Passive-Spine Hexapod
MAE 440D Senior Project with Design Proposal

Greg Hughes (MAE '13) Chris Payne (ELE '13)
Hayk Martirosyan (MAE '13) Tom Owlett ('MAE 13)
Brendan O'Leary (MAE '13)

October 15, 2012

1 Design Objective

Robots are often modeled after animals in an effort to capture their naturally stable and efficient modes of locomotion. In particular, hexapods like cockroaches can traverse a huge range of terrain with relatively little energy. Many types of legged hexapodal robots have been designed with this biological motivation, but possibly the most successful adaptation is the RHex design from UPenn's Kodlab and Boston Dynamics[1]. By using rotary, compliant legs with a curved shape, the RHex is highly versatile yet at the same time simple enough to require only one active degree of freedom per leg. The RHex and machines of its kind owe their dexterity to various passively actuated compliant degrees of freedom that provide adaptation to the environment at high frequencies and force ranges.[2]

Our design aims to further model biological locomotion by incorporating a passive backbone into a RHex-like design. Having a fully rigid chassis lacks the flexibility and natural movement of reptiles and mammals, which employ many passive degrees of freedom in their bodies for robust navigation. Observations from nature and the rigid RHex design suggest that a body with the properly designed passive articulation would lead to improved behavior. Our goal is to design and build a RHex-like hexapod that utilizes this passive backbone to achieve increased stability and energy retention over irregular terrain.

Our team is in possession of an EduBot model, a smaller variant of the RHex, which will be used to guide the design of our own mechanical and electronic systems. The EduBot emphasizes flexible legs and a lightweight design achieved with high strength-to-weight ratio motors and a casing made of carbon fiber. These two essential components of a hexapod design allow for more responsive control and increased energy recovery in walking, a theme we will advance further with our passive backbone structure.

[1]Boston Dynamics: RHex Rough-Terrain Robot http://www.youtube.com/watch?v=ISznqY3kESI

[2]U. Saranli and M. Buehler and D. E. Koditschek, RHex: A Simple and Highly Mobile Hexapod Robot, http://kodlab.seas.upenn.edu/uploads/Kod/Saranli01.pdf

The chassis will be divided into three segments, with a system of joints and springs providing multiple passive degrees of freedom between segments, while still maintaining simplicity of design. We will be able to tune the rigidity of these joints to provide optimal efficiency on specific terrains. The design includes six DC motor/gearbox/encoder stacks, and regenerative motor controllers will provide position and speed control of each motor and recover the kinetic energy of the legs when braking. An Arduino module, connected to an on-board Linux CPU, will be used for high-level control. We will use a wireless router to enable our team to login remotely to the on-board Linux CPU, allowing us to update the Arduino closed-loop settings from a base station. This connection will also allow for the initiation of various autonomous routines and yield real-time access to the robot's camera feed.

The passive backbone will be capable of locking into a fully rigid condition in order to replicate the chassis of the RHex and compare the performances of the two designs. The spinal joints will have adjustable rest configurations and compliance values to facilitate experimentation. A standardized obstacle course will be built, which will be quantitatively measured in order to evaluate the robot in terms of stability and speed. Because of the change in dynamics introduced by the flexible chassis, new gaits and methods of locomotion may be developed and fine-tuned. As versatility and stability are the primary goals of the robot, it is important that the robot is able to perform in real world terrains as well as those we create in the lab.

This year long design project will be advised by Professor Nosenchuck (MAE), with consultation from Professor Holmes (MAE). We will meet weekly with Professor Nosenchuck and bi-weekly with Professor Holmes. Additionally, Chris Payne will meet with Professor Houck (ELE) on a weekly basis to discuss primarily electronics based challenges.

2 Timeline

Task	**Duration**	**Completed By**
Research Dynamics	1 Month	November 15
Mechanical Design	2 Months	December 1
Electrical Design	2 Months	December 1
CAD Model Completion	2 Months	December 1
Experimentation with EduBot	2 Months	December 1
Progress Report	1 Week	January 11
Construction	3 Months	March 1
Successful Locomotion	15 Days	March 15
Testing on Simple Obstructions	15 Days	April 1
Testing on Obstacle Course	15 Days	April 15
Report and Presentation	1 Month	May 1

3 Budget

Electrical Parts:

Item	**Price**	**Quantity**
Arduino Mega 2560	65.00	x1
PandaBoard/IntelAtom CPU	300.00	x1
Regenerative Motor Controller	125.00	x3
Rechargeable NiMH Battery	80.00	x1
Wireless Module	200.00	x1
Fuse Box	10.00	x1
Camera Module	100.00	x1
Infrared/Ultrasound Sensors	30.00	x1
Flex Sensors/Strain Gauge	10.00	x6
Total	1220.00	

Mechanical Parts:

Item	**Price**	**Quantity**
Carbon Fiber Fabric, 5’x1’	27.37	x1
Carbon Fiber Sheets 86585K62, 12”x24”	79.24	x1
Springs, Die or Extension	1.50	x4-8
Rubber Sheet 8630K112, 6”x6”	3.50	x1
Ball Joint 60625K93, 1.5” long	19.94	x2
Aluminum Angle, 8’	14.36	x1
Maxon DC Motor 118742, 23.9mNm, 10W	274.00	x6
Maxon Gearbox 406767, 35 reduction	158.00	x6
Maxon Encoder 110511, 500 CPT	84.00	x6
Obstacle Course Construction	100.00	x1
Legs	15.00	x6
Plastic Stock 85055K111, .5x6x6”	16.00	x1
Total	3520.00	

Total Estimated Budget: $4740.00

Mon. 8 Oct '12