FAKULTI KEJURUTERAAN ELEKTRIK

SMALL SIZED ANIMATRONICS ROBOT

MECHANICAL CONSTRUCTION

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DEGREE OF BACHELOR OF MECHATRONIC ENGINEERING

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APPROVAL

I hereby declare that I have read through this report entitle "**Design and Development of Small Size Animatronics Robot Mechanical Construction**" and found that it has comply the partial fulfilment for awarding the degree of Bachelor of Mechatronics Engineering.

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DESIGN AND DEVELOPMENT OF SMALL SIZE ANIMATRONICS ROBOT MECHANICAL CONSTRUCTION

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A report submitted in partial fulfilment 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 entitles "**Design and Development of Small Size Animatronics Robot Mechanical Construction**" 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 : NG WEI YU

Date : .....

To my beloved mother and father

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ABSTRACT

Over the last decade, bioinspired legged robots or animatronics robots have become increasingly agile. Legged robot has been applied in many applications due to its high adaptability and stability. However, legged robots tend to be cheaper if compare to mobile robot due to their legged counterparts. Animal characteristic are applied in the design of legged robot due to its flexibility and mobility moving on uneven terrain. Thus, many research study has been done to study the mechanical construction of an animatronics robot. The objective of this study is to develop the mechanical part of robot that has ability to move on uneven terrain. The performance of animatronics robot is studied in terms of validity and repeatability. The designed robot is fabricated and modelled using SolidWorks software. SolidWorks is chosen as the modelling method for the robot since it provides many function tools on design and analysis of robot. Furthermore, many experiments have been carry out in this research to study and analysis the performance and the stability of the designed robot. Experiment using Matlab simulation is done to analyse the trajectory path of Theo Jansen mechanism. Furthermore, real time experiment is carried out to study the actual trajectory path of Theo Jansen mechanism on robot hardware. Then, result is collected in table to aid for discussion. At last, the simulation result and actual result is compared and discussed in graphical method since it is very pertinent to test and determine the validity and limitation of designed robot.

ABSTRAK

Marcapada ini, robot berkaki bioinspired atau animatronics robot telah menjadi semakin laris. Robot berkaki telah digunakan dalam banyak aplikasi kerana penyesuaian yang tinggi dan kestabilan. Walau bagaimanapun, robot berkaki cenderung untuk menjadi lebih murah jika dibandingkan dengan robot mudah alih kerana rangka-rangka berkaki mereka. Ciri-ciri haiwan digunakan dalam reka bentuk robot berkaki kerana fleksibiliti dan mobiliti yang bergerak di kawasan yang tidak rata. Oleh itu, banyak kajian penyelidikan yang telah dilakukan untuk mengkaji pembinaan mekanikal robot animatronics. Objektif kajian ini adalah untuk membina bahagian mekanikal robot yang mempunyai keupayaan untuk bergerak di kawasan yang tidak rata. Prestasi animatronics robot dikaji dari segi kesahan dan kebolehulangan. Robot yang direka akan dimodelkan menggunakan perisian SolidWorks. SolidWorks dipilih sebagai kaedah pemodelan untuk robot kerana ia menyediakan banyak peralatan fungsi kepada reka bentuk dan analisis robot. Tambahan pula, banyak eksperimen telah menjalankan kajian ini untuk mengkaji dan analisis prestasi dan kestabilan robot yang direka. Eksperimen menggunakan simulasi Matlab dilakukan untuk menganalisis jalan trajektori mekanisme Theo Jansen. Tambahan pula, eksperimen perkakasan robot semasa dijalankan untuk mengkaji jalan trajektori sebenar mekanisme Theo Jansen pada perkakasan robot. Kemudian, hasil yang dikumpul dalam jadual untuk digunakan dalam perbincangan. Akhirnya, hasil simulasi dan keputusan sebenar dibandingkan dan dibincangkan dalam kaedah grafik kerana ia adalah sangat penting untuk menguji dan menentukan kesahihan dan had robot direka.

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CHAPTER 1

INTRODUCTION

1.1 Motivation

According to the review, many walking robot or animatronics robot has been deployed in high risk tasks and applications due to the high reliability and adaptability. Animal locomotion with varied gait pattern are great interest to researchers but designing this kind of robot need to account many criteria such as performance, function and manoeuvrability. For example, these kind of robots is applicable in office building for helping people in carrying things, or walking in dangerous, hazardous places where human cannot simply access. [1] Therefore, researchers tend to develop legged robot with biological or animatronics characteristic so that it has the ability to move through irregular, abrupt terrain and show their significant versatility and manoeuvrability over wheeled robots. Since, legged robots have higher potential to transverse certain type of terrain with more efficient and stable manner. Nowadays, there are many outstanding research projects such as Asimo from Honda, Bigdog and Wildcat from Boston dynamics have been proposed in many fields according to its function. These legged robots can be used as investigation robot and detection robot to be implement in accident area such as collapsed building, bombing area, and other purpose according to applications needs. This greatly ensure the safety of rescue squad as the building may unsafe for people to enter due to poor footing.

In US, a robotic pack mule has been developed for US troops as a leg up on terrain condition and even for military vehicles as shown in figure 1.1. This mechanized legged robot capable of carrying all the gear soldiers and marines might need in combat. Marc Raibert, the president of Boston Dynamics also confidently said that the robotic pack mules might be use by combat troops by embedded with a Marine squad for an operational exercise. [2]

Figure 1.1: Robotic pack mule

1.2 Problem Statement

Bioinspired legged robots or animatronics robots have become increasingly agile. Wheels are much easier to construct and control. Legs have distinct advantages over wheels due to the adapting principle and mechanism. [3] Wheeled robots face a major disadvantage with short instant elevation changes. Movement such as climbing stairs or steep jagged rock piles become a big problem for wheel vehicles thus many researchers tends to find many alternative solutions to solve this kind of problem. While climbing stairs, the robot need to ascend and traverse natural slopes with many different slopes on terrain with variation of degree and climb over small obstacles in rough terrain. The uneven surface slopes can be up to 50 degrees until 75 degrees and difficult for wheeled robot to travel. [4] Moreover, the slope degree for stairs can be up to 90 degrees which is impossible for wheeled robot to travel. Besides, ordinary vehicles unable to move smoothly on the mountains roads or other difficulties and this may cause the limitation in transportation work. Since, the floor is covered with portions of the building collapsed and even the entrances are blocked with obstacles. This make the building unsafe for people to enter due to the poor footing in building. Then, the rescue squad unable to investigate from the area of origin to aid for the rescue mission. Moreover, a small size robot is pertinent to ensure that the area of movement can be expand and more task can be carry out. Therefore, the main problem we need to solve is about the short elevation of legged robot to improve its flexibility and ability to travel along different kind of surfaces and spaces.

Hence, a further research and discussion need to be made in order to develop the legged robot application especially in Malaysia. In details, we need to study what kind of mechanism have greater ability of movement such as degree of elevation and depression. In addition, we also need to consider the problem may encounter when it is travelling around different kind of surfaces. Therefore, different kind of design is needed to fulfil different kind of target and achieved a better result.

1.3 Objective

The main intention of the small size animatronics robot mechanical construction is to design and develop the mechanical part of a device that has the ability to move along uneven or rough terrain. By comparing of the design from many researchers, it will give an opportunity in choosing the best design to use in various applications. However, many data analysis and performance test need to be carry out throughout the project to make sure that the project is applicable in daily life. This project embarks on the objectives as shown below:

1. To design and develop the mechanical part of robot that has an ability travel on small area.
2. To fabricate and analyse the designed robot using SolidWorks and Matlab modelling method.
3. To evaluate the performance of animatronics robot in term of validity and accuracy.

1.4 Project Scope

The research limitation in this project defines the range of data measurement and also evaluation parameters when conducting or designing the prototype of hardware to achieve the objectives as mentioned in previous subchapter. The main focus of this project is on the design and fabrication the mechanical parts of a small size animatronic robot followed by suitable analysis and performance test using proper method. The scopes of the project are listed below:

1. Come out with three feasible designs of small size animatronics robot.
2. Study the mechanical construction use to drive the mechanism of legged robot.
3. Determine the parameters that will affect the characteristics and performance of animatronics robot.
4. Identify the suitable types of actuator needed to actuate the animatronics robot.
5. Analyse the design of animatronics robot using Solidworks and Matlab simulation software.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter explains a brief overview about my project which is small size animatronics robot mechanical construction. After studying all of the literatures, the various types of mechanism and designs are described and analysed based on researchers' findings.

2.2 Animatronics robot

First and foremost, what is animatronics robot? Animatronics refers to a robotic device or machine that able to imitate a human or an animal to make an inanimate object to "life". [1] Animatronics robot that look and operate like us could be very useful in a modern society since it has a high reliability and adaptability and able to be deploy in high risk task. Hence, animatronics robot is typically designed to be as realistic as possible to be applicable in real life. The framework figure such as skeleton, joints, shoulder, palm and even claws need to be design using motors, and actuators act as the "muscles" of the robot. After connecting all of the circuit and wires the robot will acts like a real person with "nervous system". In addition, a small size animatronics robot or microbots are capable to explore harsh environment which are too narrow or dangerous for people or larger robot to explore. As such, microbots is very useful in applications such as survivors rescue mission, exploration of mine cave, or any suitable applications. The mechanical construction of robot must consider all of the criteria and characteristics of small size animatronics in order to fulfil the project requirement.

2.3 Criteria of legged robot

There are many criteria has been discussed for the construction of robot such as types of mechanism, degree of freedom, types of actuator, type of materials selection, software used, controller used and also number of legs for the robot. Lastly, the benefits of legged robot are discussed.

2.3.1 Linkage mechanism

Based on the papers, the two most effective leg mechanisms are Joe Klann's mechanism which resembles a spider leg and Theo Jansen's mechanism which resembles a human leg. Jansen's linkage mechanism designed by kinetic sculptor to simulate a smooth walking motion and Klann linkage mechanism provides many benefits in more advanced walking vehicles. [5] However, a mechanical spider using Klann mechanism is chosen since it has more advantages than Jansen mechanism. Klann mechanism is simpler and less complicated with lesser linkage for movement. The mechanism is a six-bar linkage with one degree-of-freedom mechanism on each leg that constructed from six links and seven joints. These six linkages are connected to two shafts, with three linkages space equally divided on each side of the frame.

Moreover, Theo Jansen's mechanism is 8 bar linkages with one degree of freedom on each leg. The 8 bar linkages are a combination of 4 bar linkage and two 3 bar linkages. [1] Moreover, Hrones-Nelson and Theo Jansen mechanism are compared due to the similarity of their designs which are both comprised solely of rigid triangular bodies attached to four-bar linkages. Theo Jansen mechanism comprised of two four bar linkages attached to each other in series with only one of the linkages driven by the shaft and crank.

Besides that, four bar chain leg mechanism is also one of the mechanism to construct legged robot. The mechanism has 5 linkages per legs. Four bar chain mechanism can be used to modified form as a locomotion element. [6] The basic structure of this mechanism

consists mainly of torso frame and legs which are attached to it. Besides, kinematic modelling of quadruped robot consists of two sections that are direct kinematics and reverse kinematics. At last, a two bar chain mechanism can be applied in the development of a biomimetic quadruped robot. [2] Due to enormous complexity in the mechanical structure of biological systems and multiple degrees of freedom in each leg, the designed robot is simpler by reducing number of legs or degrees of freedom. [2] There are many similar types of quadruped robot but has short comings in the ability of carrying a load unless the controller is separate from the machine as it used up a lot of space. In conclusion, four-legged configuration are much simpler than six-legged ones but insufficient in stability. On the contrary, the simplification of the design can improve its stability of the robot. The comparison of linkage mechanism of legged robot is listed in table 2.1.

Table 2.1: Comparison of linkage mechanism

Article	Author	Mechanism	Number of linkages	Degree of Freedom (DOF)
Mechanical Spider Using Klann Mechanism [5]	U. Vanitha	Joe Klann's mechanism	Six linkages per legs	One DOF per legs
Modelling and Fabrication of Quadruped Robot Based on the Theo Jansen's Mechanism by using MATLAB [1]	M. Balaji, B. Bapiraju	Theo Jansen's mechanism	Eight linkages per legs	One DOF per legs
Design, Analysis and Fabrication of Quadruped Robot with Four Bar Chain Leg Mechanism [6]	Sachin Oak, VaibhavNarwane	Four bar chain leg mechanism	Five linkages per legs	Two DOF per legs
Design and Finite Element Analysis of Mechanical Spider [7]	Urvil P Patel	Joe Klann's mechanism	Six linkages per legs	One DOF for four legs
Development of a Biomimetic Quadruped Robot [2]	Thanhtam Ho, Sunghac Choi, Sangyoon Lee	Two bar chain mechanism	2 linkages per legs	One DOF for two legs

2.3.2 Fabrication and modelling method

Based on the research, Theo Jansen mechanism comprised of two four bar linkages attached to each other in series with only one of the linkages driven by the shaft and crank. A four-legged robot made by using Theo Jansen's mechanism and the composed of the mechanism is model by using MATLAB and linear motions are observed on the graph for the Theo Jansen based quadruped robot. For the modelling and fabrication of product, the linkage lengths were taken directly from Theo Jansen's book "The Great Pretender". [1] The fabrication involves many complicated processes like cutting of material, selection of motor, drilling of centre rod, fixing motor and final finishing work. The analysis of the robot performance is done by using the AutoCAD software and MATLAB software. The analysis of trajectory leg movement is done by simulation of mechanism using MATLAB to record the X and Y position of end effector. The coordinate system of its legs path is then recorded and tabulated in table form.

For analysis and fabrication of quadruped robot with four bar chain leg mechanism, the robot was first design and develop using CAD model software to ensure overall dimensions of robot are fixed. [6] A table of joint angles for the hips and knees is then tabulated as results of experiment. Further discussion is made to study the different exist each of the joint angles. The different of angles are because of restriction to servomotor revolution and mounting arrangement on quadruped.

For Joe Klann mechanism spider robot, the frames and links are made of aluminium as aluminium is light and strong material to reduce the weight of device and able to withstand the force on it. [7] For gears and pinions are made of nylon material. The electrical motor is connected to frame and pinions is then connected at the shaft of electric motor. All the links and final assembly is then modelled by using Creo parametric 3D CAD software. When power is supplied, rotation motion of crank and gears is transferred to a connecting arm causing an accurate reciprocating movement. For analysis sections, author carry out static structural analysis, gravitational acceleration analysis and modal analysis to determine its vibration characteristic. Ansys workbench software is used by author to study the finite element deformation and stress in the body. [7] The fabrication of robot has many advantages such as high efficiency, low construction cost, less maintenance, and capable of carrying

heavy loads. However, there are a few limitations for this design like high power source, limited speed and smoothness of motion.

At last, acrylic material is used to fabricate quadruped since it is light and rigid body. The fabricated parts are then assembled by using bolts, nuts, carbon rods and carbon pipes. Numerous experiment is done by the author to study the robot performance and efficiency. For example, experiment on effect of frequency on the velocity, effect of angle on velocity and also payload experiments. According to the research findings, bounding motion has a superior ability in terms of the locomotion velocity and payload. [2] Though the prototype yet to be improved such that the could be perform better while carrying circuit and battery. Furthermore, ADAMS software can be used as the mechanism simulation software. [2] Numerous experiment is done by the software to study the robot performance and efficiency. For example, experiment on effect of frequency on the velocity, effect of angle on velocity and also payload experiments. The comparison of fabrication and modelling method of legged robot is listed in table 2.2.