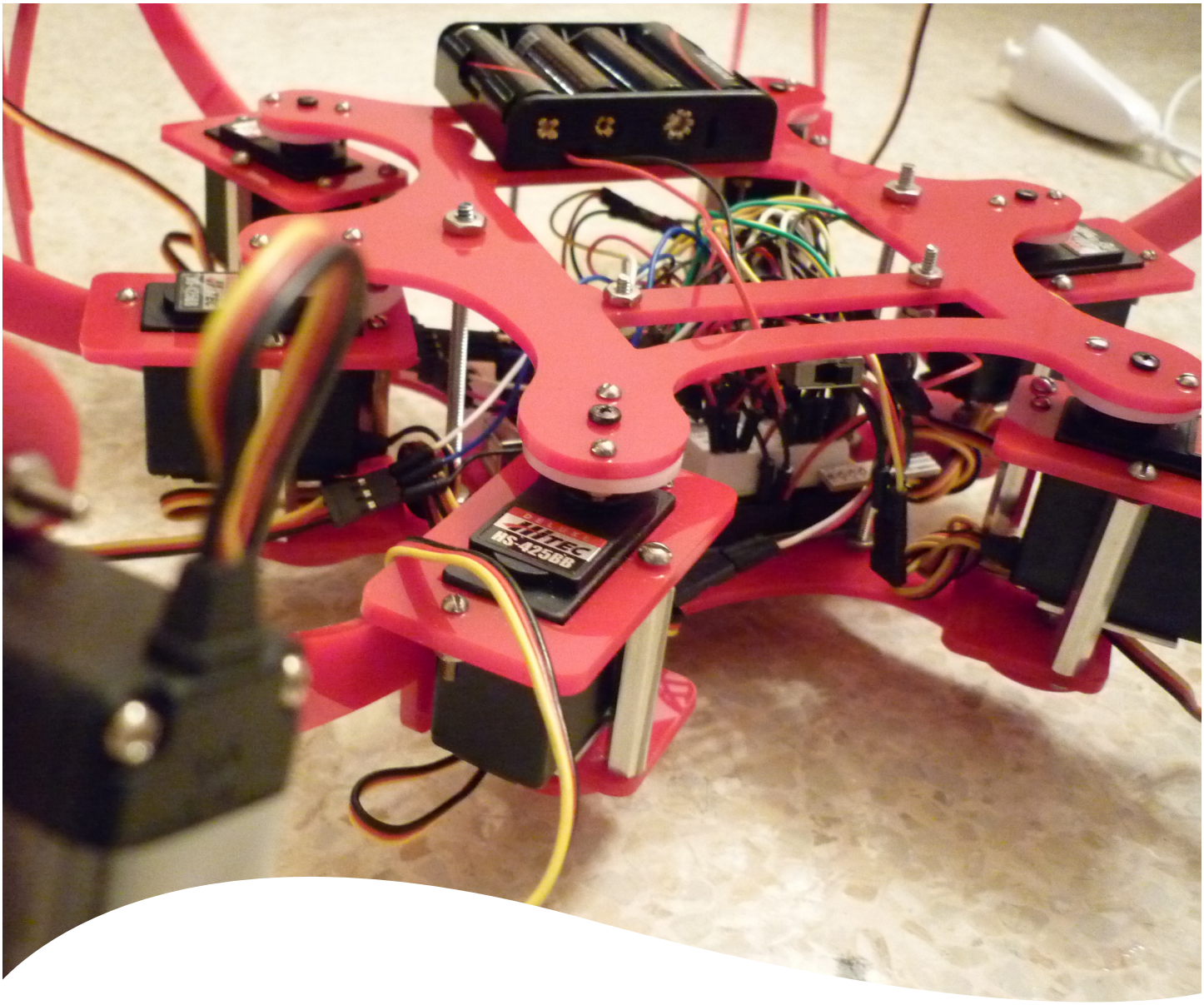

HexaCrawler

Carnegie Mellon University
Making Things Interactive

Anthony Zhang

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ABSTRACT

I have always been fascinated by technology and consequently very curious as to how so many cool gizmos and inventions are created. Knowing near to nothing about robotics, circuitry or electronics, I wanted to find a fun and interesting way to learn more about these topics and provide others with the same opportunity.

HexaCrawler was the solution to this problem. HexaCrawler is a six-legged robot that is controlled via the Nintendo Wii Nunchuck. The robot works by using twelve servo motors (two for each leg) to move around. HexaCrawler has a more or less simple construction and is easily reprogrammable.

Although the initial idea behind HexaCrawler was so that I could explore what I have learned in this course and come out with a cool toy in the end, in hindsight, I believe this product could be marketed as a build-it-yourself set so that others may go through the same educational process of building and programming the robot. Unfortunately, HexaCrawler is not quite there yet. After just one iteration, the robot's design and build have yet to be perfected and all of its potential functionality has yet to be explored. Until then, it cannot be marketed in this way.

BUILD IT

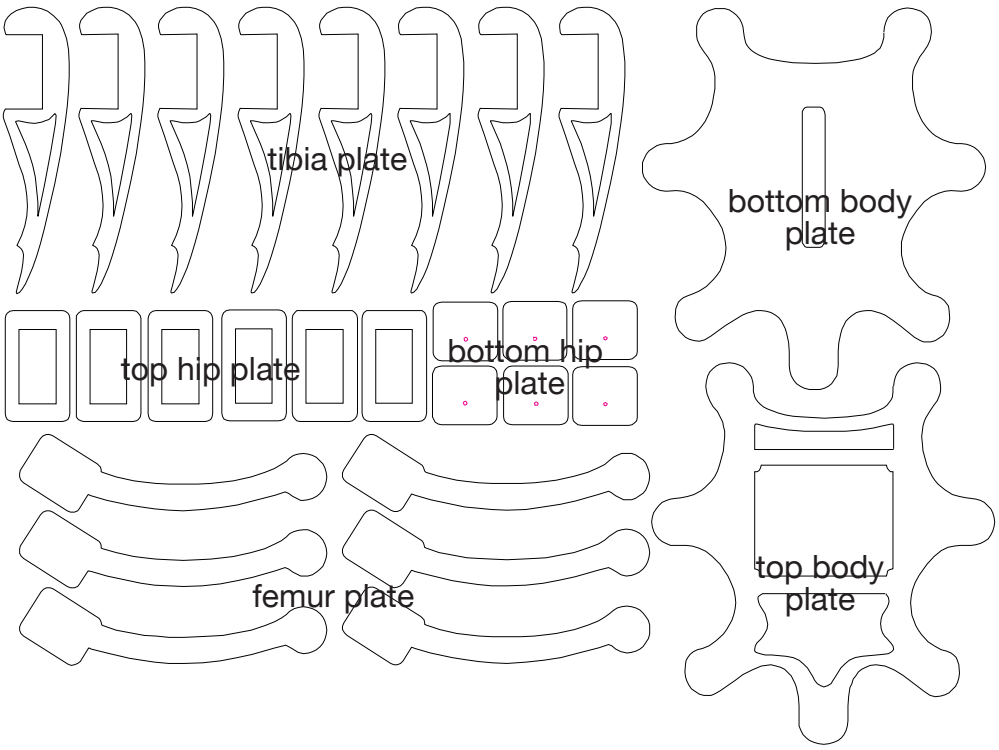
1. gather the materials

In order to build the HexaCrawler, you will need:

- 3 square feet of Acrylic Plastic + access to a laser cutter
- Arduino Duemilanove MicroController + Wires
- Mini-Breadboard
- 12 Servos (suggested: Hitec 425BB or higher)
- 2-56, 4-40, 6-32 screws + corresponding washers/nuts
- 1.5” threaded spacers (4-40 thread size)
- 3 three-inch threaded rods (6-32 thread size)
- 2 three-inch threaded rods (4-40 threaad size)
- 6 insulated nuts (4-40 thread size)
- 6 L-Brackets (1”x 1”x 1”)
- Tools: screwdriver, power drill, pliers, nut wrench

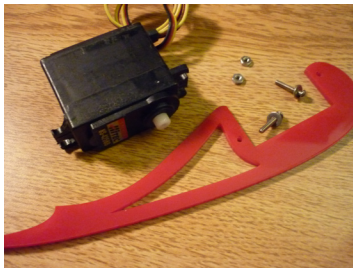
2. laser cut the pieces

After a lot of thought, planning and measurement, I created a body plate template on Illustrator that I had laser cut onto the acrylic plastic. This template was proportioned perfectly and even included markings for screw holes.



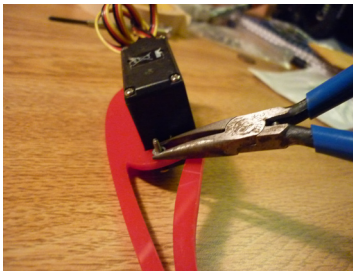
BUILD IT cont'd

3. build the tibia



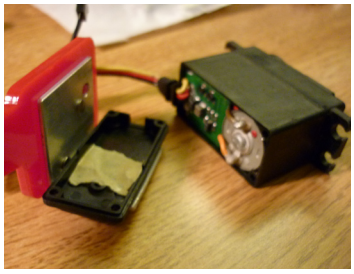
The components involved in this step include one servo, two screws (2-56) and corresponding washers/nuts and the tibia plate.

Place the screw and washer through the servo (choose locations diagonal to each other). *Pay close attention to the orientation of the servo, the servo horn is furthest from the foot.*



Tighten screws with nut on the other side. Use pliers to make it easier.

4. build the femur



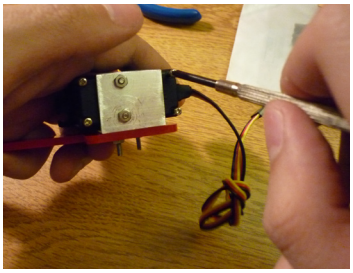
Using the L bracket, screw one side to the rectangular end of the femur plate and the other side to the bottom of a servo. Each attachment uses 2 screws (2-56) and 2 nuts. *Pay close attention to how many left legs you make and how many right legs you make (3 of each).*

Note: This is one of the largest design flaws of my build. Ideally, no drilling should have to be done on the servo itself. At the time, I thought this to be the best way to attach the servo to the femur plate.

Optional: Place masking tape over the screws attached to the bottom of the servo in order to minimize chances of short circuiting the servo (should the screws come loose).

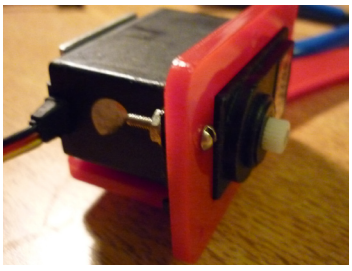
BUILD IT cont'd

4. build the femur - cont'd



Screw back together the servo with the L-bracket + femur plate attached.

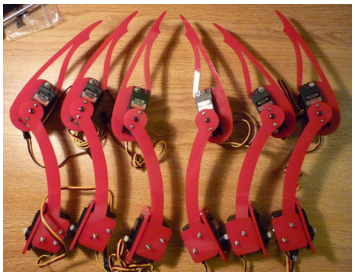
You should now have a servo attached to the femur plate via the L-bracket. For the next step, you will need the top hip plate and two screws/nuts (2-56).



The top hip plate should fit perfectly onto the servo's top. Screw the plate in place using the screws and nuts. Once again, pliers may be useful here.

5. attach the femur and tibia

Attach the servo horn (from the tibia's servo) to the circular end of the femur plate using the marked screw holes. *Pay close attention (once again) to the number of left and right legs you make.*

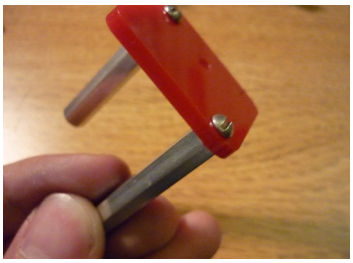


Repeat the above steps for all six legs. You should now have created all of the legs for the HexaCrawler!

BUILD IT cont'd

6. assemble the hip

The components involved in this step are the two 1.5" spacers, the bottom hip plate and two screws (4-40).

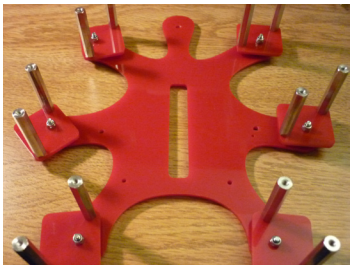


Screw the two threaded spacers onto the bottom plate. The spacers should be at a diagonal from each other.

7. attach the hips to the body

The components involved in this step are the bottom hip plate (with the spacers attached), the bottom body plate, three large washers, one screw (4-40) and one insulated nut.

Place the screw through the bottom body plate and the three large washers as shown in the picture.



Place the bottom hip plate (with the spacers attached) through the screw as well. Use the insulated nut to hold the pieces together (a nut wrench will make tightening it easier).

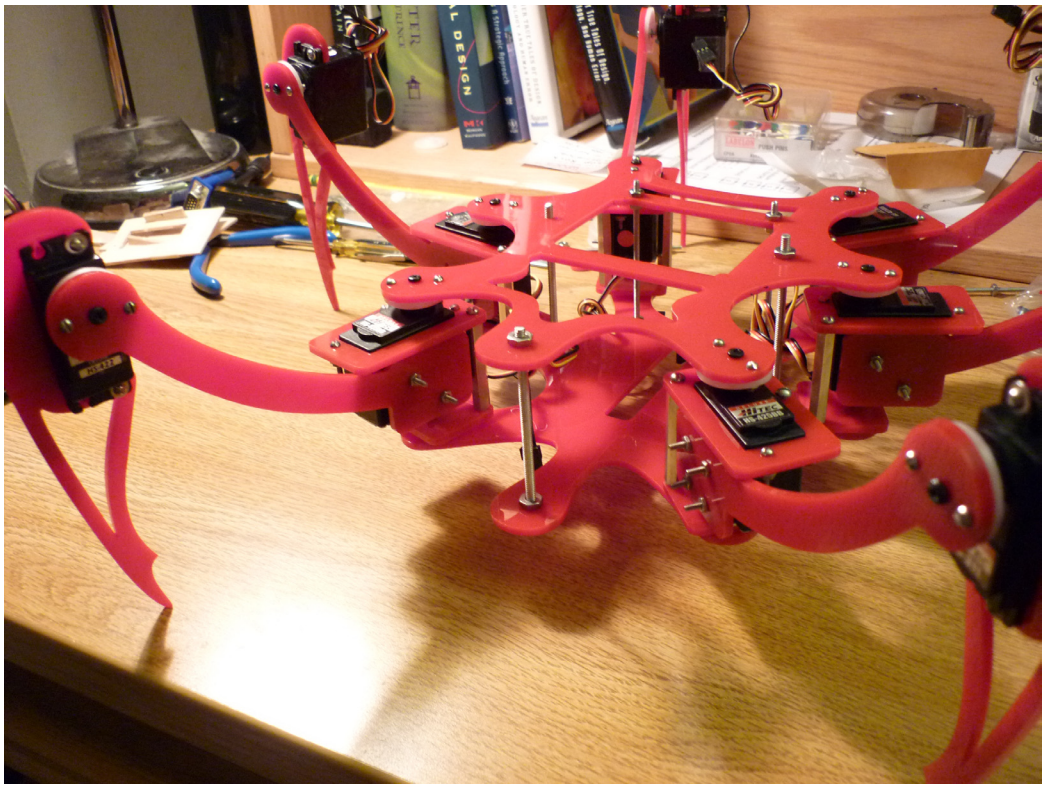
Note: An insulated nut is necessary. A regular nut will loosen within a few turns of the hip. The rubber on the insulated nut keeps it from loosening

8. attach the legs

Place each leg on a corresponding hip (watch for left and right). Screw the legs onto the other end of the spacers (from the bottom hip plate). *Pay close attention to the orientation of the hip. The insulated nut should be directly under the femur's servo (forming a vertical axis of rotation).*

9. cover with top body plate

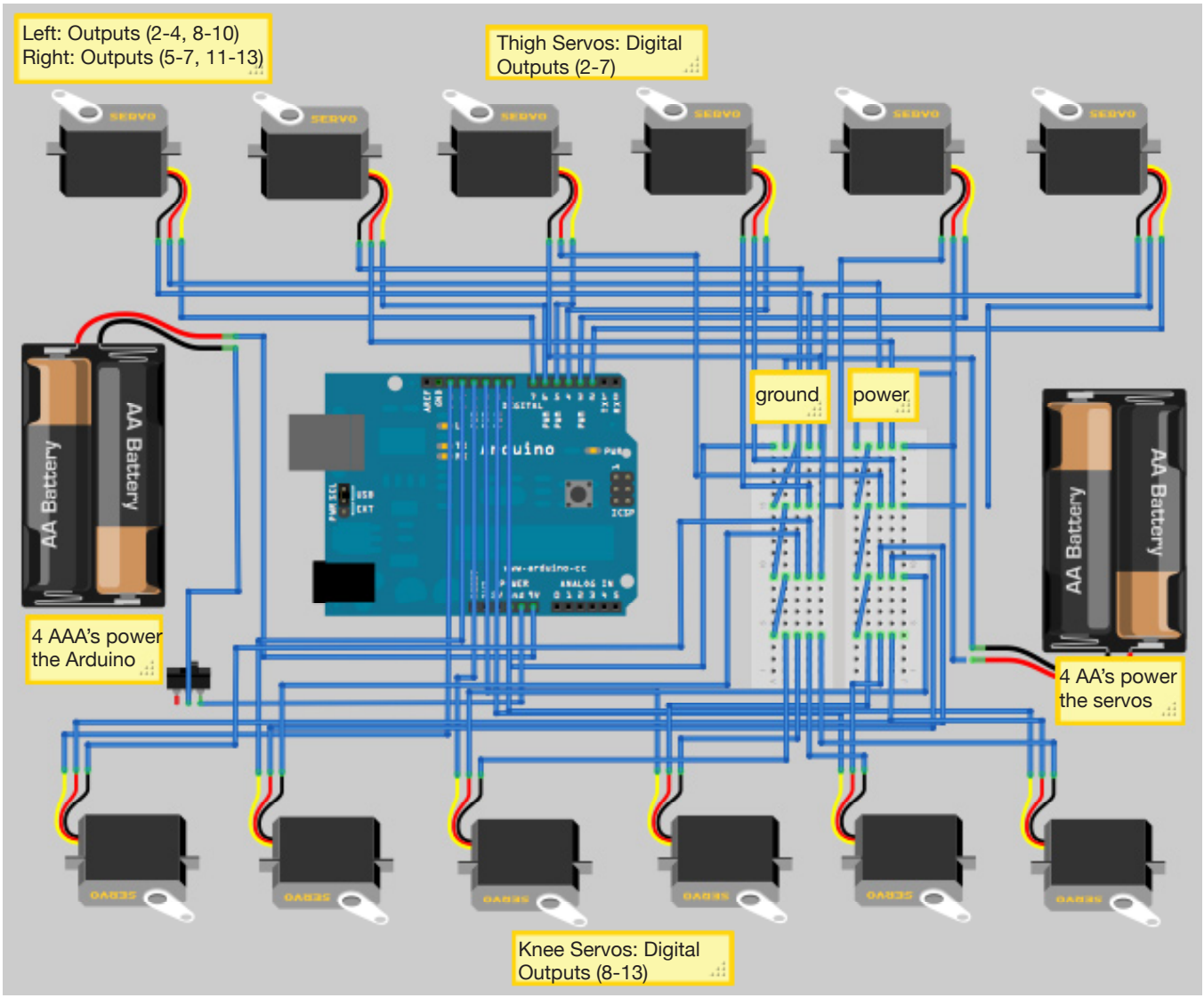
The last step of the build is to place the top body plate on top of everything. The top body plate should snap perfectly onto the horns of the femur servos. Nutting the five threaded rods through the marked holes on the body plates gives the body additional support to hold together. Each threaded rod needs four corresponding nuts (two to sandwich the top plate, and two to sandwich the bottom plate).



Note: In order to complete all the wiring, you will need to take off the top body plate Upon doing that, a battery supply will also need to be attached. This step-by-step guide does not include these steps.

WIRE IT

Despite its looks, the wiring of the robot is actually not very complicated. Each of the twelve servos are powered, grounded and connected to one digital output of the Arduino. To make things easier for programming, I connected all of the "hip servos" to the first six outputs and all of the "knee servos" to the last six. Additionally, I grouped the connections for left and right servos. The below schematic along with its notation should clarify this.



Notes:
Two power sources are suggested (but not required) because all servos have a possibility of releasing a power spike during its use. A power spike could kill the Arduino chipboard (not good). Since the HexaCrawler uses twelve servos, it's a good idea to split the power supply to avoid this entirely.

The schematic is missing the Wii Nunchuck wiring. Please refer to the following website for documentation on this: http://todbot.com/blog/2008/02/18/wiichuck-wii-nunchuck-adapter-available/

GETTING IT TO WORK

Currently, I have only perfected basic functions for the HexaCrawler. All it really does right now is move (forward, backward, turn in place in either direction). How I managed to do that is through a relatively simple walking algorithm. In order to move in one direction (let's say we want to go forward), all of the robot's legs must go the opposite direction (backward). By having all of its legs go in the opposite direction, the robot is pushing itself toward the desired direction. When a leg cannot go any further in that direction (furthest back it can go), it lifts off the ground and moves over (moves to the most forward position) so that it can continue the cycle again - think about how a person walks.

Expanding on this concept, I programmed the HexaCrawler's legs to have three positions: forward, middle and back and paired off its legs into three pairs. Each pair is assigned one position and cycles through them based on the desired movement. By doing this, I simplified the number of ways the robot can move and maintained consistency between each of its legs. This principle also helped me establish order to its movements so that I could come up with an efficient coding algorithm.

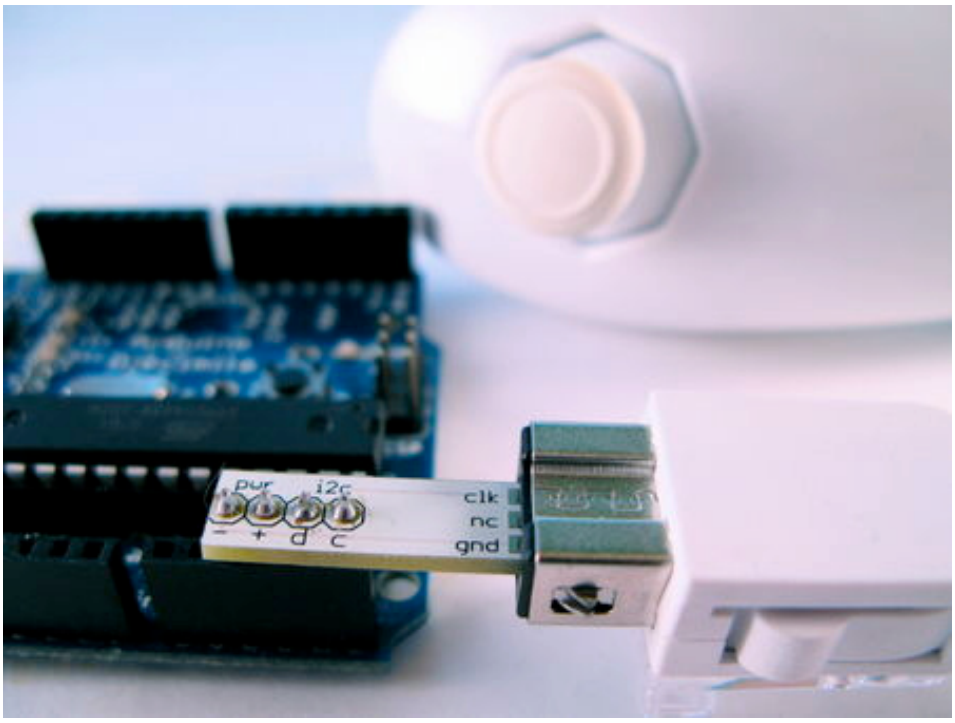
To establish additional control and order, I implemented each movement function as a cycle so that all movements begin and end in the same positions. This way, there is complete compatibility between all movements so that I can call any movement at any order. To ensure that the robot remained stable at all times, I maintain that at any given time, four legs are on the ground (pushing) and two legs off the ground (repositioning).

The other functionalities I created for the HexaCrawler were pretty trivial in comparison to making it walk. All other functions were pretty standard and just involved directly writing some set degree into the desired servos.

WII NUNCHUCK

I chose to use the Wii Nunchuck because I already knew that the robot itself would not have that many functions beyond moving. The nunchuck seemed perfect in its simplicity but at the same time provided novelty from the built-in accelerometer.

Because there is already so much documentation on communication between the nunchuck and the Arduino, it was pretty simple getting this to work.



http://todbot.com/blog/2008/02/18/wiichuck-wii-nunchuck-adapter-available/

With the help of this adapter and the various documentation found on the subject in the above link, I was able to get this working almost instantly.

REFLECTION

There are hundreds of these types of robots in the world. I researched many of them and modeled a lot of ideas off of them. In particular, I mirrored many ideas from Micromagic System's Hexapod *(http://www.hexapodrobot.com/index.html)*. One of the things I admired most about them was their clean and simple design. They had a smart build in that their joints were directly connected to the servo horns - as opposed to other robots that relied on additional metal rods to enable movement. Their design also allowed for a lot of functionality. Notably, they utilize a third servo in their legs, allowing the robot to squat / stand up as well as walk on uneven levels. This along with a built-in camera really puts their product ahead of the rest.

Regardless to how I compare I am still very satisfied with how my project turned out. I managed to take what I wanted from their design and incorporate new ideas on my own. I learned a tremendous amount about robotics and electricity and in the end, I was successful in building something really neat. In the future, I hope to improve on HexaCrawler's movements and functionality. In particular, I'd like to perfect the leaning functionality I have begun to incorporate using the Nunchuck's accelerometer and possibly implement an additional state where the robot may move and act on its own accord.

As noted earlier, this was my first project of this kind. I have never done anything like this before and consequently, I made many mistakes. If I were to start from the beginning, I would surely do a number of things differently. One thing is that I would rethink some parts of my design (in particular, the use of the L-bracket to connect the servo to the femur plate). I would also look into other chip boards, perhaps one that has eighteen (or more digital outputs) so that I could play around with having three servos per leg.

There is a variety of issues with my current design and many, many ways to improve it but I think knowing that is what makes it fun.