruped robot is used to carry the object and deliver it to a target places which human is not able to enter due to its flexibility and mobility. Although quadruped robot always used to compare with wheeled robots, however it is well known that legged robots are superior to wheeled robots due to legged robots have better performance on discontinuous terrain than that of wheeled robots and thus quadruped robot will be focus in this research.

This project is motivated by some motivation to start up the research of quadruped robot. The first motivation is from the Sasago Tunnel collapse accidents happen in japan in 2012. This accident caused nine people died and two were injured, making it the deadliest Japanese roadway accident in history[1]. Besides the disaster such as earthquake also cause a lot of people died and injured. If a quadruped robot is well developed, it can help the rescue team go inside the disaster area to search for the survivors.

The second motivation is come from the quadruped robot designed by Bostan Dynamics. It is a high technology research and development company that develop quadruped robot. The most famous product from this company is the robot called "BigDog"[2]. BigDog was funded by the Défense Advanced Research Projects Agency (DARPA) in the hopes that it will be able to serve as a robotic pack mule to accompany soldiers in terrain too rough for conventional vehicles. Besides, these machines only need a discrete number of isolated footholds, their mobility in unstructured environments can be much higher than their wheeled counterparts, which require a more or less continuous path of support.

Through these motivations, the research about quadruped robot is done in this project and through this research, it can be helpful in the development in quadruped robot in future.

1.2 Problem Statement

In this research project, there are few knowledges are required to study which are robotics, programming, electric circuits and the quadruped motion. These knowledges can help to solve the problems that will faced during the research.

In robotics, the knowledge of kinematic is studied, which is a branch of classical mechanics that describes the motion of points, bodies (objects), and systems of bodies (groups of objects) without considering the forces that caused the motion. For the electric circuit knowledge, the connection between the microprocessor and the other electric components are learnt. Programming knowledge help to design the program needed and import it to the microprocessor. For quadruped motion, it is helps to study the terrestrial locomotion in animals using four limbs or legs.

The main problem that need to solve in this project is to decides the motion for the quadruped robot. There are few types of gaits in quadruped motion which are mammal-type and sprawling-type[3]. A mammal-type means the robot which locates its foot vertically downward from the base of the leg as a standard posture. A sprawling-type means the robot whose first leg segment (thigh) is in horizontal direction and second leg segment (shank) is in vertical direction as a standard posture. For both types of quadruped motion, they have their own pros and cons and it must be understood before decides which motion is suitable for the quadruped robot to move on various surface environment.

The next problem is to solve the design of the robot. After decides the motion of the robot, the next step is to design the shape and size of the robot, so it can perform the motion chosen. The design of the robot must concern about the center of the gravity and also the kinematic of the robot so that the robot can be balance and move.

The other problems are the electric components that required to use such as motors, microprocessor. The microprocessor must decide first so that the other components can fit the microprocessor. After programmed the microprocessor and connected to other electric components, the power must be calculated so that it can use as a reference to choose the required battery capacity and others specification.

1.3 Objectives

The objectives of this project are:

i. To design and construct a 4-legged walking robot controlled by using remote controller.
ii. To design various movements for the robot to move on flat, tarred and grass surface environments.
iii. To analyse the walking pattern of the robot.

1.4 Scopes

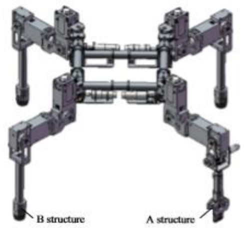
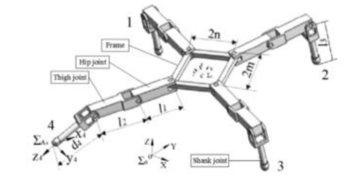
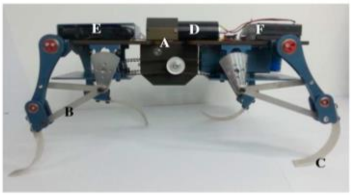
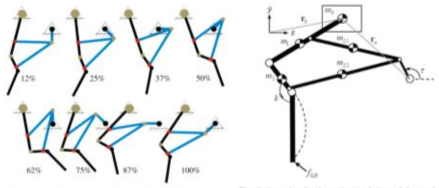
i. Use 3 degree of freedom for each leg.
ii. Walking on flat, tarred and grass surface environment.
iii. Control the movement by using a controller.
iv. It should perform 2 type of walking pattern.
v. Using Arduino Mega as the microprocessor
vi. Use 12 servo motors as actuators
vii. Can perform forward movement on both walking pattern
viii. Can perform backward movement on both walking pattern
ix. Can perform rotational movement on sprawling-type walking pattern

CHAPTER 2

LITERATURE REVIEW

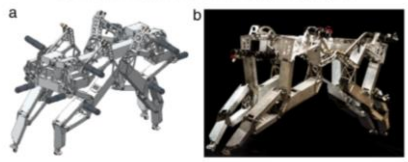
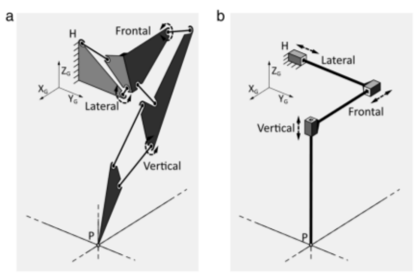
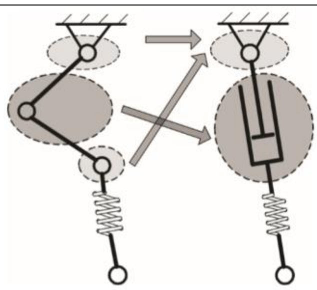
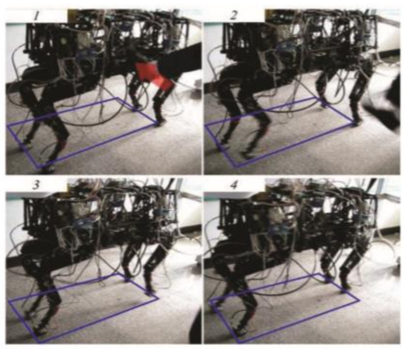
2.1 Overview of the System

Category	Studied articles	
	Journal 1 [4]	Journal 2 [5]
Title	A geometric approach to solving the stable workspace of a hand-foot-integrated quadruped walking robot.	Design of one degree-of-freedom quadruped robot based on mechanical link system: Cheetaroid-II
Aim of this paper	Solving the robot's workspace, including searching steady condition of operation of the robot.	A five-bar linkage mechanism is proposed to emulate the locomotive motion of a leg of a quadruped robot with the reduced number of actuators. (to reduce the weight of robot)
Method	Geometric method of kinematic analysis	Experimental method by observing the locomotion of a dog
Software used	MATLAB, VB and SolidWorks software programs.	MATLAB, Fmincon.m
Walking pattern	Sprawling type	Mammal type
Degree of freedom (each leg)	3	1
Actuator drive system	Servo motor	a Brushless DC (BLDC) motor, a gearing system
Structure and mechanism	Parallel and serial mechanism	five-bar mechanical link system

Dimension of Robot	Length of hip: 67.5mm Length of tight: 232mm Length of shank: 359mm Length of body: 276mm Width of body: 325mm Mass of body: 8681g Mass of thigh: 1471g Mass of working arm: 1359g	N/A
Design of the robot	 Fig. 1. Completely assembled model of ZQROT-I.  Fig. 4. Assembly of the robot and some of its assembly relationships.	 Fig. 1. A picture of the proposed quadruped robot, Cheetaroid-II. It consists of: **A**: a main frame, **B**: five-bar link systems, **C**: compliant feet, **D**: a direct-current motor, **E**: a battery, and **F**: an embedded controller.  Fig. 5. One cycle motion of the mechanical link system of Cheetaroid-II Fig. 7. A setting for dynamic simulation of the mech link system; f_{GR} represents the ground reaction

Category	Studied articles	
	Journal 3 [6]	Journal 4 [7]
Title	A new algorithm to maintain lateral stabilization during the running gait of quadruped robot	Control of a quadruped robot with bionic springy legs in trotting gait
Aim of this paper	i. Calculating the lateral position and speed of the fore swinging leg when it next makes contact with the ground.	i. This paper addresses the problem of trotting control of a quadruped robot with bionic springy legs. The goals are to enhance the robustness of trotting of a quadruped robot and to see

	ii. Controlling the roll angle by mean of inertia forces using the stance leg.	if the quadruped running could be smoother and more stable by introducing certain biological characteristics. ii. The robot reaches the highest speed of 2.0 m·s−1 and keeps balance under 250 Kg·m·s−1 lateral disturbance in the simulations. iii. The effectiveness of these approaches is also verified on a prototype robot which runs to 0.83 m·s−1 on the treadmill.
Method	Kinetic Momentum Management Algorithm (KMMA)	Robot kinematic analysis
Software used	ADAMS and MATLAB	co-simulation of ADAMS and Matlab/Simulink.
Walking pattern	Mammal type (running gait)	Mammal type
Degree of freedom (each leg)	3	6 Degrees of Freedom (DOF) on torso and 5 DOF on each leg.
Actuator drive system	Brushed DC motors	i. Each leg has four active joints driven by four identical hydraulic cylinders, as well as a passive prismatic spring. ii. The robot has 41 sensors including displacement

		sensors and load cells on the hydraulic cylinders and springs, 3-component force sensors in feet and an Inertial Measurement Units (IMU) on torso.
Structure and mechanism	Uncoupled leg mechanism (three sequentially arranged four-bar mechanism)	N/A
Dimension of Robot	Mass: 43 kg Length: 0.68 m Width: 0.9 m	Mass: 67 kg Length: 0.63 m Width: 0.3 m Height: 0.85 m Thigh length: 0.233 m Shank length: 0.31 m Foot length with spring in normal position: 0.31 m
Design of the robot	I. Gonzalez-Luchena et al. / Robotics and Autonomous Systems 83 (2016) 57–72  Fig. 3. (a) CAD robot model. (b) Real robot prototype. I. Gonzalez-Luchena et al. / Robotics and Autonomous Systems 83 (2016) 57–72 	 Fig. 6 Function separation in JCA I.  Fig. 16 Sequence of the marking time trot under lateral disturbance.

Category	Studied articles	
	Journal 5 [3]	Journal 6 [8]
Title	TITAN-XIII: sprawling-type quadruped robot with ability of fast and energy-efficient walking	Kinematic analysis for trajectory generation in one leg of a hexapod robot.
Aim of this paper	Development of a sprawling-type quadruped robot named TITAN-XIII which is capable of high speed and energy efficient walking	Kinematic analysis of a single leg of a hexapod robot is introduced and the trajectory generation is implemented.
Method	i. Calculate cost of transport (COT) to get the energy efficiency ii. Forward kinematic	kinematic and dynamic
Software used	N/A	VRML 2.0, open GL
Walking pattern	Sprawling type	3-types: i. Front disposal (Reptilian type) ii. Sagittal disposal (Mammal type) iii. Circular disposal
Advantage / Disadvantage of walking pattern	<u>Mammal-type</u> i. Walk faster than a sprawling-type quadruped robot by utilizing two actuators (e.g., hip and knee) in each leg. ii. Required small torque on each joint by	N/A

	straightening its leg, especially when the robot stands. iii. Because of the its small footprint, the robot can walk through narrow space or side of a cliff like a mountain goat doing. <u>Sprawling-type</u> i. High stability, because the robot can locate its centre of gravity at low position and have a wider supporting leg polygon. ii. Wide range of motion because of its proximal yaw axis iii. Since its centre of gravity is low, even if the robot falls down, the damage to the robot is considered to be relatively small. iv. The sprawling first segment, the proximal pitch axis always has to generate the torque to support its own weight, therefore its energy	