Biomimicry: Design and Construction of a Multilegged Robot

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Abstract

The goal of this project is to develop skills in robotic locomotion and biomimetics, and to apply those skills in designing and building a robot to compete in the Colorado Space Grant Consortium's 2017 robotics challenge at the Great Sand Dunes National Park on April 15, 2017.

Design Inspiration

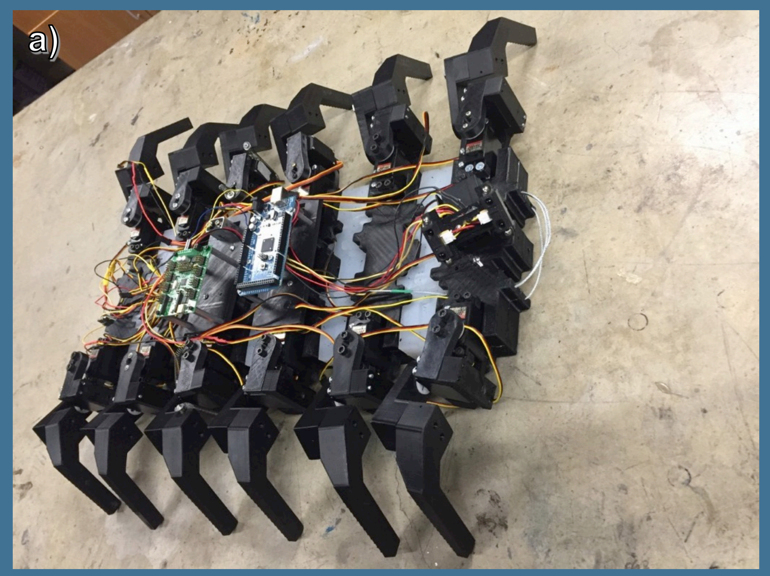
Biomimetics is the imitation of the models, systems, and elements of nature for the purpose of solving complex human problems. For my design, I began by examining animals that can successfully navigate an environment similar to that which would be encountered at the robotics competition. Ultimately, I found it most useful to study centipedes as they have evolved to exhibit not only robust movement (in that they can navigate terrain with variable features) but also use static walking. With static movement, the body's center of gravity is positioned in such a way that balance is continually maintained.

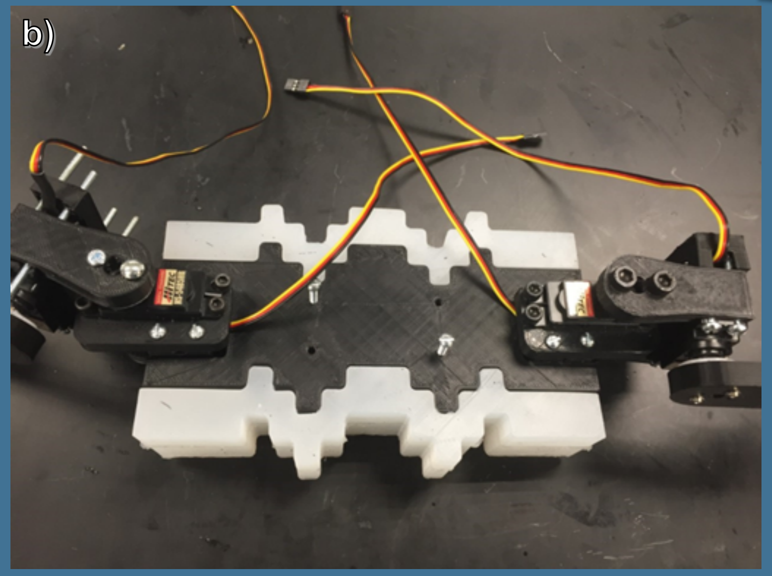
Locomotion

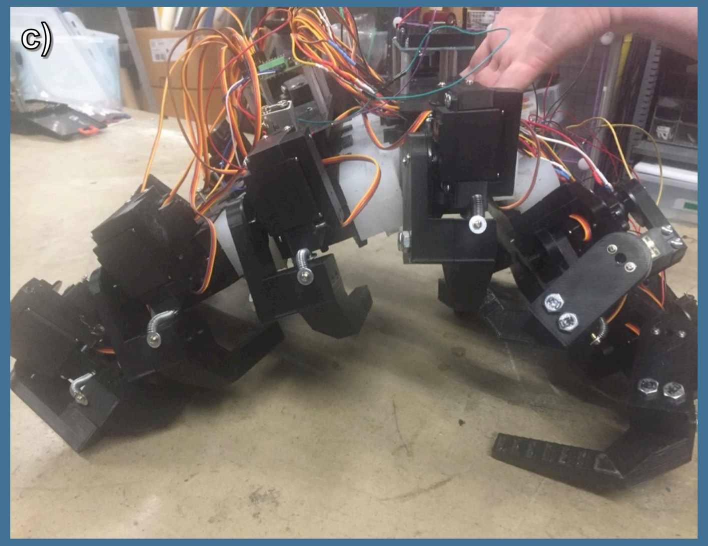
Centipedes move by a form of locomotion known as metachronal motion. Metachronal motion is coordinated, mechanical, sequential motion having the appearance of a traveling wave. This was achieved through using timing triggers to program the footfall patterns. The timing is set so that each foot shares the same ground contact and lift duration. In addition, this timing maintains the sequential motion of the legs. With this, I was able to achieve the desired traveling wave pattern. Moreover, during this motion, at least four feet on each side are in contact with the ground at any one time to maintain stability.

Body Design

The design is based on centipede physiology; multiple body segments each having a single pair of legs.





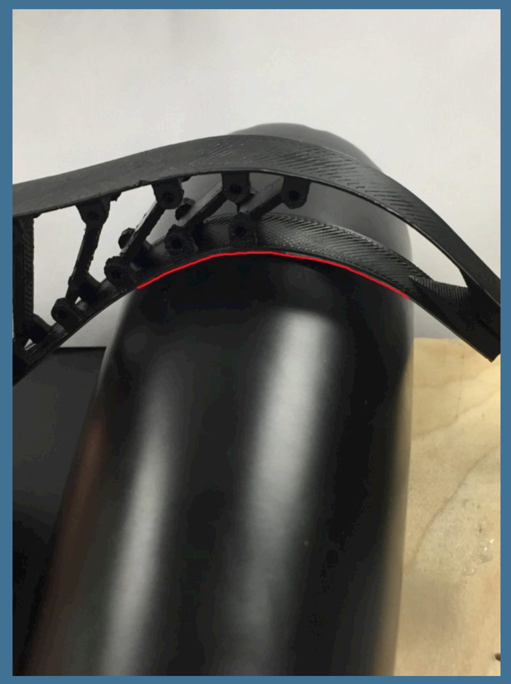


a) Completely assembled robot without tarsus
b) One vertebra with silicon discs
c) Example of disk elasticity and robot flexibility

One of the biological characteristics that I wanted to reproduce is flexibility. To achieve this, I mimicked the workings of the human spine. Each body segment could be considered a rigid vertebra, and, between each vertebra, are two silicon "discs". The vertebra were designed and 3D-printed in plastic so that they would have the desired rigidity as well as being lightweight. I molded the spinal discs using a soft silicon rubber, which I found in testing to successfully model the desired elasticity while maintaining its structural form.

Tarsus Design

Dung beetle tarsi are unique in the fact that they have the ability to grip and manipulate objects by conforming to their shape. This can be modeled through the use of the Fin Ray Effect, which is derived from the physiology of fish fins. Each fin ray is made of two pliable edges connected at the end at an acute angle. The edges are connected by ribs which hold the edges apart and allow elastic movement. When one edge is subjected to a force the structure automatically bends in the opposite direction of the applied force.



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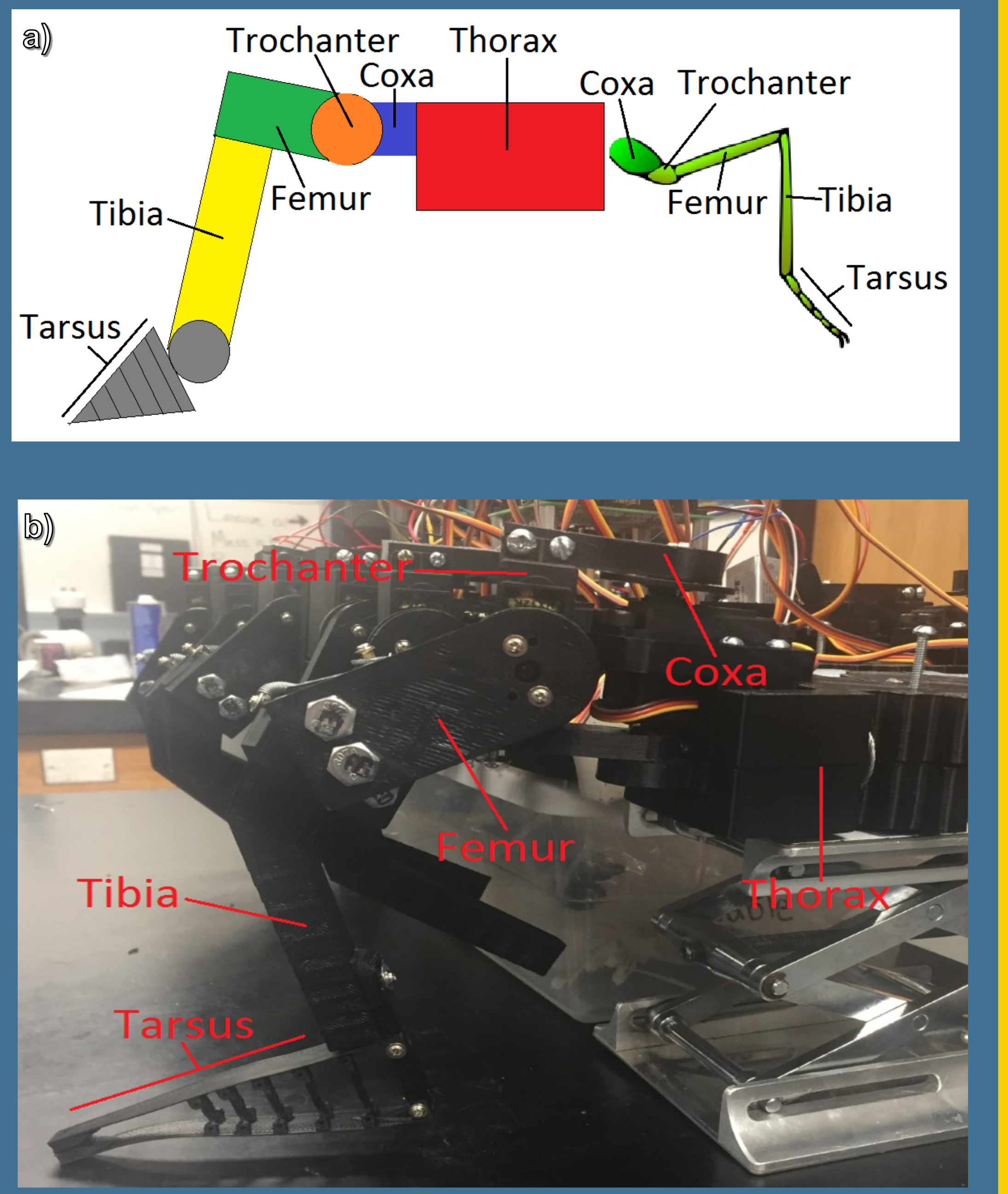
Leg Design

The legs of the robot were developed to mimic that of a typical arthropod leg.

Unlike a typical centipede leg, which is comprised of seven segments, the robot has legs comprised of 4 segments - the Thorax-Coxa, Coxa-Trochanter, a fused Trochanter-Femur-Tibia, and a Femur-Tarsus with 2 moveable joints at the Coxa-Thorax joint and at the Trochanter-Coxa joint.



a) Model of robot leg vs actual arthropod leg
b) Fully completed physical structure

Future Research

- Studying the effect of the flexible tarsus on the mechanics of the leg
- Machine learning for self optimization of gait over terrain unknown to the robot