THE HOPPING ROBOT WITH ONE LEG

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MAY 2007

"I hereby declared that I have read through this report and found that it has comply the partial fulfillment for awarding the degree of Bachelor of Electrical Engineering (Control, Instrumentation and Automation)"

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Supervisor Name : Mr. Mohd Shahrieel Bin Mohd Aras

Date : 7/5/07

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Faculty of Electrical Engineering
Universiti Teknikal Malaysia Melaka

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"I hereby declared that this report is a result of my own work except for the excerpts that have been cited clearly in the references."

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ABSTRACT

The control of dynamically stable legged locomotion has made great strides in the past decade. Usually powerful hydraulic actuators are harnessed for control of legged robot. In this report, focus on a planar one-legged hopper or leg Hopping Robot with one leg which is electrically actuated. This type of actuation technology is clean, safe, and cheap, suitable for indoor use and autonomous robot. However, because DC motors (servo motor) have much smaller torque/mass ratio than hydraulic actuator. The one leg Hopping Robot with was designed and constructed, and it is used the PIC 16F877A microcontroller to control the servo motor coupled with spring or legged. The legged of The Hopping Robot used spring retracted to store energy in leg compression and released the energy. The cycle repeats to make it bounce. The Programming Language C is achieved through mikroC software and download to the microcontroller. Special consideration must be paid to design and control of the Hopping Robot.

ABSTRAK

Banyak kajian telah dilakukan pada dekad ini untuk mengawal kaki robot yang stabil. Biasanya kekuatan penggerak hidraulik digunakan untuk mengawal kaki robot. Laporan ini difokuskan kepada robot melompat dengan satu kaki yang menggunakan penggerak elektrik. Penggunaan teknologi penggerak elektrik ini adalah murah dan sesuai untuk diaplikasikan pada mana-mana robot. Bagaimanapun motor arus terus atau motor servo mempunyai daya kilas yang kecil berbanding dengan penggerak hidraulik. Robot ini telah direkacipta dan dibangunkan dan ia menggunakan mikropengawal PIC10F877A untuk mengawal pergerakan kaki robot yang disambungkan pada spring. Kaki pada robot melompat ini akan ditarik untuk menyimpan tenaga dan dilepaskan agar tenaga pada spring tersebut dapat dilepaskan. Kitaran ini akan berulang untuk membolehkan ia melompat. Pengaturcaraan bahasa C digunakan pada perisian mikroC dan program ini akan dimuat turun ke dalam mikropengawal. Penelitian yang jitu diperlukan untuk membangunkan projek agar ia berjaya dilakukan.

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CHAPTER 1

INTRODUCTION

1.0 Introduction

As human beings we have remarkable abilities to go almost anywhere on this planet under our own power, using arms and legs, instinct and cunning. A large chapter of the history of technology is about inventing machines that augment our abilities to move ourselves and our materials. Now there is a category of machines emerging that are intended to move about the world on their own to carry out human purposes. Many of these machines roll, some fly, but a number have adopted the peculiar advantages of legs.

This understanding could lead practical benefits in medicine such as advance in prosthetic technology. Understanding the nature of legged locomotion could also lead to the development of machine capable of traversing a much wider variety of terrain than is possible with wheeled and tracked vehicles.

For the Hopping Robot with one leg project are concerned with examining the mechanism behind the process of legged locomotion. The principle of investigation is a synthetic approach by trying to create machines that have these behavior, this report will discover all of factors that are fundamental of locomotion without distracted by detail specific to animals.

To date, a robot that can hope has constructed. The dynamic legged locomotion has been concerned with such as hopping rather than statically stable locomotion. The machine is supported on its legged and could freeze its motion and remain standing.

In the text of this report, the perspectives of this on going research effort. The result is The Hopping Robot with one leg, which is the subject of this report.

1.1 Objective

Objective of this project is aim to produce low cost Hopping Robot with one leg that is capable to hope over uneven terrain.

1.2 Scope of project

This project is to design a simple and build a simple control of the hopping robot that has a single leg so hopping is only way it can use. The hopping Robot is just like a prototype. The characteristic of this robot are:

- The leg use spring so that it can be compressed between one step and next to add energy.
- This robot driven by servo motor controlled by PIC 16F877A to pull a spring.

1.3 Problem Statement

When a human learn to walk, there is a long process of trial and error. The baby tries a behavior, and the result modify further attempts. In developing this robot, a similar procedure takes place. A behavior is planed and attempts are made, so observation is used to modify the software to achieve the behavior desire. The human experimenters are learning loop for the robot.

This robot are not energetically or computationally autonomous, and have an umbilical to supply power and communication and not incorporate with sensing, who can remotely steer the machine and chosen to simplify the problem to two dimensions. This constrains captures many features of the problem while allowing easier development.

1.4 Why Study Legged Robots.

This report is about the machines that use legs to hope. The purpose of this robot is to study the principles of leg locomotion. Such principles can help us to understand animal locomotion and to build useful legged vehicles.

There are three main reasons for exploring the use of legs for locomotion. First is the study of the mobility in the difficult terrain. Today is vehicles use wheel to move and provide motion only on prepared surface such as rails and roads. However most of places have not been paved. It seem possible to build vehicles which use leg like animals for locomotion.

The second reason to study legged machines is to understand human and animal locomotion. The principles of control which is used in human and animal locomotion is to build machines that locomote using legs.

The third reason which motivated the study of legged locomotion is used to build artificial legs for amputees. For below knee amputee and above knee prostheses some practical feet have been built, but there is still long way to find appropriate mechanisms which can be substitute the real organs.

CHAPTER 2

LITERATURE RIVIEW

2.0 Introduction.

A major motivation for studying the principles of legged locomotion is to develop useful legged vehicles, which should be able to move on rough terrains that are unreachable with conventional wheeled or tracked vehicles. Such scientific research will also lead us to a better understanding of human and animal locomotion. Running is a process of falling, storing energy and rebounding.

The Hopping Robot with one leg actually is getting the inspiration from the project Uniroo a One Leg Dynamic Hopping Robot by Garth J.Zeglin for his undergraduate report at the Massachusetts Institutes of Technologies on May 1991 and The Bow Leg Hopping Robot for his Phd Thesis at Carnegie Mellon University on October 1999.

2.1 The Uniroo.

The Uniroo is an attempt to more closely simulate the physical structure of an animal. The Leg is kinematically similar to real kangaroo and is proportional in size to a kangaroo of similar mass. One common feature of the robots constructed is two link pneumatic leg that changes length by telescoping. A linear hydraulic actuator and an air spring in series inside the provide energy input and storage. This design works, but suffers from low ground clearance and mechanical difficulties associated with the long linear bearing and the number of custom built parts.

A Uniroo used the actuator at it leg but The Bow Leg Hopping Robot only used just bow leg which is flexible and work likes a spring for the hopper. So to solve the problem he has to make a new design what we call The Bow Leg Hopping Robot that is simple and principled. From this design The Bow Leg Hopping Robot can be adapted and the concept and parameter of the one leg hopping robot can be used because the both design are similarly.[1]

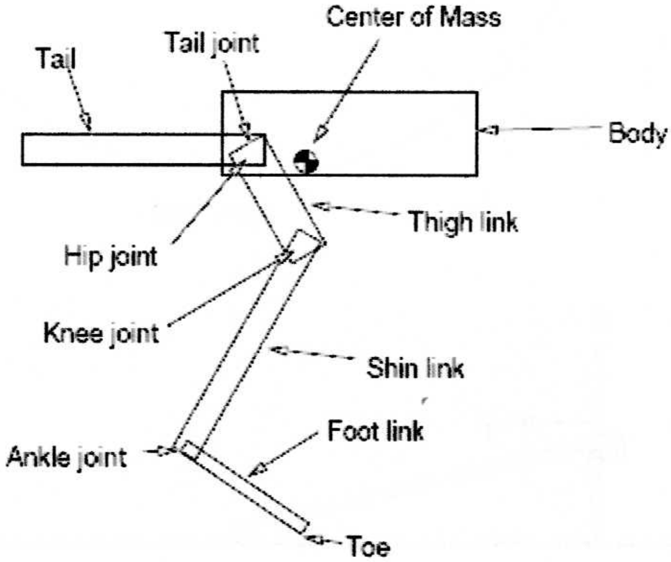

Figure 2.1 : Schematic Diagram of Uniroo.

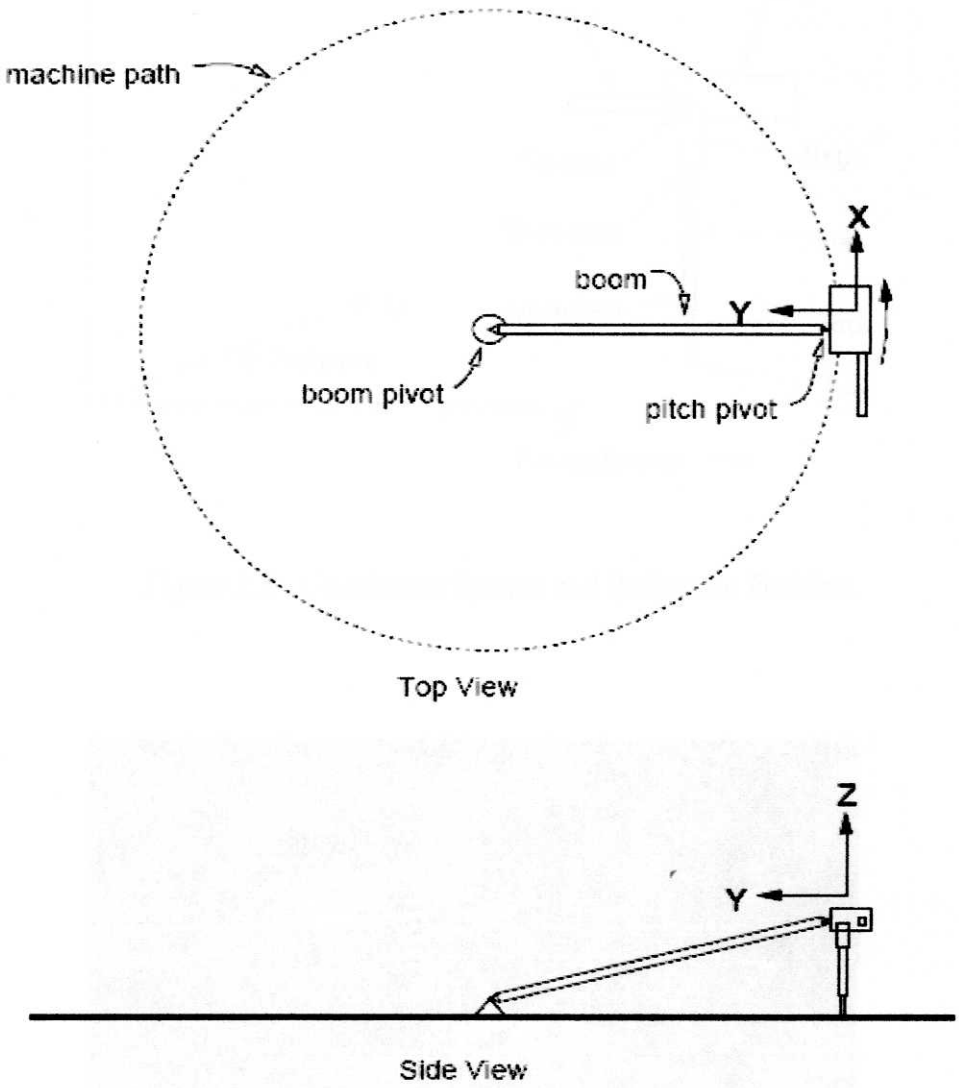

Figure 2.2 : Schematic Diagram of Planarizer.

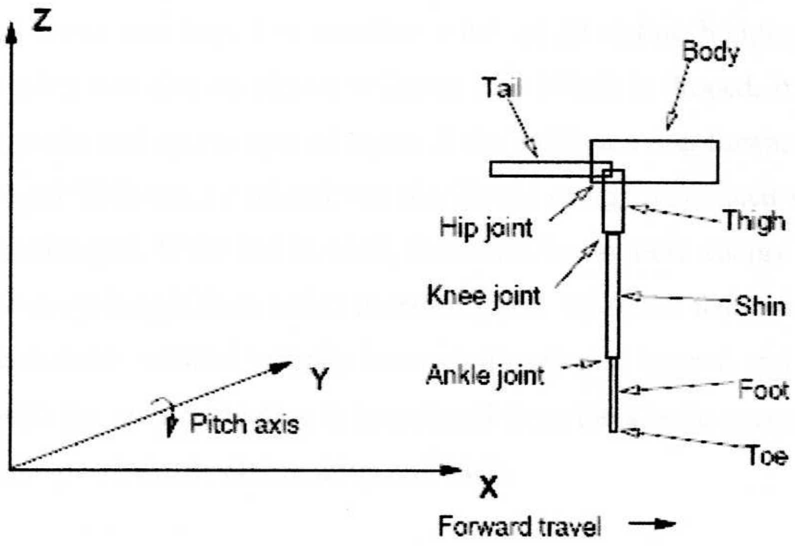

Figure 2.3 : Coordinate System and Reference Position.

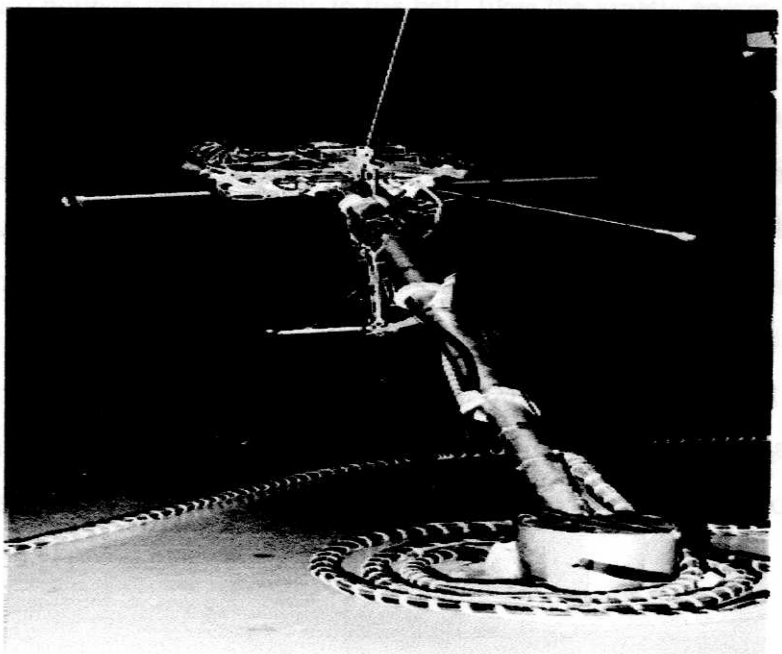

Figure 2.4 : The Actual Photo of the Uniroo.

2.1.1 What is hopping?

The Uniroo can hop. Let consider what might define hopping. Consider the simplest hopping machine as shown in figure 2.5. If ball is droped, it will fall to the ground, compress, and spring upward again. If the ball is moving forward, it will remain moving forward. This can be related that the kinetic energy associated with its forward velocity is unchanged. If the ball is ideal, there will be no more energy lost, and it will bounce to the same height from which it was dropped. The chief features of this hopping machine are that the vertical velocity reverses direction at impact, and that the energy associated with the vertical motion is transferred from the kinetic energy of falling into a potential energy of elastic deformation and back.

If consider a slightly more complicated machine, we can get an idealized hopper as shown in Figure 2.6. It consists of mass at one end of telescoping leg, which is two part leg with sliding joint, which has compressive spring inside and a toe on the end. If the hopper is dropped straight down, and the toe is directly under the center of mass (COM), it will bounce very similarly to the ball, likes the kinetic energy of the body will be absorbed by the spring and released, the vertical velocity will have reversed direction, and the horizontal will still be zero. This assumes a highly ideal operation, with the mass exactly over the toe, since the leg is an inherently unstable inverted pendulum. If the hopper is moving forward as it fall the horizontal kinetic energy can be absorbed and released similarly to the ball. For this to work, the leg must be positioned forward at landing at a position such that it will be at a symmetric position at litoff, which will maintain same horizontal speed. A problem that now arises now is that the leg must be moved from the liftoff position to the take off position, which requires applying torques that will rotates the body. Our solution to this problem is include a tail to counterbalance the leg motion.[1]

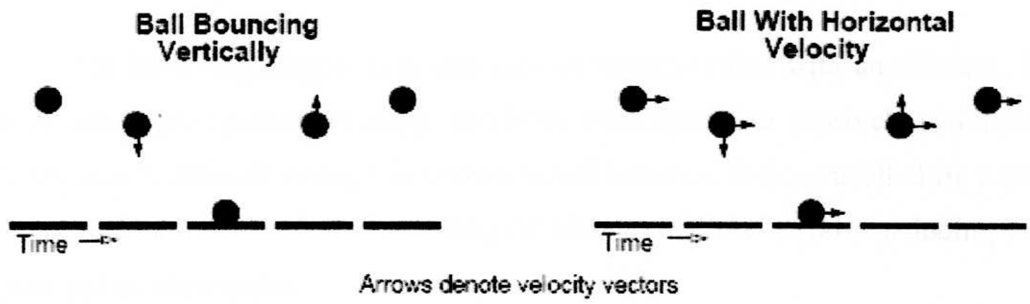

Figure 2.5: Bouncing Ball Hopper.

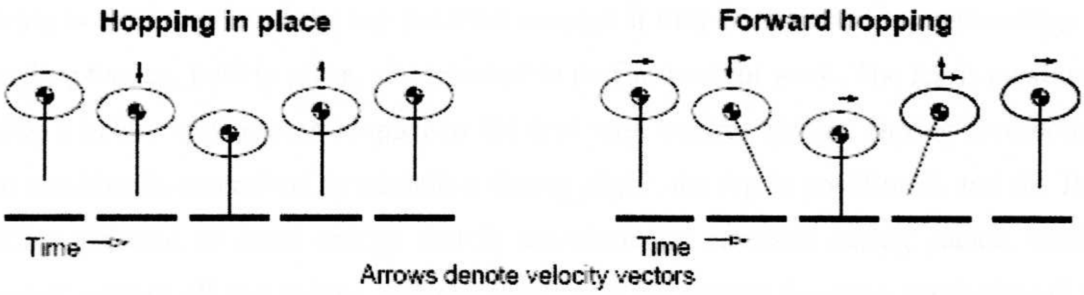

Figure 2.6 : Idealized Hopper.

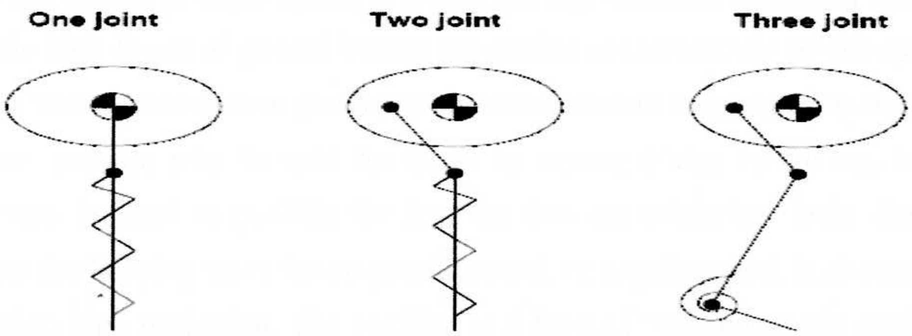

Figure 2.7 : An evolution of leg.

2.2 The Bow Leg Hopping Robot.

The Bow Leg Hopper is a new type of running robot with an efficient, flexible leg. A one-legged planar prototype has been developed that passively stabilizes body attitude and is efficient enough to use on-board batteries. It is controlled by a real-time planner and has demonstrated crossing of simple artificial terrain including stepping stones and shallow stairs.

The machine hops using a Bow Leg, a new type of resilient, flexible leg named for its similarity to an archery bow. The Bow Leg comprises a curved leaf spring, foot, freely pivoting hip, and the Bow String that holds the leg in compression. The Bow String is used to control the leg potential energy: it may be retracted to store energy by bending the leg, held in place, and released to perform useful work. The leg is positioned using a hobby servomotor coupled to the foot with control strings. During locomotion, the machine is controlled by actuation during *flight*: the leg is positioned, and the Bow String retracted to store energy that is automatically released during stance. During ground contact all the strings become slack, and the hopper bounces passively off the ground with no forces or torques supported by actuators. The hip joint is attached to the body slightly above the center of mass so the body effectively hangs from the hip during ground contact and the natural pendulum forces passively stabilize body attitude.

In this design a single spring provides the leg structure, elasticity, and energy storage. The high forces of ground impact are carried conservatively by the spring and hip bearing. This addresses four problems central to dynamic legged locomotion such as a low-power actuator may be used for thrust by storing energy in the leg; low-force actuation may be used to position the leg, the free hip minimizes body disturbance torques; and the hopping cycle is energy efficient since negative work is eliminated and the spring has high restitution. The machine is a form of "programmable mechanism" configured by leg position and stored energy during flight to control the evolution of the bounce dynamics.

The physics of the machine have been modelled in closed form using a combination of idealized analysis and empirically determined functions. These models are used by a planner that finds sequences of foot placements across known terrain to a goal position by searching a graph representing the trajectories reachable from any given landing. The planner uses heuristics to discretize the continuous control space and estimate path costs. Paths are generated in real time as needed in conjunction with a feedback controller that rejects local disturbances.[2]

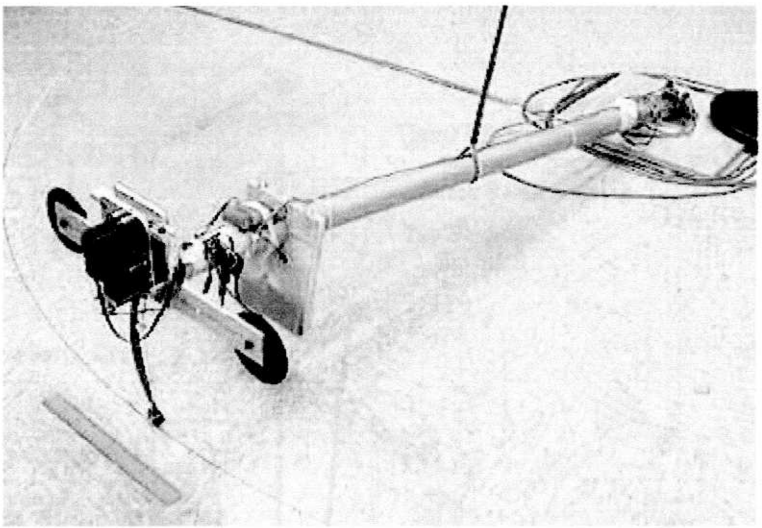

Figure 2.8 : Schematic of the constraint boom.

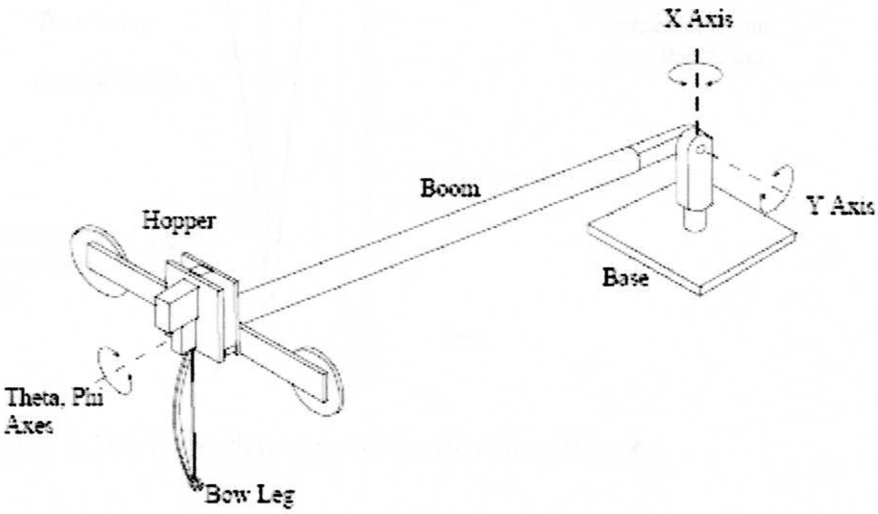

Figure 2.9 : Photograph of the hopper prototype.

The hopper runs in a circle defined by the boom. The boom allows three degrees of freedom on the surface of a sphere (x ,y) _ position and body rotation. The leg rotates around the hip (Ø axis) parallel to the body rotation.

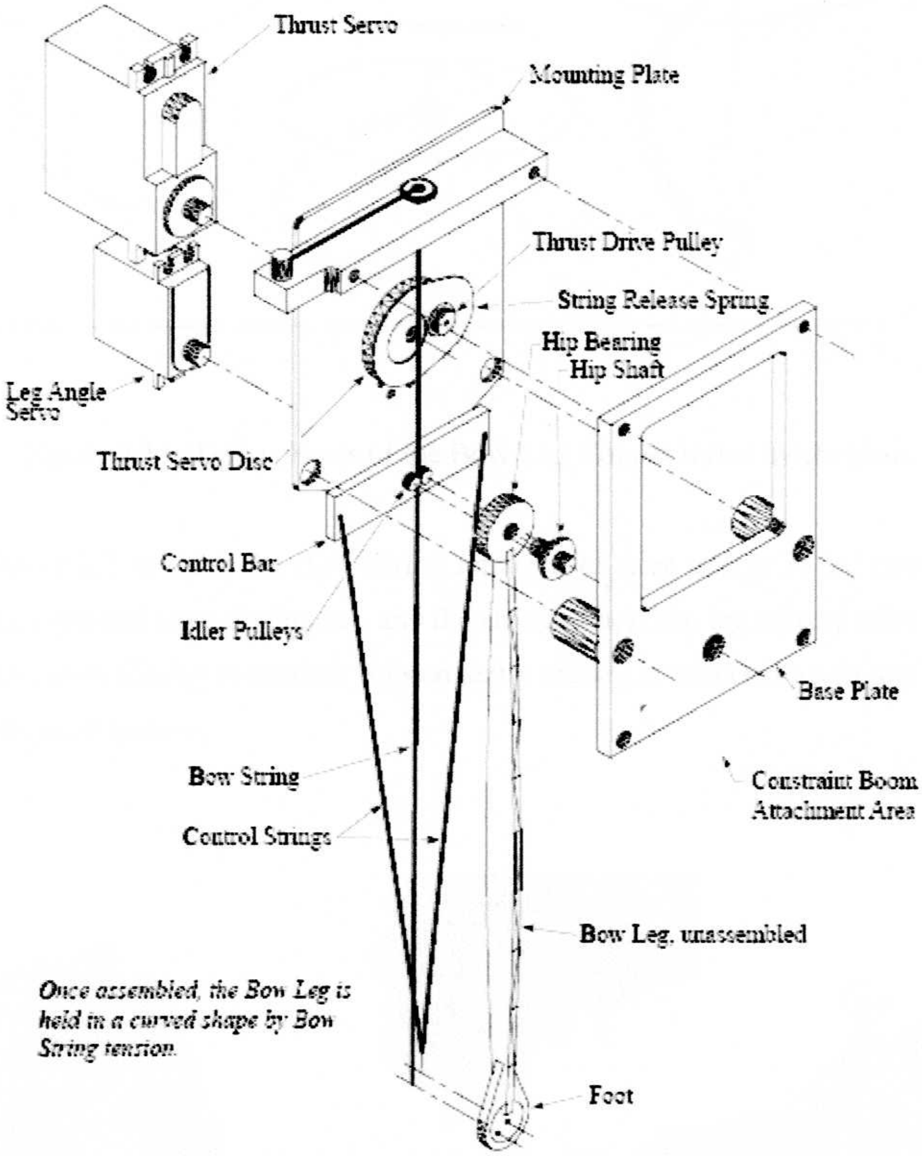

Figure 2.10 : Exploded view of the Bow Leg Hopper.

The top servo rotates a disk carrying the drive pulley that can engage the Bow String in order to compress the leg. The bottom servo positions the leg. The hip is an