Interdisciplinary Spider Robot Project

Winner of the 2003 ASME Syracuse Senior Section George Farnell Senior Design Award

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Machinists:
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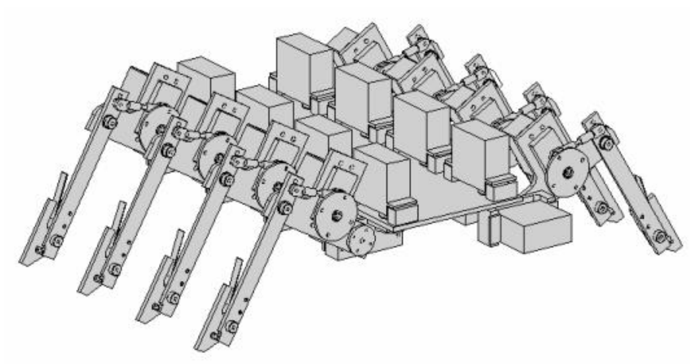


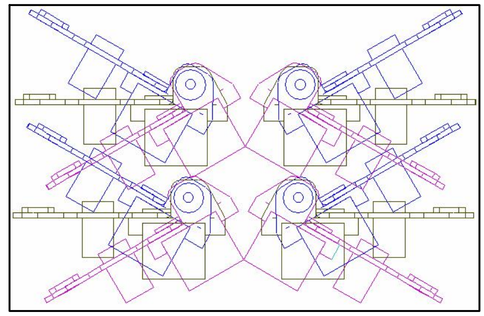
Here is a group picture of the mechanical engineers holding the spider robot. Pictured from left to right: Ben Axelrod, John Tacklyn, Nick Romeo, Gary Poon.

Concept:

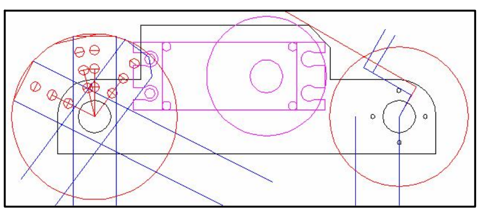
The goal for this project was to create an eight-legged robot to test new walking algorithms. We loosely based our design on a spider, because there has not been very much research on octopedal locomotion. Hopefully the algorithms developed will be of use to the robotics community and in the future, society.

The terrains of the real world often do not suit wheeled locomotion. Wheels are simply ineffective on rough and rocky terrains. Therefore, robots with legs can outperform robots with wheels, which is why we choose to design a walking robot.

If robots are to become useful tools for society, they will need to be able to walk. However, there are not thoroughly robust walking algorithms yet, because they are still in their infancy. Once these algorithms are developed, they can be used in for search and rescue robots, extra-terrestrial exploration, and other applications where wheeled robots just don't cut it.



Here is a picture of when we were deciding on the dimensions of the body plate. Here, the hip blocks are shown mirrored, however, we found that the legs will have more mobility if they weren't.

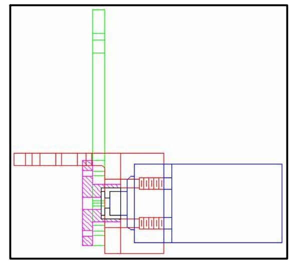


Here is a picture of the partially designed new upper leg. The black outline is the purposed upper leg, purple is the servo, and the other lines are things that can possibly interfere with the servo or leg.

Design:

Designing complex mechanical assemblies can be difficult, but when machine time and money is limited, the task can be even more daunting. To accomplish this, we designed the entire robot on a 3D CAD (computer aided design) program, discussed all drawings with the machinists, and used prefabricated parts wherever we could.

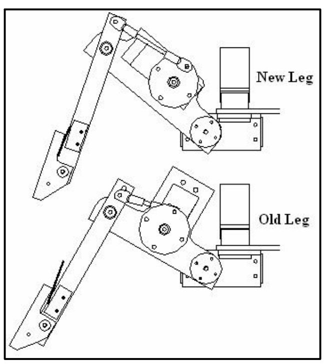
In order to complete the project on time, we knew we would have to carefully design the entire robot on the computer before cutting any metal. We used various 2D and 3D CAD packages for this. These programs allowed us to compile an assembly of every piece of the robot, precisely. This helped us check for interferences with mating parts. We could also rotate the parts to check the range of motion of the legs. However, this task was very difficult due to the number of joints on each leg. At the end of the first semester, we decided to have only one leg manufactured to verify our CAD results. The only major problem was the servo placement in the upper leg. With a prototype leg, we were able to see that the upper leg could be redesigned for a much better range of motion.



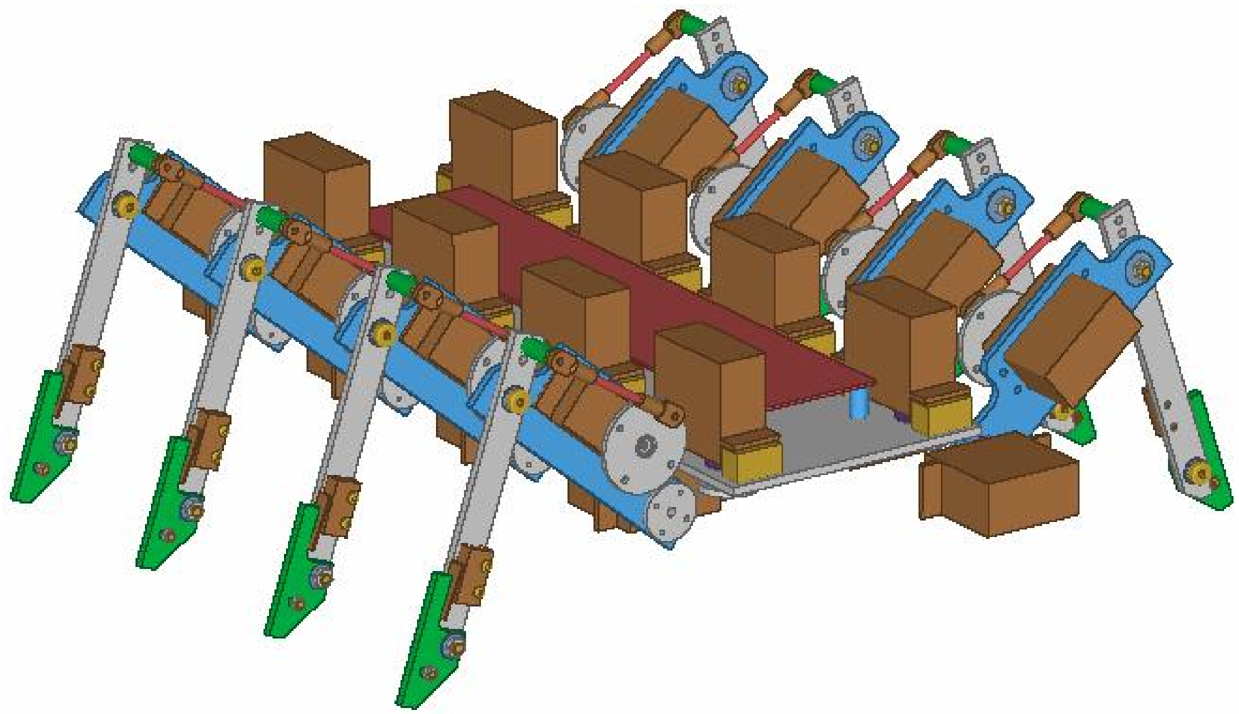
After we completed the mechanical drawings for each part, we put them together to make sure everything fit.

Throughout the design process, we discussed our drawings with the machinists. They provided valuable information on how to modify the parts to make them easier to machine. For example, they noticed that increasing a certain bore from 0.310 to 0.3115 inches would save almost an hour per part. This is a significant improvement because we have 16 of such parts on the robot.

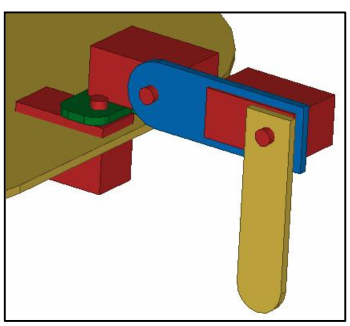
Other time and money saving techniques can be seen on the robot. Specifically the use of prefabricated parts. This is why we used the 4-bar linkage for the knee and shoulder screws as the shafts for the knee and ankle joints.



Here are the new and old legs.



This is the entire robot modeled in a 3D CAD program. Here, different pieces are given different colors for clarity.

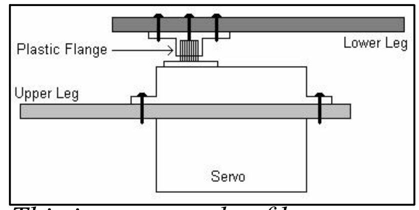


Here is one of the first concept sketches.

Notable Features:

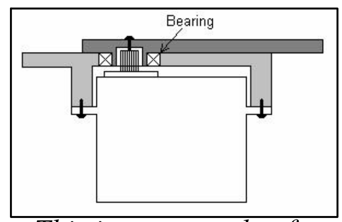
Lever-action feet – These specially designed feet allow the robot to determine when each foot is on the ground. This is important information for the algorithm. This design keeps the electronics up off the ground and can be interchanged for different terrains.

Solid joint construction – Having a robust design is something we strived to achieve. Using the hobby servomotors, it would have been easy to design the leg joints as shown. However, this design puts a lot of stress on the servo, introduces a large moment due to the distance between the leg plates, and is too flexible due to the plastic flange of the servo.

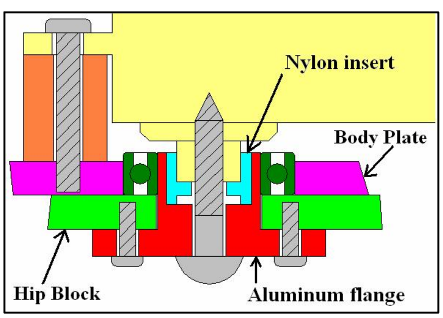


This is an example of how servos are usually used. It is a simple but very weak joint.

We used a much more robust design as illustrated here. Now the bearing takes care of the stresses that used to be subjected to the servo. With the two plates flat up against each other, there is less moment and the joint is more stable. However, the parts required for this design are much more complicated. Essential to this design is the glue that secures the plastic servo insert into the aluminum flange. The nylon insert contains the splines that engage the servo. They would prove too difficult to manufacture, so we had to integrate the nylon into our design. We tested a variety of surface preparations between the nylon and aluminum. When tested to failure, it was the nylon splines of the insert that failed, not the glue. This means that the joint will fail way above the maximum torque that the servos can provide. So, we have a very strong joint.



This is an example of a complex but strong joint.



This is a cross section of the hip joint. You can see that it is a very complex assembly.

3 degree of freedom legs – We wanted the robot's legs to effectively simulate the legs of a spider in addition to being able to demonstrate a variety of walking gaits. Two is the minimum amount of degrees of freedom (or bends) in a leg for walking. That would be very inefficient walking, and would not be of much use for research. (For humans, walking with two DOF would be like trying to walk around with locked knees and ankles.) By having 3 DOF instead, our robot will be able to exhibit a much smother walking gait as well as crouch and "walk tall."

Next to come:

Unfortunately, the electrical system for this robot was never completed. So, the primary goal for the years to come is to put a brain into this robot. The computer engineer in our group chose to use a PIC microcontroller to control all of the 24 servos. However, this might not be the best way to approach this problem. It might be better to use a distributed methodology. A number of smaller microcontrollers, possibly one for each leg, could be used to control the servos individually. Then a larger microcontroller will be in charge of higher processes and tell each of the leg controllers when to step. If you are interested in taking this project to the next level, please contact one of the project advisors, depending on your discipline.

A number of improvements can be made to the mechanical design of the robot: the robot can be made out of lighter materials, and the entire robot can be scaled down. If the robot was made out of a plastic or composite material, then it would be a lot lighter. These materials would not be as strong as aluminum. However, the robot will be lighter and put less stress on its limbs.

Scaling the entire robot down would also be a big improvement. By choosing smaller servos, the design of the robot would not change much; everything would just be smaller. Of course, the smaller servos would not be able to provide as much torque, but again, the robot will be lighter so less torque is necessary. It is estimated that the new smaller robot will weigh about 3.4 lbs, compared to this robot's hefty 5 lbs. We also found that the smaller servos will be more powerful per-unit-weight than the bigger ones, by almost 25%!

Obviously, this robot will never walk outside of the lab. However, one day because of the algorithms that will be developed, you might see similar robots cleaning up mine fields, exploring other planets, or rescuing people trapped by a collapsed building.