# ANALYSIS OF RECTANGULAR BASE HEXAPOD USING TRIPOD WALKING GAIT ON DIFFERENT SURFACES

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## DECLARATION

I declare that this thesis entitled "ANALYSIS OF RECTANGULAR BASE HEXAPOD USING TRIPOD WALKING GAIT ON DIFFERET SURFACES" 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.

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## APPROVAL

I hereby declare that I have checked this report entitled “ANALYSIS OF RECTANGULAR BASE HEXAPOD USING TRIPOD WALKING GAIT ON DIFFERET SURFACES” and in my opinion, this thesis complies the partial fulfilment for awarding the award of the degree of Bachelor of Mechatronics Engineering with Honours

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## DEDICATIONS

To my beloved mother and father

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First, I would like to praise to Allah, the Almighty, on whom blessing I can successfully complete my final year project and finish this report on time.

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# ABSTRACT

Surveillance robot becomes important part of rescue missions. It helps rescuer to get knowing unfamiliar places and possible survivor before any move or strategy is carried out. The early development of surveillance robot is dominated by wheel and track type chassis robot. However, there is limitation constrain of available wheel and track robots as they not able to surpass many of found difficulties like uncontinuous surfaces or higher obstacle. Hence, in this project will focus on design and development hexapod legged robot as modern solution of uneven terrains. Objective of this project are to design and develop rectangular base hexapod using tripod walking gait and then analyse it basic walking performance on difference surfaces chosen which are carpet, cement floor, tar road and short grass surfaces. As to achieve high reliability movement, hexapod tripod gait are embedded with Lagrange Interpolation Polynomial technique to improve servo accuracy along with inverse kinematic and Third-Order Interpolation Polynomial path trajectory planning. Overall result of basic walking test show that hexapod successfully walking through all the surfaces tested although have some losses on actual distance travel due to surface obstacle and slipping. Repeatability result of hexapod also provide acceptable repeatability precision since hexapod able to achieve standard deviation as low as 0.18cm on grass and only up to 1.87cm on tar road surface.

# ABSTRAK

Robot pengawasan menjadi bahagian penting dalam misi menyelamat. Ini membantu penyelamat untuk mengetahui tempat-tempat yang tidak dikenali dan kemungkinan terselamat sebelum sebarang langkah atau strategi dijalankan. Pengembangan awal robot pengawasan didominasi oleh robot casis jenis roda dan trek. Walau bagaimanapun, terdapat had batasan robot roda dan trek yang tersedia kerana mereka tidak dapat mengatasi banyak kesulitan yang dijumpai seperti permukaan yang tidak berterusan atau halangan yang lebih tinggi. Oleh itu, dalam projek ini akan menumpukan pada reka bentuk dan pembangunan robot berkaki hexapod sebagai penyelesaian moden bagi kawasan yang tidak rata. Objektif projek ini adalah untuk merancang dan mengembangkan hexapod berdasarkan segi empat tepat dengan menggunakan tripod berjalan dan kemudian menganalisisnya pada prestasi berjalan asas pada permukaan perbezaan yang dipilih iaitu permaidani, lantai simen, jalan tar dan permukaan rumput pendek. Untuk mencapai pergerakan kebolehpercayaan yang tinggi, gaya berjalan tripod hexapod disertakan dengan teknik polinomial Lagrange Interpolation untuk meningkatkan ketepatan servo bersama dengan perancangan lintasan polinomial interpolasi kinematik dan urutan ketiga. Keseluruhan hasil ujian asas berjalan menunjukkan bahawa hexapod berjaya melalui semua permukaan yang diuji walaupun mengalami kerugian pada jarak perjalanan yang sebenarnya kerana halangan permukaan dan tergelincir. Hasil pengulangan hexapod juga memberikan ketepatan kebolehulangan yang dapat diterima memandangkan hexapod dapat mencapai sisihan piawai serendah 0.18cm di rumput dan hanya permukaan jalan tar hingga 1.87cm.

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| | | |
|---|---|---|
| FDM | – | Fused Deposition Modelling |
| PETG | – | Polyethylene Terephthalate Glycol |
| PLA | – | Polylactic Acid |
| RF | – | Radio Frequency |
| PWM | – | Pulse Width Modulation |
| DC | – | Direct Current |
| IDE | – | Integrated Development Environment |
| I/O | – | Input and Output |
| I2C | – | Inter-Integrated Circuit |
| SDA | – | Serial Data |
| SCL | – | Serial Clock |
| Li-Po | – | Lithium Polymer |
| UART | – | Universal Asynchronous Receiver-Transmitter |

## LIST OF APPENDICES

# CHAPTER 1

# INTRODUCTION

## 1.1 Motivation

Natural either nor man-made disaster, becoming threat to human health and life before and now. In fact, study on number of earthquakes each year (Figure 1.1) has stated that total of 1,637 earthquakes recorded with magnitude of five or more just year of 2019. Whereas, the highest total earthquakes recorded is in 2011 by 2,481 [1]. Large earthquake not only cause tragic loss of life but also significant damage to infrastructure and property. In June 2005, Malaysia recorded the impact of M5.9 earthquake that sacrificed 18 people on Mount Kinabalu and very large damage to nearby mosque, hospital, hotels and other utility infrastructures in Kundasang and Ranau [2].

Although with some prevention, not every country well in predicting the disaster. However, if disaster happened, rescue mission is compulsory to reduce the impact. Should be known that, rescue mission usually leads to deadly risks especially if it involves in very dangerous places. For example place where earthquake or very high radioactive radiation happen, the land might be fragile and air might not be safe to breath. Sending human rescuer to find unknowing number and location of victim is not worth if too much risking and life-threatening. As the result, people start sending robot for surveillance task. They are really crucial to get knowing unfamiliar places and possible survivor before any move or strategy is carried out.

Surveillance robot can have a lot of advantages when it came to highly mobility in most of the natural terrains. Early development of surveillance robot is dominated by wheel and tracked robot. Wheel robot is the fastest and energy efficient method compared to tracked and legged robot. It is also simpler in mechanism and lightweight. However, this type of chassis demand at least regular surfaces in order to move. Moreover, it is almost impossible for the wheeled robot to pass though vertical obstacle that is bigger than the half size of its tyres. Other than that, wheel robot tends to lose it grip and get stuck in soft surfaces like snow and sand surfaces. Even if it manage to get out from the depression, it will cost highly power consumption. As the result, it is not suitable of uneven and rough terrain.

Even with the alternative of tracked chassis robot to increase the mobility in difficult terrain, it is still not able to pass though many of found difficulties and power consumption still consider relatively high. In addition, should be known that both wheel and tracked robot leaves continuous ruts on surfaces that it has going through, which is not good if sees in environment point of view. There may need of additional work to recover the damage. Hence, legged robot are propose to solve the traditional robot issue. Legged robot are more superiorly robust in most of the natural terrain area due to their discrete footholds for each foot. Besides, due to its multiple degree of freedom on each legs joints it is possible to vary the robot body to gives better grip and balance on uneven surfaces [3].

Should be known that higher number of leg give easier control during static stable locomotion, this project is considering six legged robot or hexapod as it able provided better stability than four legged robot. Other than that, legged robots have highly failure tolerance advantages during static stable locomotion [3]. Unlike legged, wheeled or tracked chassis robot will likely to lose it mobilisation as soon as it primary motor stop working or damaging. Legged robot consists redundant number of legged. So, any other legs that still working able to cover up the lost and maintain static stable locomotion until it able to return back to working station.

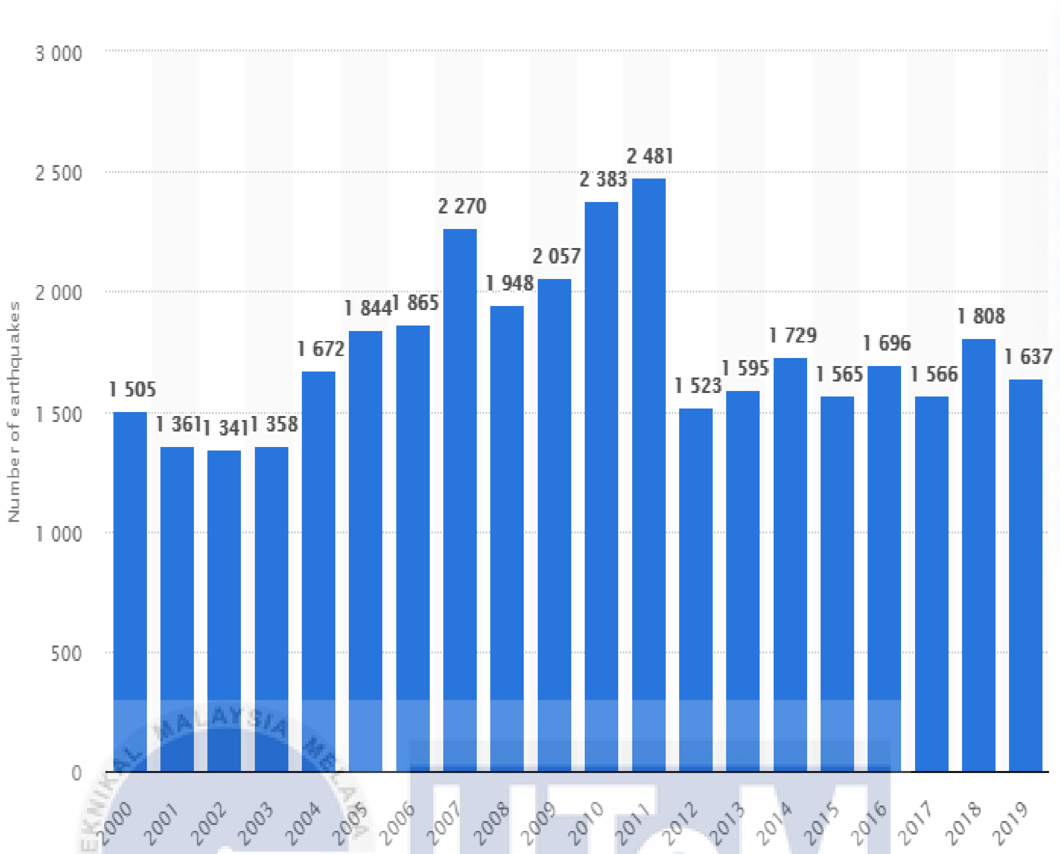


Figure 1.1: Number of earthquakes (M5+) worldwide from 2000 to 2019 [1]

## 1.2 Problem statement

The main problem is the limitation constrain of available wheel and track robots. Early development of surveillance robot is dominated by wheel and track type chassis robot. Although, both wheel and track chassis robot have their own advantages, they also have limitation on most of large obstacles and uneven terrains. Wheeled robots are fast but need for at least regular surfaces in order to move since it not able to pass vertical obstacle that larger than half the size of tyre [5, 6]. Moreover, soft surfaces like sand and snow is the scariest things for wheeled but not tracked chassis robot. There is where wheeled robot is most likely to get struck or consuming large amount of power just to get off from the depression [3]. Even with the alternative of tracked chassis to increase the mobility on tough terrains condition, they not able to surpass many of the found difficulties and end up slower speed and higher power consumption [3, 4]. Hence, give difficulties to rescuer due to inaccessible of most of surveillance area.

## 1.3 Objectives

1) Design rectangular based hexapod robot using LaGrange Interpolation Technique
2) To analyse performance of hexapod robot in difference surfaces

## 1.4 Scope

Scope of the project is as below:-

1) 3D design and programming of hexapod is fully develop by scratch

2) Only one walking gait will be used for hexapod

3) Experiment combine simple walking test and repeatability test on difference surfaces which are;

- On a cement floor
- On a carpet
- On a Tar Road
- On the short grass

## 1.5 Thesis Outline



This project focus on design and development of hexapod. Project report is divided into five chapters. Chapter 1 will covered the motivation, problem statement, objective, and scope of the project. Chapter 2 is literature review which covered the related study and understanding before project execution. Other than that, chapter 3 is project methodology, which covered the necessary preparation and activity executed in order to achieve project objective. Next, chapter 4 is experiment and result. Lastly, all the result and discussion will be conclude in chapter 5.

# CHAPTER 2

# LITERATURE REVIEW

## 2.1 Most Used Chassis for Ground Robot

The advance of development of mobile robotics brings the revolution of various forms of chassis built specifically to complete certain tasks. Should be known that each of the chassis has their own advantages and disadvantages. Choosing the right chassis should considering four type of factors which are the requirement of task, restriction of the terrains, limitations of actuators, and the required power supplied to the robot [1]. This section will review the advantages and limitation of the most type of chassis is mostly use which is wheeled, tracked and legged robot.

### 2.1.1 Wheeled Robot

Wheeled chassis is the most favourite being used compared to tracked and legged chassis. It can be obsoletely seen on modern ground vehicle nowadays like on cars, vans, lorries, trucks and even tractors. That is because of the ability of this chassis to travel faster and lesser power consumption on road over long distance [3, 7]. Moreover, tires provide better grip on the surfaces. So, gives greater forward power to the vehicle [6]. In fact, most of the chassis design only need two motor which are to move (forward or backward) and changing direction (left or right). As a result, due to the less actuation makes the vehicle simpler design with less complicated mechanical interference, low production cost and light weight [5, 6]. In adaptation of uneven terrain, the vehicle can be upgraded by increasing the size of tyre and adding the suspension spring as damper [9, 10, 11, 12]. The base of the wheeled robot also has to be tall so that it able to maximize the shock absorbance by the suspension spring which makes it reliable to overcome obstacle like rock and bump.

However, wheeled type of chassis robot demand at least a regular surfaces which made it less preferred in highly uneven terrain. In order to passing over a vertical obstacle, wheeled has to be at least two times taller as vertical obstacle [5, 6]. In addition, wheel chassis robot tends to slippery on soft surfaces such as sandy soil and snow [4, 5, 7]. Hence, it consume large amount of energy just to get off from the depression or it can just get stuck. In fact, wheel vehicle will likely to leave continuous damage on the ground which is not good especially from environmental point of view [3, 4, 7].


Figure 2.1: Six Wheel Robot with Gripper [10]



Figure 2.2: Six Wheel Robot for Sewer Inspection [11]

### 2.1.2 Tracked Robot

Tracked chassis is already known by its robustness and reliability on the most of the surfaces. Early stage of the tracked chassis is for military application but today extended and widely use into construction, mining and logging application [13]. It is able to move better and power efficient on a rough terrains where wheeled chassis would get stuck [4, 5, 7]. The strength of this chassis come from its continuous tracks tyre design that has increase the surface area contact to the ground. The weight of the tracked chassis is evenly separate on the entire area of continuous tyre [5, 6, 7]. Hence, less impact to the ground especially on soft surfaces like snow and soil. Moreover, the aggressive looks of the tracked chassis makes it look outstanding than wheeled [10, 20].

Although the advancement of mobility in though terrains, tracked robot still disadvantage on many of found difficulties and power consumption still considered relatively high [3]. Other than that, the power transfer for mechanical movement is complex and can lead to more mechanical failure. As the result, lead to more maintenance cost [7]. Other than that, tracked chassis robot suffer lower speed compared to wheeled chassis robot [3, 5, 7]. That is due to the increasing of friction and complex power transfers on it mechanical system [10]. Hence, even though the power consumption of tracked robot is smaller than wheeled robot on rough terrains, the power consumption is higher on paved and regular surfaces [3, 7]. Like wheeled should add the fact that tracked robot also will leave continuous ruts on the ground but less steeper and damage [7]. Despite that, it clearance to be seen and harm to the land [3].

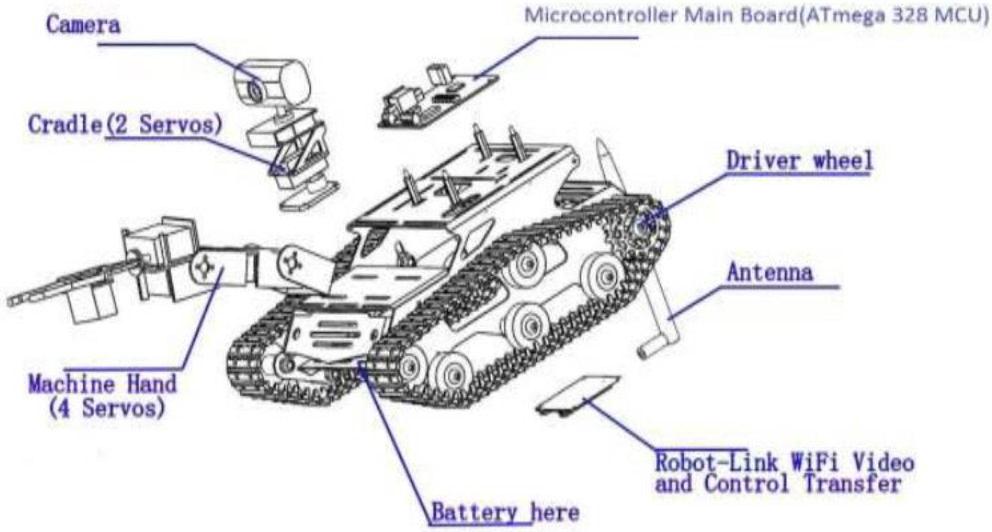


Figure 2.3: Design idea for tracked surveillance robot [14]

Figure 2.4: Tracked robot [6]

### 2.1.3 Legged Robot

The advance development of legged robot is due to demand of high mobility in extreme terrains and tough surfaces at any part in the world [15]. This field has performed by a lot researcher and developer by past few year, due to the large potential [4, 16, 17, 18]. Legged robot provide accessibility to any kind of surfaces that not able to access by wheeled and tracked robot. Most of the legged consist of three joint by each leg, which is coxa, femur and tibia which giving them three degree of freedom [16], refers to Figure 2.4 below. Its high degree of freedom on each leg which helped by multiple legs, give the ability to adjust its own centre weight of body to achieve maximum stability on type of surfaces. Moreover, in case of damaged land due to earthquakes, legged robot able to just jumping or stepping into over the non-continuous path or obstacle easily Hence, less amount of power is consume to overcome the highly tough surfaces compared to wheeled and tracked robot [3, 4]. Next, should be known that every multiple amount of legs cannot just locomotion purposes only, but also be used for manipulator support [3]. Learned from animals themselves, their hand is the same foot that they used for walking. In addition, legged robot can also be failure tolerance due to multiple legs [3]. This is because legged robot not likely to losing it mobility with several legs are broke down.  It still able maintain static balance and continue walking until return back to repair station. So, the chances for operator to going out to dangerous place is reduced. Other than that, discrete legs of legged robot can also avoid foothold or damage to the land it has walk [15]. Hence reduce landscape damage and avoid trail if secret operation is necessary.



Despite those advantages, design of one legged robot is not easy task because of engagement of complex mechanism and computation method [15]. Legged robot is consist redundant of legs. Hence a proper gait (pattern of movement) and design should be consider to avoid clash over leg during locomotion [4]. Whereas, redundant leg will waste a lot of power and damage the prime mover [17]. Moreover, cost in development of legged robot can be really high especially with more legs [15]. One leg may need at least two or more motor for higher degree of freedom. As the result, cost should put into consideration for every researcher or developer before deciding to develop the robot. Other than that, legged robot travel slower and high energy consumption compared to track and wheel robot on normal surfaces [3, 4, 15]. This is due to a lot of kinematic motion are needed to move every single leg in order to maintain the static locomotion. Lastly, continuous changing direction of motor on legged robots joint can also be noisy [19]. Although the motor can be replace with quieter one, the motor may be expensive and need for additional cost. Hence, may not be suitable army for military secret operation.

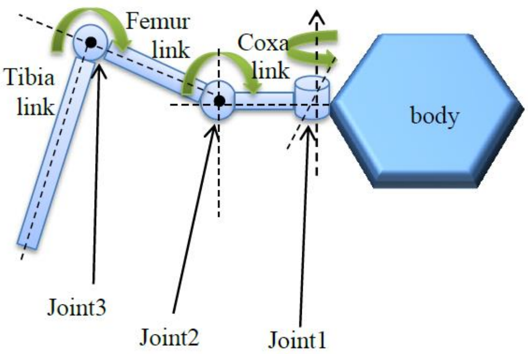


Figure 2.5: Front view of Coxa, Femur and Tibia joint rotation angle [5]

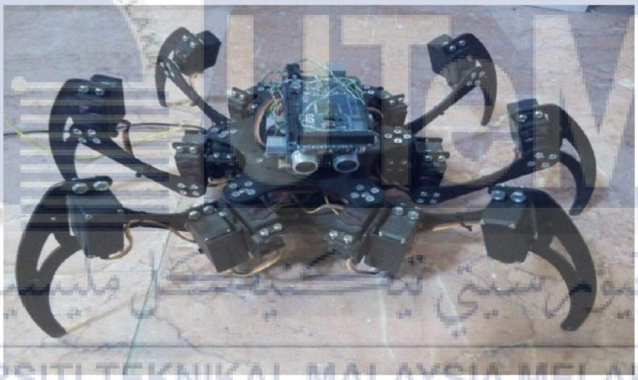



Figure 2.6: Biomimetic physical modelled of spider [5]

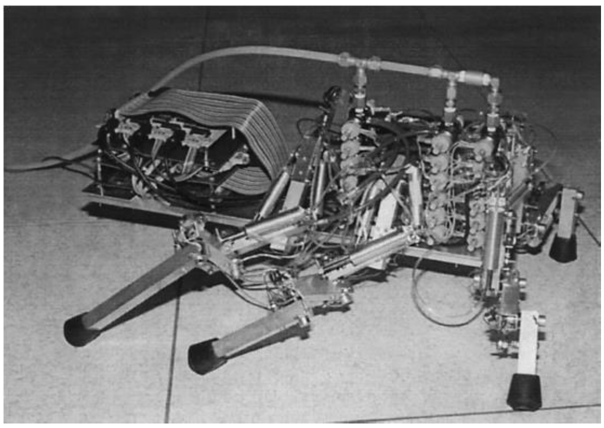

Figure 2.7: Biomimetic physical modelled of American cockroach [17]