Abstract

Robotics is a relatively new and fast growing industry with many different opportunities and fields of study. One such filed is the research and development of Bipedal and Quadrupedal Walkers (QPW). These amazing machines have the potential to revolutionize the way we conduct remote exploration, natural disaster relief and more. Traditionally tracked vehicles have been leading the way in such applications, but this is changing fast. With the many different QPW designs one challenge we see most prevalent is the inability for these walkers to traverse rough and uneven terrain. Some have found even through serial actuation of rotary motors and the implementation of a toe and foot joints it is still difficult to implement such activity because of the high torque generated by the loading weight of the body[10].

This problem can be solved by implementing a self stabilizing ankle that will give any such walker the ability to evenly distribute the mass load and maintain balance while navigating extreme conditions. With this in mind we have begun conceptual designs of an ankle and plan to take this design and implement it on a larger project called "Big Bear", which was inspired by "Big Dog" a QPW developed by Boston Dynamics (as shown in Figure 1) [2]. The knowledge required to complete this project will include Mechanical Engineering,

Figure 1 Big Dog[2]

Electrical Engineering, Computer Systems Engineering, and Mathematics. The goal for the 2010-2011 school year is to complete an ankle assembly capable of self stabilization.

Introduction

In modern robotics some common challenges in developing an ankle is maintaining fine motor skills and stability while navigating uneven terrain. One such design was developed by Jungwon Yoon, H. Nandhal, DongGyu Lee and Gap-soon Kim from the School of Mechanical & Aerospace Engineering, Gyeongsang National University, Jinju, Korea. This design presents a new four degree of freedom (4-dof) serial-parallel mechanism with three platforms which is shown in Figure 2[10].

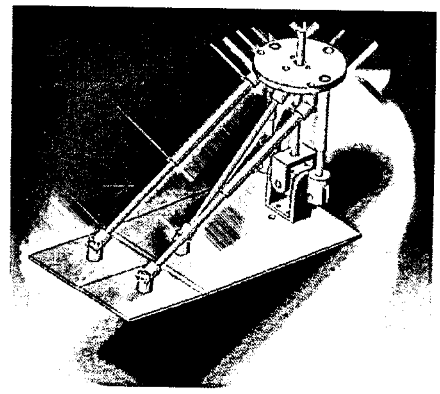

Figure 2 Developed Humanoid Foot[10]

This mechanism can generate pitch and roll motions at each platform[10]. Another example of current research is an Ankle-Foot Emulation System developed by Samuel K. Au, Peter Dilworth and Hugh Herr of *MIT* Media Lab Massachusetts Institute of Technology[11]. This complex system is described as follows, "The emulator system is comprised of a high performance, force-

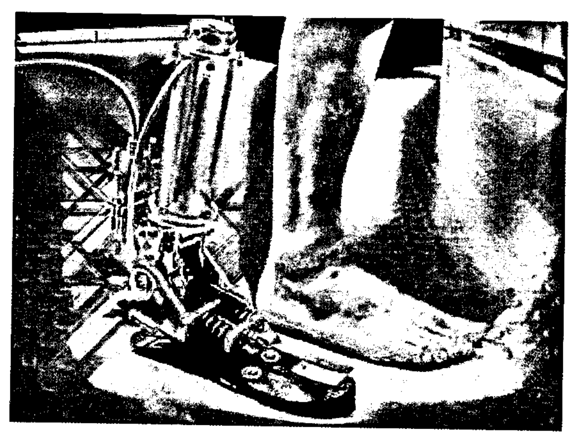

Figure 3 Foot Emulator[11]

controllable, robotic ankle foot worn by an amputee interfaced to a mobile computing unit secured around his waist. We show that the system is capable of mimicking normal ankle-foot walking behavior " (Figure 3)[11].

These various design all contribute in furthering our ability to design and develop advanced walkers capable of navigating varies terrains. With this in mind our team is working towards taking these concepts of humanoid foot designs and develop a self stabilizing ankle assembly that will provide fine motor functions for any QPW. We find that some of the challenges that we may face are creating self adjusting algorithms that react to the ground while maintaining a center of gravity relative to whatever platform the ankle is mounted on. These challenges will be meet with extensive testing and research. The outcome of this project will be a major contribution in the advancement of robotics and the University of Alaska Anchorage.

Project Design

We have divided up the design and manufacture process into four sections. The first section is concept design, second is soft design, third is design for assembly analysis, and fourth is fabrication.

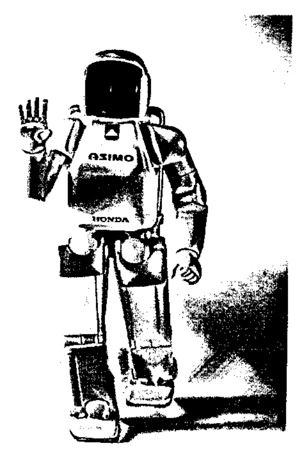

Figure 4: Honda ASIMO Robot

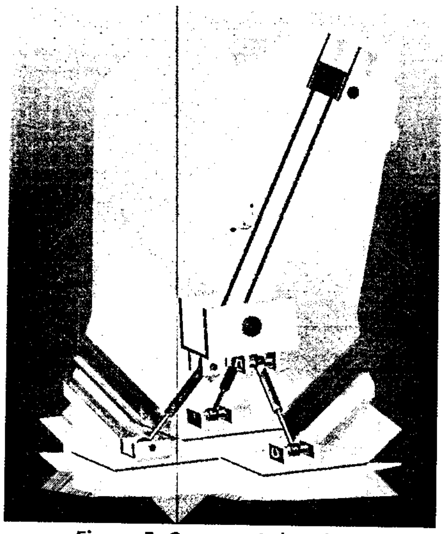

Figure 5: Concept 1 drawing (9)

During concept design, the group came up with multiple designs. One such design was based off of a 3 linear actuator ankle principle as seen in Figure 5 and was not chosen because the speed of linear actuators is inadequate for timely stabilization reactions. The chosen concept is based off of the Honda ASIMO robot pictured in Figure 4. The ankle is comprised of two 180 degree sweep rotating axes as seen in Figure 6. These two axes are stacked one on top of the other and perpendicular in orientation. These two axes will allow for rotation from front to back and left to right. This will allow for full bidirectional rotation of the robots ankle for the purpose of keeping the center of gravity of the leg as near to directly above the center of the foot as possible for stability.

The soft design section of the foot and ankle assembly is being developed using Pro/ENGINEER (ProE), a 3-D parametric modeling program (Figure 7). This program will allow us to create a working 3-D model of the assembly. The components of the foot ankle assembly will be tested for proper support and strength of the components during the Finite Element Analysis (FEA).

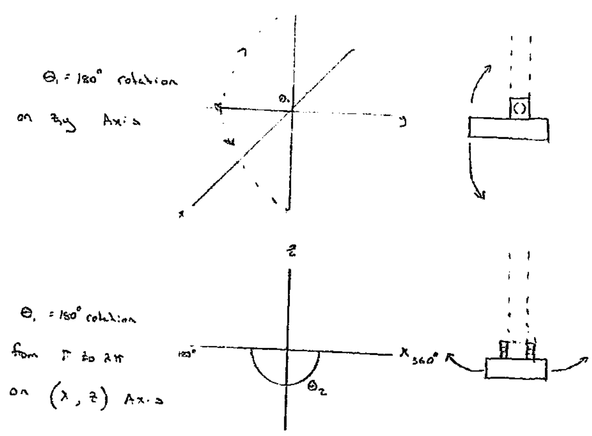

Figure 6: Servo motion (9)

Any trouble areas or unneeded components will be fixed or eliminated to facilitate ease of manufacturing of the prototype. Manufacturing will take place at the UAA Design Studio and machine shop. The components that make up the foot/ankle assembly include: 2 servo motors, a servo driver, a microcontroller, 2 accelerometers, materials for mechanical parts, and fasteners. The accelerometers will be attached to the structure above ankle. The accelerometers will be communicating with the microcontroller during operations. We will be using the accelerometers to determine if the foot is parallel to the ground. The micro controller uses linear transformations and inverse matrix theories derived from linear algebra to convert the accelerometer signal into a polar coordinate system that will control the motion of the servo motors. These matrix relations are depicted in Figure 8. This will be done for each servo motor simultaneously to allow for a full hemisphere of rotation of the foot. This simultaneous servo motor movement is critical to the stabilization of the ankle.

Figure 7: ProE Rendering (8)

$$Ax = B$$

$$x = A^{-1}B$$

$$A^{-1} = [A\ I] \sim [I\ A^{-1}]$$

$$T(x) = Ax$$

$$A = \begin{bmatrix} cos\varphi & -sin\varphi \\ sin\varphi & cos\varphi \end{bmatrix}$$

Figure 8: Linear Equations(12)

Anticipated Results

By the end of this project we have several outcomes that we expect to have completed; a manufactured ankle/foot assembly, servo motors implemented for bidirectional motion, and auto-stabilization control.

The manufactured ankle/foot assembly will have a complete hemisphere of rotation that will be controlled by the servo motors. The servo motors will have the ability to rotate in a bidirectional motion that will be instrumental in the auto-stabilization controls. The final result we expect to have completed is the auto-stabilization controls. This will give the ankle/foot the ability to self stabilize while maintaining a proper orientation with the ground, all while the lower leg is moved in varied directions.

Future Work

With the completion of this project, we plan to immediately start the next phase of the larger project which is the construction of a complete leg system using the knowledge gained. If future advancement continues after this, we will proceed with construction of the "Big Bear" in spring of 2012, which would be a fully functioning QPW robot and targeting this project for the mechanical engineering senior design class.

Project Budget

Item	Quantity	Unit Cost	Total Cost
Servo Motors	2	$415.00	$830.00
Accelerometer	2	$99.00	$198.00
Micro Controller	1	$400.00	$400.00
Analog Digital Cable	2	$100.00	$200.00
Steel Pipe 3' OD, .12" wall	10 ft	7.50/ft	$75.00
Manufacturing Components	N/A	N/A	$100.00
Shipping	N/A	N/A	$197.00
		Total	$2,000.00

Budget Justification

Servo motors:

- Actuate ankle in XZ and YZ planes.

Accelerometer:

- Receives and sends data that will allow the micro processor to analyze and determine polar position of foot.

Micro Controller:

- Receives data from Accelerometer and translate data to a polar position so that the servo can rotate.

Analog Digital Cable:

- Allows 8bit signal to travel from the micro controller to the servo.

Steel Pipe 3' OD, .12" wall:

- This will be used to construct a solid ankle and foot assembly.

Manufacturing Components:

- Components will consist of Bolts, Nuts, Washers, Pins and other small items that may not be foreseen during construction.

Shipping:

- Costs for shipping components from **lower 48**.

Project References

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(10) Jungwon Yoon', H. Nandhal, DongGyu Lee' and Gap-soon Kim2, A Novel 4-DOF Robotic Foot Mechanism with Multi-platforms for Humanoid Robot (SICE-ICCAS 2006) 26 February 2007.Retrived Oct 29,2010 www.IEEExplore.org

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Timeline

Task	Duration, Days	Start	Finish
Pro/ENGINEER Ankle	45	10/25/2010	12/03/2010
Order Parts	20	12/03/2010	12/23/2010
Ankle/Foot Manufacturing	30	12/23/2010	1/23/2011
Test Accelerometer	16	1/23/2011	2/8/2011
Test Motor Control	10	2/8/2011	2/18/2011
Test Motors with Ankle	10	2/18/2011	2/28/2011
Test Motor Control with Platform	30	2/28/2011	3/30/2011
Test Complete Assembly	14	3/30/2011	4/12/2011
Prepare Presentation	7	4/12/2011	4/19/2011
Presentation at UGR Symposium	Mid-April 2011		
Expenditure Deadline	April 30, 2011		
Final Report Deadline	May 15, 2011		