EEM355 | Mammal-type Quadruped Robot

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ABSTRACT

Quadruped robot is highly researched in die modern day and age for a variety of reasons, including military use and to help where it dangerous for people to operate. This project is to design a quadruped robot which able to walk at different type of terrain such as rocky, steep, muddy and sliperry surface. This proposal describes the mechanical configuration of the quadruped robot. This robot has four legs, and all are actuated by servo motors, each leg consists of three rotary joints. The microcontroller used in this project is Arduino. Arduino is an open-source electronic prototyping platform with simple programming language and ease to connect circuits. Arduino can control the huge number of servo motors used in this project.

Keywords: *Quadruped robot; Arduino; Mammal-type; Servo motors*.

1. INTRODUCTION

The wheeled robots can travel very fast, but they usually require a flat floor over which to work. Tracked robot can move on rougher terrain, but slower than wheeled robot. Legged robot is superior to wheeled and tracked robot since they have higher terrain adaptivity, possess greater mobility and also flexibility, do little damage to the environment, etc. The legged robot is more complicated on structure and difficult to control than wheeled or tracked robot.

Quadruped robot possesses structures similar to those of four-legged animals, and they easily can adapt to rough terrains and environments such as mountains. In consequently, numerous studies on such robots are currently being conducted in terrain that are inaccessible to wheel or caterpillar-based vehicles. In particular, BigDog and AlphaDog developed by Boston Dynamics have been demonstrated to have the mobility and ability for carry the large masses, which are traits useful during military or disaster relief tasks.

We can control all of these robots with a simple control approach that broke the behavior down into the three primary activities, supporting to the body with a vertical bouncing motion, controlling attitude of the body by servoing the body through hip torque during each leg's stance phase, and by placing feet in key location on each step using the symmetry principle to keep the robot will balanced as they moved about. The detail of the control varied from machine to machine, they all shared for these three essential ingredients.

The Spring-Loaded Inverted Pendulum (SLIP) is commonly used to analyze and control the dynamic walking and running of human and animal. In the SLIP, a point mass, with entire body mass concentrated at its center, and massless springs are connected to a pivot joint. Various movements can be realized by performing swing motions around the joint and extension motion based on the compression and extension motion of the spring.

2. OBJECTIVES

1. To design and fabricate an autonomous four legs robot that can walk.

2. To determine the most suitable mechanism of a robot to make it walk. This includes the factor of stability, speed and load available of the robot.

3. To understand the working concept (conservation of electrical energy into mechanical energy) of various type of motor.

4. To expertise the skill of fabrication process of a robot, such as 3-D printing, drilling, and wiring.

5. To understand and improve ability of writing programming language (C++ Language).

3. LITERATURE REVIEW

3.1 Self Identification and Control of Four-leg Robot

Most of the robots widely used today do not have the ability to build the model themselves. Actions of the robot are controlled by a controller based on a certain model. If the robot is damaged, which means that the model of itself is changed, the controller may be no longer available for the robot. The key for a robot to determine the damage by itself is the robot can real time detect its model. There are two methods for a robot to detect its model [1]. The first method is by adding more sensors to detect the damage, the other method is by using the sensors already used in the robot. The former method needs more sensors, which adds the data processing amount for the robot controller. This raises the cost of producing the robot and reduces the reliability. A robot can detect its model with information from the limited sensors that are used for certain mission [2][3]. If this method is applied to robots, they would acquire the ability to self-identification via reprogramming control software and no need to alter the hardware [4].

Figure 3.1: Self-identification four leg robot.

3.2 A Four-Leg Locomotion Robot for Heavy Load Transportation

Various applications of locomotion robots have recently been introduced into many practical fields. Especially, mobile robots in new applications such as disaster relief and demining are required to apply them into the practical use. Such kinds of robots must be mounted the movability at any rough terrain. For such request, the leg locomotion is advantageous to move on irregular terrain. In such applications, real demand is to carry the heavy load such as a victim in the rescue activities. However, present leg mechanism is not suitable for carrying the heavy load. For example, quadruped robot driven by DC motors realizes smooth action like as an animal, but its loading capacity is so small that it can only carry its own body. This is caused by shortage of torque generated by motors. Additionally, it consumes the large amount of energy because a motor requires electric current at any time when it generates the torque [5].

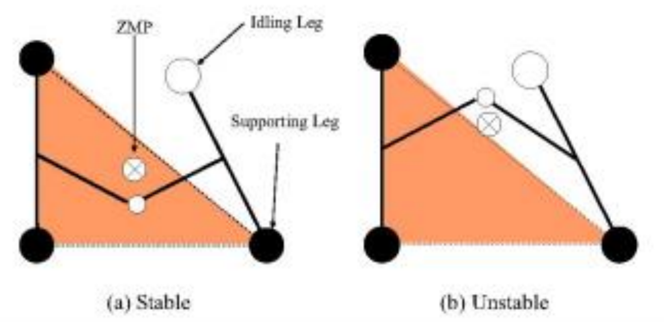


Figure 3.2: Stability locomotion idling leg

3.3 Biometrics and Kinematics of a Four-legged Robot

The animal locomotion or movement is the act of moving or a change in place or position. However, in the engineering world, a movement is described as an act to rhythmically apply forces to the environment. This could be caused by releasing mechanical energy stored in the leg mechanism. The rhythm of applied force could be caused by multiple degrees of freedom through the trajectory of each leg as shown in the example given in Figure 3.3 [6].

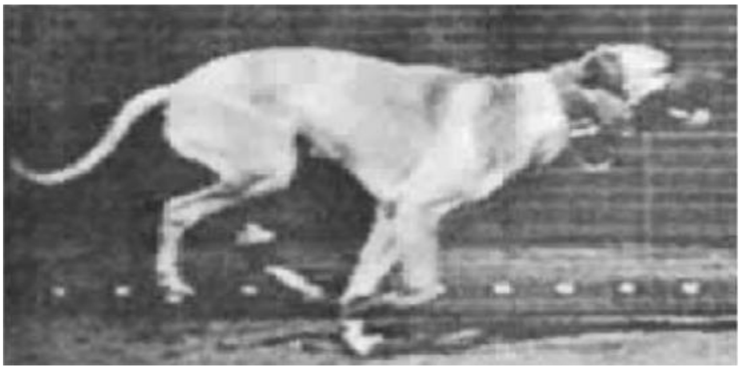


Figure 3.3: A dog executing a movement.

Animals differ from one another only in the timing of that stepping. The reason that manner of walking is so universal, is that it provides the maximum static stability. In other words, when walking slowly, a horse's or dog's body is always supported by three feet on the ground, which form a triangle as described in Figure 3.4. The closer their centre of mass is to the centre of those three points, the more stable they will be. The chosen walking algorithm to be adapted into the crawler robot would be from a lizard [7]. The lizard was chosen because it inherits several criteria such as, dynamical stability, Low centre of gravity, Less actuation(trajectory), Uses two degree of freedom, Good control and balance

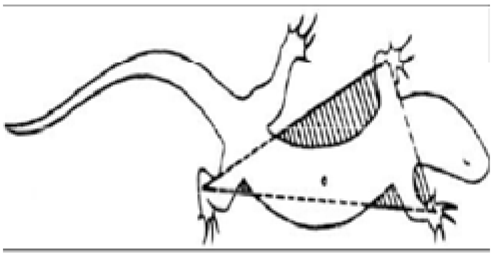


Figure 3.4: Walking algorithm of a lizard, with support polygon

3.4 The Rough-Terrain Quadruped Robot

The concept of this robot is to overcome the problem of outdoor terrain that is steep, rocky and wet. This robot designed with rough-terrain mobility and able to travel to anywhere a person or animal could go using their legs. There are 4 hydraulic actuators on each leg to control and power the joints which allowed it step on different altitude or angle of ground. There are total of 50 sensors which measure the altitude, levelling and acceleration of the body. BigDog's control system coordinates the kinematics and ground reaction forces at the feet while responding to basic postural commands. The control system adapts to terrain changes through terrain sensing and posture control. The control system uses joint sensor information to determine when feet are in contact with the ground and to determine the desired load on each leg and actuator. This control system allows BigDog to travel on rough-terrain easily. The advantage of this mechanism is it can walk on any type of ground while the disadvantage will be the high manufacturing cost.

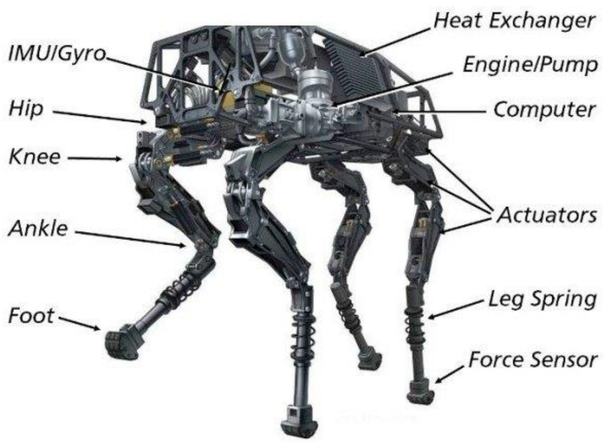


Figure 3.4: Parts on BigDog

3.5 Single Actuator Tatrapod Walking Spider Robot

This robot also designed to go to location where wheeled robots are not capable of. Usually, the common legged robot contain one actuator on each leg, this research paper aimed to reduce the number of actuator and simplifying the control problem. The 1 degree of freedom can be achieved by using Genava mechanism. The motion of the Genava mechanism transmit to the CAM so that the legs simultaneously contact with the ground. The Genava mechanism rotates only 120° and waits for 240° while the DC motor rotates one revolution. The advantage of this mechanism will be it required less actuator thus the size and weight of the body can be reduced. While the disadvantage is it only has 1 degree of freedom which the motion of the robot is restricted.

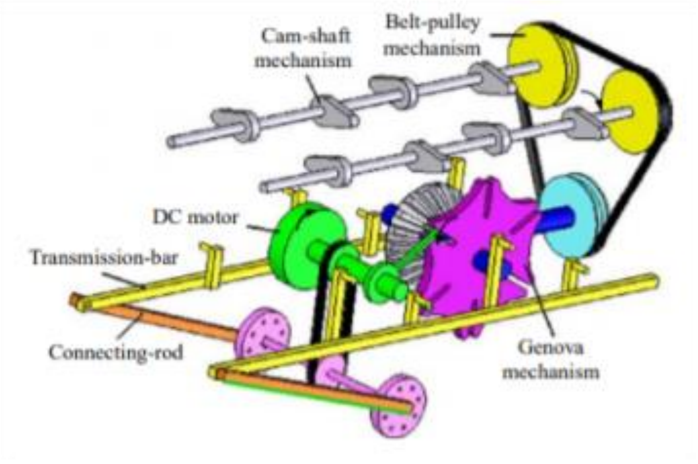


Figure 3.5: GENAVA mechanisim

3.6 Petoi Nybble -Walking Robot

Nybble is the robotic cat that really walks. Built on an open source platform, Nybble has endless possibility in the way we can teach tricks or behaviors as you program it and help it grow. Nybble is not only a robotic cat that can walks, it's a new type of pet, an advanced robotic kitten that the human can bring to life with a computer, customizable software, components kit, and whatever. The frame of Nybble is not difficult to assemble able puzzle. For the wooden frame is a retro cat design in honor of its popstick framed ancestor. Higher voltage will increase the servos torque, making Nybble move faster.

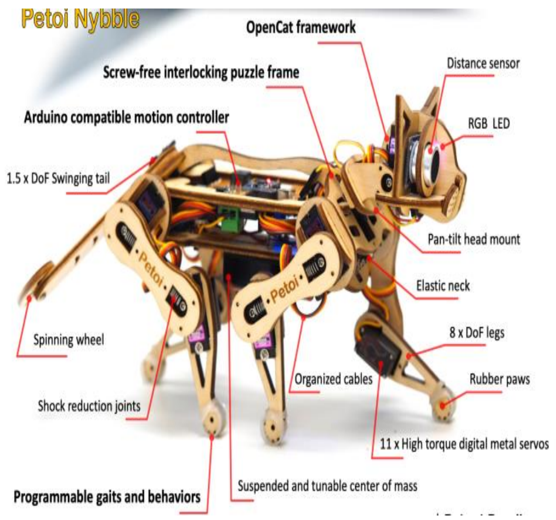
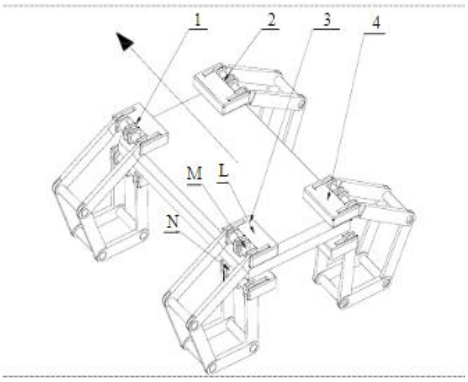


Figure 3.6 PETOI NYBBLE – Features

3.7 Four-foot robot structure based on Five-bar Mechanism

The mechanism of the robot based on the five-bar linkage parallel legs, as shown in Figure 3.7.1. Figure 3.7.1 is a schematic structural diagram for quadruped robot, and the whole robot is composed by four identical legs mechanism and a fuselage. Four legs of the robot assigned to the numbers 1, 2, 3, and 4, respectively. Three rotary drive motors are respectively added into the rotary pairs L, M and N



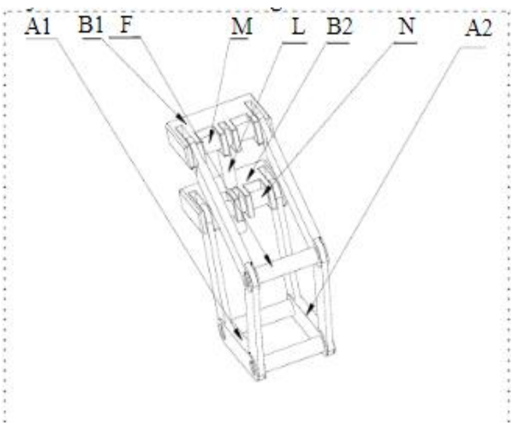


Figure 3.7.1 Schematic diagram of quadruped robot Figure 3.7.2 The leg structure of a single leg

For the legs structure of a single leg is shown in Figure 3.7.2. The two identical five-bar mechanisms A1 and A2 has five revolute joints of ABCDE, as shown in Figure 3. The two five-bar mechanisms are connected parallel through the three identical joints. The end of A of the five-bar linkage is coupled with upper base B1 by rotation, and the end of E of the five-bar linkage is coupled the lower base B2 for rotation. M, N is a revolute joint that move the leg up and down around of the body. L is a revolute joint that can moves the leg back and forth around the body.

The diagonal gait is a common gait for quadruped robot. According to the research, diagonal gait is the most energy saving gait for the nature. For this model, we are analyzing the stability of the robot during its advancement, and changing in the center of gravity. The whole cycle time is about 12s. Within 2s, the legs 1 and 4 are raised, the legs 2 and 3 are grounded, and within 2s to 4s, legs 1 and 4 are rotated. Legs 2 and 3 Legs are still on the ground, 4s to 6s, Legs 1 and 4 are on the ground. Within 6s to 8s, Legs 2, 3 raise, 1 and 4 Legs on the ground. Within 8s to 10s, the legs 2 and 3 rotate, the legs 1 and 4 still touch the ground. within 10s to 12s, the legs 2 and 3 land. For this time, all four legs are on the ground.

3.8 Four-legged robot

The aim of this project is to design and build a legged walking robot, much like a spider, that would be capable of traversing terrain that would otherwise be difficult or unstable for a wheeled or tracked vehicle. Unlike other type of system, walking robot shown in Figure 3.8 are more complicated to design due to their relative complexity, as they normally require complex mechanical system to support the walking algorithm [10] and [11]. Most existing walking robot requires many motors to realize the movements and are often suited for a sole task. Without major modification to the design, it is difficult to use for another job. Therefore the general walking robot, which could be easy adapted depending on job required, is of interest. This project emphasizes simplicity in the design with mechanical components that are easy to manufacture. It incorporates modularity in the design concept so that the later development of add-on units such as vision, sound, and other mechanical and electronic control units which would use their own processor can be added to enhance the control units which would use their own processor can be added to enhance the control and movement commands to the controller for the legs. Figure 1 Shown the walking robot.

Figure 3.8: Spider-bot –Space Exploration

3.9 Spider Robot

The robot presented in a four-legs walking robot as shown in Figure 3.9. Such a design gives better proportions of width to length and also reduces the number of components and weight. This project design of the leg drive mechanism, hardware architecture and the leg control method for walking machines. The body of knowledge that apply on robots is quite well developed. In designing a walking robot a power supply issues must be considered which is the required power to generate movement of the joint using a servo motor and the required of a algorithm to enable the robot to move. Leg lift is individually controlled through twelve small motor, which make the robot able to walk on uneven and sloped surface.

Figure 3.9: Spider Walking Robot

4. PROJECT REQUIREMENT

4.1 Software:

- Arduino programmer
- Solidworks
- CURA slicer

4.2 Hardware:

- Arduino UNO/Mega
- MG92B 3.5 kg/cm RC Servo (Metal gear)
- 12 Channel Servo Driver
- Ultrasonic Sensor
- IR sensor
- Accelerometer
- Bluetooth module
- 18650 3.7V Li-ion battery with charger
- 18650 Battery holder
- Breadboard
- Jumpers
- PLA Filament
- Srews and Nuts

4.3 Parts specification

No.	Item	Quantity	Part Number	URL	RM / unit
1	RC Servo motor (Metal gear)	12	MG92B	CTRL+LINK	29.00
2	12 channel servo driver	1	HAT-SERVO	CTRL+LINK	50.00
3	3.7V Li-ion battery	8	18650	CTRL+LINK	9.00
4	18650 battery charger	1	LI-CR-18650-2	CTRL+LINK	16.00
5	18650 dual battery holder	4	-	CTRL+LINK	7.80
				Total :	517.20

5. METHODOLODIES

5.1 Idea Review

Based on the literature reviews and researches, we decided to design a mammal-type quadruped robot. Mammal-type quadruped robot has higher centre of gravity, but its four legs are much closer to the body compare with sprawling-type quadruped robot. With this advantage, the robot can be controlled easily in term of stability of the body which it will not swing easily when the legs are moved. Another advantage will be the body can remain steady why the robot is moving forward whereas body of sprawling-type quadruped robot will be turned slightly when the robot is moving forward. This may cause the sprawling-type quadruped robot not moving in a straight line.

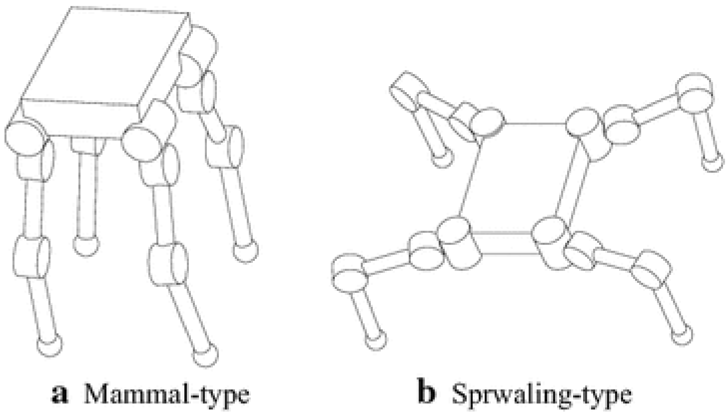


Figure 5.1 Two types of Quadruped Robot

5.2 Conceptual Design

This part shows the preliminary drawing showing the idea that has been developed. The drawings are drawn using Solidworks and showing the basic structure of our mammal-type quadruped robot as shown in Figure 5.2.1.

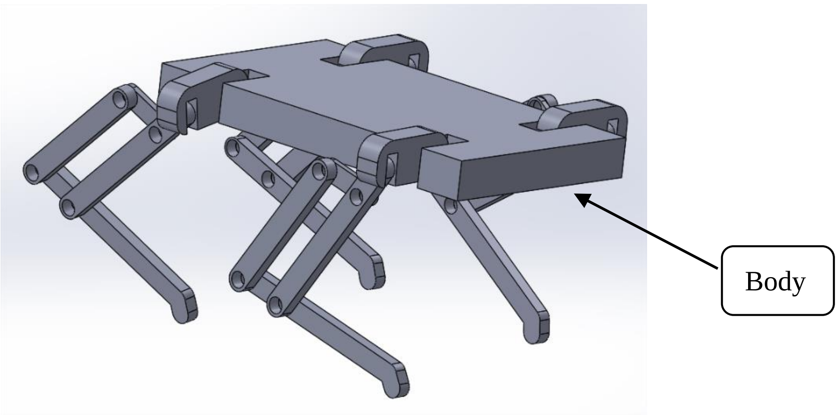


Figure 5.2.1: Basic Structure of Mammal-Type quadruped robot

The center part is its body which microcontroller, sensors, driver and battery will placed on top of it. The body is attached with 4 legs, each leg is controlled by 3 RC servo motor. Figure 5.2.2 shows the breakdown of the leg with side view and front view.

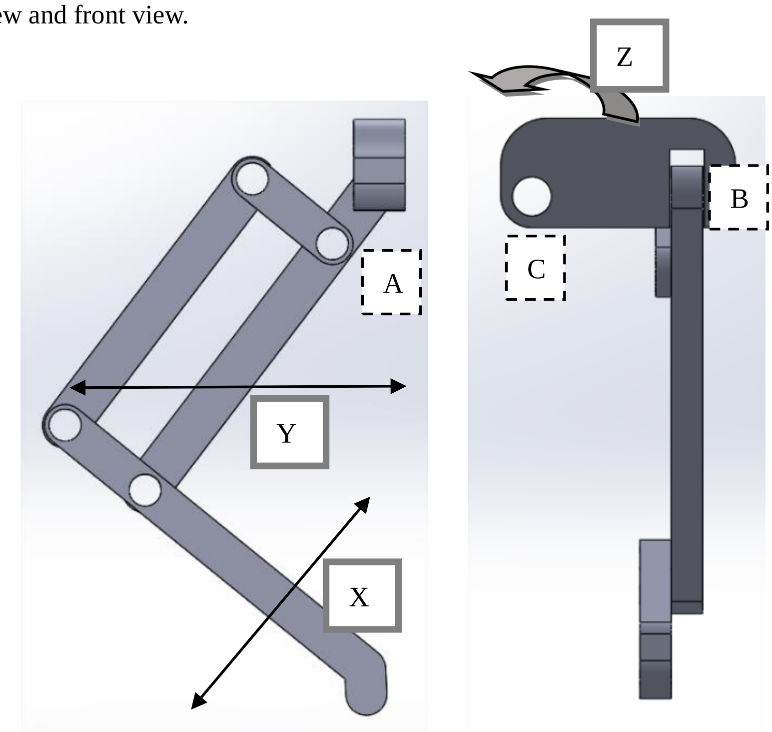


Figure 5.2.2 Side view and Front view of leg

Three points are labelled in Figure 5.2.2 showing the position of servo motor. Servo at Point A is to control the lower leg to move in X direction to retracts or expand the leg. Servo at Point B is to control the whole leg in direction Y to move forward or backward. Servo at Point C is placed at the body and control the leg move in Z direction for changing direction and achive stability.

The moving mechanism involving all legs to move together. The legs are paired diagonally and move simultaneously. The first pair of leg is rised by servo at point A, the servo at B will move the legs to positive Y direction, then the servo at A will lower the leg to touch the ground. At the same time, the second pair will remain touching the ground to maintain the stability, but servo at B will turn in negative Y direction to move the body forward. Thus, the quadruped robot can move forward.

5.3 Control system

The control system of the mammal-typed quadruped robot is wrote using Arduino and control by Arduino microcontroller. All servo motors will be control directly by the Arduino. Another closed-loop control system is implemented on the robot by placing IR and ultrasonic sensor. When the sensors sensed obstacle, it will automatically avoid the obstacle. Besides, the robot can also control using android phone by communicate with Bluetooth module on Arduino.

5.4 Prototype

Most of the parts will drawn and printed using 3D printer. The parts will then assembly using screws and nuts to create a solid structure of the robot. The electronic components such as servo motor, sensors and servo driver will all connected on a breadboard and placed on the body.

5.5 Testing

One of the important tests is to test the centre of gravity of the robot including all hardware and electronic components. Next will be the angle of rotation for each servo motor at Position A, B and C.

6. PROJECT TIMELINE

NO	TASKS	Timeline (week)													
		1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	Literature Review														
2	Conceptual Design														
3	Prototyping														
4	Robot Assembly														
5	Testing														
6	Report Writing														

7. CONCLUSION

The conclusion reached is four legs walking robot can widely use in industries such as delivering item to other departments. This research is more on natural view which is evident from natural walkers, like the dog, lizard and spider that the mechanics of the system play a vital role in stable and agile walking. If we are content to build legs that are only well suited to walking, than it would seem that there is great scope for producing very powerful walking machines with the technology already available. There is a temptation here to try to imitate the capabilities of natural systems, which tend to be multi-functional, but this again causes over-complication of the problem. Whilst a fast running animal is likely to be able to use its legs for other things, it does not need that flexibility of application for the task of running. Given that human technology can already build robot arms capable of greater precision than any organic system, it makes sense to split the roles of robot systems.

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