SIX LEGGED ROBOT WALKING GAITS

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

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"I hereby declare that I have read through this report entitle "Six Legged Robot Walking Gaits" and found that it has comply the partial fulfillment for awarding the degree of Bachelor of Mechatronics Engineering"

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I declare that this report entitle “Six Legged Robot Walking Gaits” 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 :……………………………………………….

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Date :

To my beloved mother and father

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This final year report is made possible through the help and big support from everyone including my supervisor, family and friends.

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ABSTRACT

Legged robots are used in many applications as they suitable to travel on both even and uneven surface. Six legged robot or hexapod managed to perform well in uneven surface such as space or area after earthquake had happen as it is statically stable in term of its body structure. Six legged robot can walking with different types of gaits and results the different performances of the robot. It is found that six legged robot can perform different task with different algorithms. In order to analyse the effect of different gaits to performance of six legged robot, a single task which is line following is assigned to the robot. In this project, the objectives are to implement line following behaviour to a six legged robot with tripod and wave gaits, analyse the speed of the robot and measure the error from deviation of robot from the line when the robot is moving followed the line. To achieve the objectives in this project, a six legged robot with total of 18 degree of freedom is used. In order to conduct the analysis, the line following algorithm is applied to the robot. Experiments such as the time taken to complete the path to measure speed and the measurement of error deviation between centre of robot and line are carried out to validate the performance of the proposed line following algorithm applied to the robot. By implementing the walking gaits to the robot, the movement of robot‟s legs in performing tripod gait and wave gait are observed. Based on the structure of robot, it is found out that joint angles for a single leg should be about 50˚ to allow the robot stand in stable position. The line following behaviour is implemented successfully to the robot by insert the line following circuit. All experimental results are justified with the proposed methodology.

ABSTRAK

Robot berkaki digunakan dalam banyak aplikasi kerana ia sesuai untuk perjalanan di permukaan yang rata atau tidak rata. Robot berkaki enam atau hexapod berjaya menunjukkan prestasi yang baik pada permukaan yang tidak rata dari segi ruang atau kawasan selepas berlaku gempa bumi kerana ia adalah stabil dari segi struktur badannya. Robot berkaki enam boleh berjalan dengan pelbagai gaya berjalan dan menghasilkan prestasi robot yang berbeza. Robot berkaki enam didapati boleh melakukan pelbagai tugas berdasarkan algoritma yang berbeza. Untuk menganalisis kesan gaya berjalan yang berbeza terhadap robot berkaki enam, sebuah tugasan iaitu robot bergerak mengikut garisan telah diberikan kepada robot. Dalam projek ini, objektif adalah untuk melaksanakan kaedah mengikut garisan terhadap robot berkaki enam dengan gaya berjalan tripod dan gaya berjalan gelombang, menganalisis kelajuan robot dan mengukur ralat sisihan antara pusat robot dan garisan apabila robot bergerak mengikut garisan. Demi mencapai objektif dalam projek ini, robot berkaki enam yang mempunyi sebanyak 18 darjah kebebasan telah digunakan. Untuk menjalankan analisis, algoritma bergerak mengikut garisan telah dilaksanakan pada robot tersebut. Eksperimen seperti pengukuran kelajuan robot daripada kiraan masa untuk robot dalam menyelesaikan perjalanan dan pengukuran ralat sisihan antara pusat robot dan garisan telah dijalankan untuk mengesahkan prestasi robot terhadap algoritma bergerak mengikut garisan yang dicadangkan. Dengan melaksanakan gaya berjalan yang berbeza terhadap robot, pergerakan kaki robot dalam gaya berjalan tripod dan gaya berjalan gelombang dapat diperhatikan. Dengan melaksanakan gaya berjalan ke atas robot, pergerakan kaki robot dalam melaksanakan gaya berjalan tripod dan gaya berjalan gelombang dapat dipatuhi. Berdasarkan struktur robot, sudut robot berdiri dalam kedudukan stabil didapati pada sudut 50˚. Robot dapat berjalan mengikut garisan selepas memasukkan litar berkaitan dengan algoritma bergerak mengikut garis. Semua keputusan eksperimen adalah diwajarkan dengan kaedah kajian yang dicadangkan.

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LIST OF ABBREVIATIONS

PWM	-	Pulse width modulation
DOF	-	Degree of freedom
m	-	meter
mm	-	millimetre
Nm	-	Newton per meter
L	-	Length
W	-	Width
H	-	Height
V	-	Volt
g	-	grams
kg/cm	-	kilograms per centimetre
ms	-	milliseconds
cm	-	centimetre
IR	-	infrared
LED	-	light-emitting diode
LDR	-	light-dependent resistor
ADC	-	analog to digital conversion

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CHAPTER 1

INTRODUCTION

In this chapter, motivation, problem statement, objective and the scope of the project will be presented.

1.1 Motivation

Legged robots have more advantages compared to wheeled robots. Legged robots are suitable for both even and uneven surfaces, while wheeled robots are designed to operate in even surface. Legged robots also help human in exploring the animal locomotion such as study of inserts‟ locomotion from the construction of hexapod robot. Legged robots also manage to avoid obstacles by step over them while wheeled robots only manage to take another path to avoid the obstacles [1]. For legged robot, the stability is increased as the number of legs of robot is increased. Six legged robot also known as hexapod is a robot that is statically stable and can walk in unstructured terrain. According to [1], the hexapod robot concept is used in rescue job where it used to find the earthquake survivors. The hexapod robot designed or also known as Dynamic Autonomous Sprawled Hexapod (DASH) is inspired by structure of cockroach was designed to survive in unstable condition. DASH able to climb between the fallen buildings after earthquake to find survivors as a camera is mounted on the body of robot [1].

Figure 1.1: DASH with wings [1]

Figure 1.1 shows the latest design of DASH which wings are applied on the hexapod robot. The hexapod structure enables DASH to move in uneven terrain and launches the feet on a stable position when descending from a high position [1].

It has different walking gaits that gave it an advantage in performing different kind of applications. However, different walking gaits can formed different locomotions of hexapod although it is performing a same task. Hence, the walking gaits analysis of a hexapod in completing a task is crucial to maintain the well performance of hexapod although different gaits are applied.

1.2 Problem statement

Hexapod has six legs where each leg is actuated by 3 position-controlled servomotors and the control of six legs become complex. Gait planning must be considered well as gait is important to robot locomotion. Based on the previous study, most of the previous researches are done analysis on a single type of walking gait. The analysis are normally done by apply the same type of walking gait in performing different tasks. However, different tasks required different experimental setup and workplace. This is hard to analyse the effect of walking gait to the performance of robot as each of the tasks assigned to the hexapod is carried out in different environment and the variables compared are different. Hence, this project proposed a single task which is the line following task is assigned to hexapod robot. Two types of walking gaits which are tripod gait and wave gait will be implemented to the robot. Since the experimental setup for both walking gaits are same, hence the effect of different walking gaits to the performance of robot can be analyse and compare. Different walking gaits results the change in performance of a hexapod in term of speed of robot to complete the task and accuracy of the body of robot relative to the line while moving.

1.3 Objectives

The objectives for conducting this project are:

1) To implement line following behaviour to the hexapod with tripod gait and wave gait.
2) To analyse the speed and measure the errors from deviation of centre of robot from the line in performing line following task with tripod gait and wave gait.

1.4 Scope

In this project, the six legged robot used in this project has 18 degree of freedom. Each degree of freedom represented by a servo motor with torque value of 2.2kg/cm. The hexapod is designed to perform line following task with two types walking gaits. Two types of walking gaits of hexapod involved in this project are wave gait and tripod gait. The walking surface is on flat surface due to the limitation of degree of freedom on legs and assumption of no leg slipping is made while the robot is moving. In line following task, the robot is set to follow black line with the width of 2.5cm and 8.5cm in a white area. All analysis done on the hexapod is based on one cycle to complete the whole walking line path start from the „START‟ point and end when the robot reaches „END‟ point.

CHAPTER 2

LITERATURE REVIEW

This chapter presents about some basic principles and theories involved in the project and review of previous works about the design of six legged robot and the method to analyse its performance as well as some designs of line following robot and method to analyse its performance.

2.1 Theory and basic principle of six legged robot

In this section, the basic principles such as the shape of body and leg structure of six legged robot and types of walking gaits that involved in six legged robot are discussed. The theory involved in analysis of six legged robot will presented in this section as well.

2.1.1 Study of six legged robot

Six legged robot or hexapod robot can be divided into two categories which are rectangular hexapod and hexagonal hexapod. Rectangular hexapod has a rectangular body with two groups of three legs that arranged symmetrically along the two sides of body. Hexagonal hexapod has a hexagonal or circular body with the six legs are placed evenly along the body. The rectangular hexapod is less stable as compared with the hexagonal type [3].

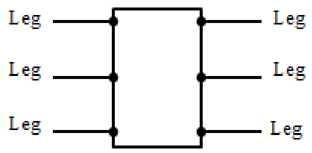

Figure 2.1: The placement of legs for rectangular hexapod [3]

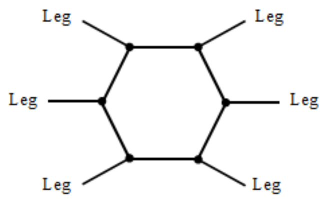

Figure 2.2: The placement of legs for hexagonal hexapod [3]

The construction of the hexapod is inspired by the body structure of insect. There are four main segments for general insect‟s leg which is coxa, femur, tibia and tarsus. From the leg structure of insect, hexapod is created with each leg has 3 degree of freedom.

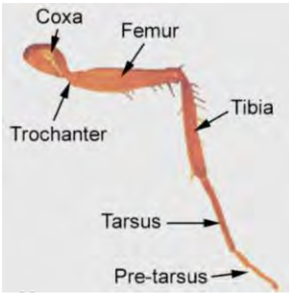

Figure 2.3: Structure of leg for ant [4]

2.1.2 Type of walking gaits for six legged robot

Six legged robot has different types of walking patterns which known as gaits. The types of gaits are classified according to the movement and the number of legs supported the body. The hexapod is considered as statically stable as long as at least three legs are in contact with ground.

2.1.2.1 Tripod gait

Tripod gait is considered as the most well-known gait for a hexapod. In this type of gait, three legs remained on the ground to support while another three legs are lift up and swing to move forward [5].

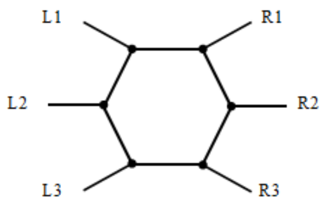

Figure 2.4: The leg arrangement for a hexagonal hexapod

Based on Figure 2.4, when the hexapod is moving forward, L1, L3 and R2 will lift up and swing towards forward, while L2, R1 and R3 will remain on ground and push the body to forward. Another leg configuration can be L2, R1 and R3 raised and swing forward, L1, L3 and R2 remained on ground and push forward.

2.1.2.2 Wave gait

Wave gait is considered as the most stable type of walking gait in hexapod. All legs on one side will move forward, followed by the opposite side. For the walking mechanism, one leg will only lift up on each time, while the other five remained on the ground. Based on Figure 2.5, the robot moves forward by raises up L3, swing forward L3 and put down L3, followed by L2, L1, R3, R2, R1. This type of walking mechanism is based on the movement of an insect to move forward [6].

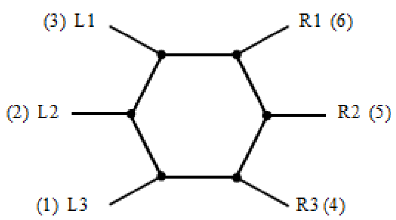

Figure 2.5: The moving sequence of legs in wave gait

2.1.3 Theory involved in analysis of six legged robot

This part describes about the term that used in analysis part of robot.

2.1.3.1 Degree of Freedom

Degree of freedom (DOF) is important in the study of robotics. Degree of freedom can be referred as the ability of an object to move in a single direction independently. The number of degree of freedom is normally known as the number of component required to create motion. The motion generated can be divided into two types which are translational and rotational degree of freedom [7].

2.1.3.2 Stability

Stability is crucial in movement of robot. It can be divided into two types which are static (stand without falling) and dynamic (moving without falling) [8]. Static stability defined as the robot is stable when no motion of robot is required. A robot needs to have a minimum of four legs to achieve static stability. The static stability can be achieved by the mechanical design of the robot which is the structure of the robot itself. Dynamic stability is achieved by control of robot such as the movement of legs of robot [9].

2.1.3.3 Duty factor

Gait can be classified according to its duty factor, β. The duty factor is in range of 0 to 1 and it can be defined as the ratio between leg stand duration and the cycle time [10].

$$\beta = \frac{T_{st}}{T_{st} + T_{sw}} \tag{2.1}$$

where, T_{st} = Duration of foot is standing on ground

T_{sw} = Duration of foot is swinging on air ($T_{sw} + T_{st}$ = total cycle time)