Franklin W. Olin College of Engineering

Robotic Dolphin

ENGR 2330: Intro to Mechanical Prototyping

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Executive Summary

As a prototyping exercise, teams of five constructed aquatic-themed robots using rapid prototyping materials, equipment, and techniques. Our team decided to create a biomimetic robotic dolphin. After initial background research, the dolphin was designed and modeled using SolidWorks. It incorporates a novel rolling joint system along with a bi-directional cable cam drive (it moves both up-and-down and side-to-side). The drive system is fully self-contained for robustness and maintainability, and it can be covered by a dolphin-shaped shell. The actuation system is run by two AAA batteries, two small DC motors, and an integrated gearbox. The design was printed in ABS plastic on a 3D printer, and a layer of Epoxy was used to coat the body and provide additional strength. The final prototype is fully functional and exhibits nice biomimetic motion in two degrees. This report details the design of the robot.

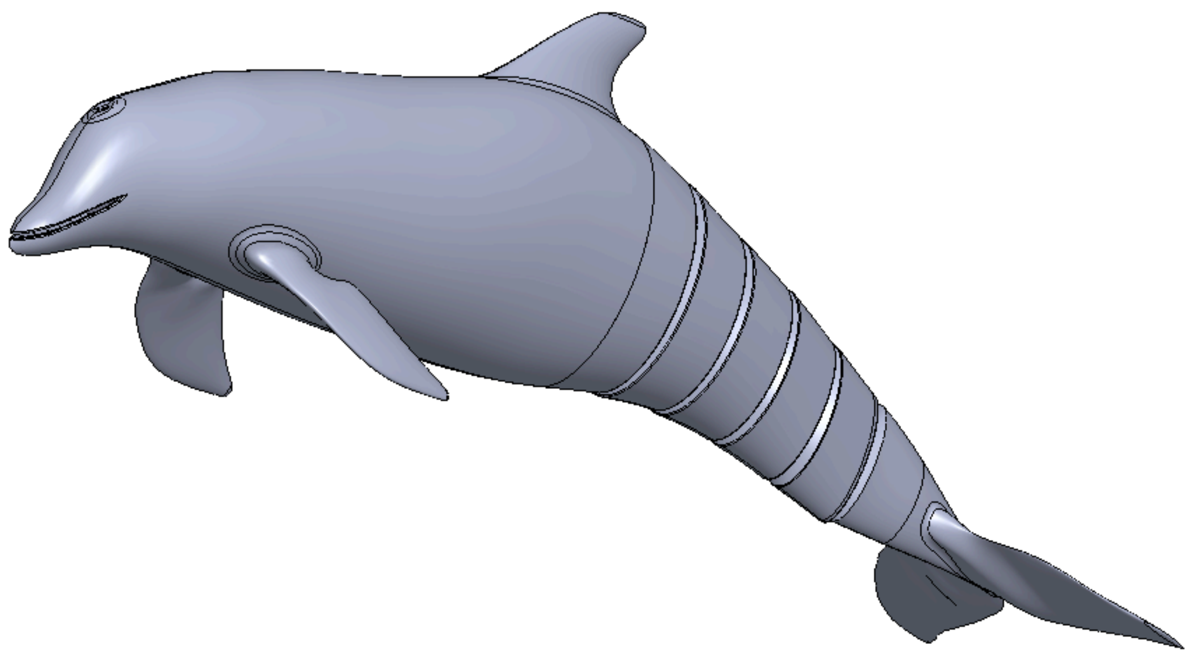

Figure 1: CAD Model of Dolphin

Design

We began by researching the shape, motion, and behavior of actual dolphins. Using this background, we discussed how best to emulate this motion in a robot. We decided that motion in multiple directions as was key to convincingly imitating the swimming motion of dolphins. We went through several design iterations on how to actuate the tail before deciding on a modified ball and socket joint with four “tendons” (as described in the Structure section). We also collected a variety of reference pictures and designs to base our 3D model on). Because we were using advanced manufacturing tools such as 3D printing in this project, we were able to go all out with our design and create a truly bio-inspired body for the robot (Figure 3).

Figure 2: Reference Dolphin

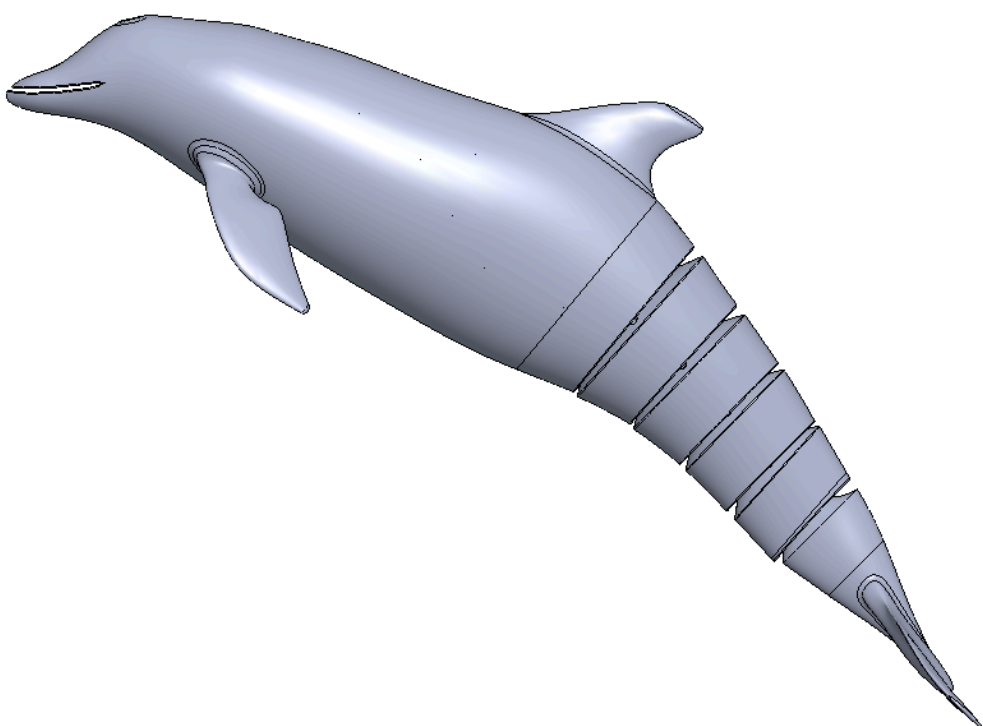

Figure 3: Profile of CAD Dolphin

Structure

The dolphin was designed to be simple and robust. As such, it includes a relatively small number of pieces. The structural components of the robot are all made of 3D printed ABS plastic with an epoxy coating. In general, all parts were designed to be thicker than needed (>.1 in). Ideally, parts could simply be printed and assembled, but RP plastic is not completely uniform and is fairly weak in certain orientations. For consistency and generally improved strength, it is better to coat printed parts with epoxy or fiberglass them. In our case, the main body shell came out of the 3D printer with large errors (.5 in missing from the head and badly mangled pectoral fins). Fortunately, we were able to repair the body with epoxy and filler. Though the process is time consuming, it recovered the desired shape of our body in addition to strengthening it. This serves as an example of the usefulness and versatility of composite materials.

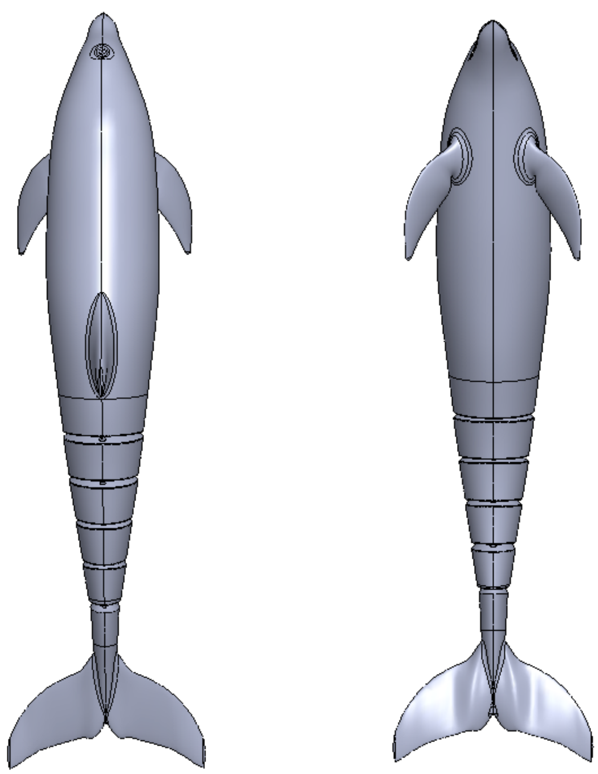

Figure 4: Top and Bottom Views of Dolphin

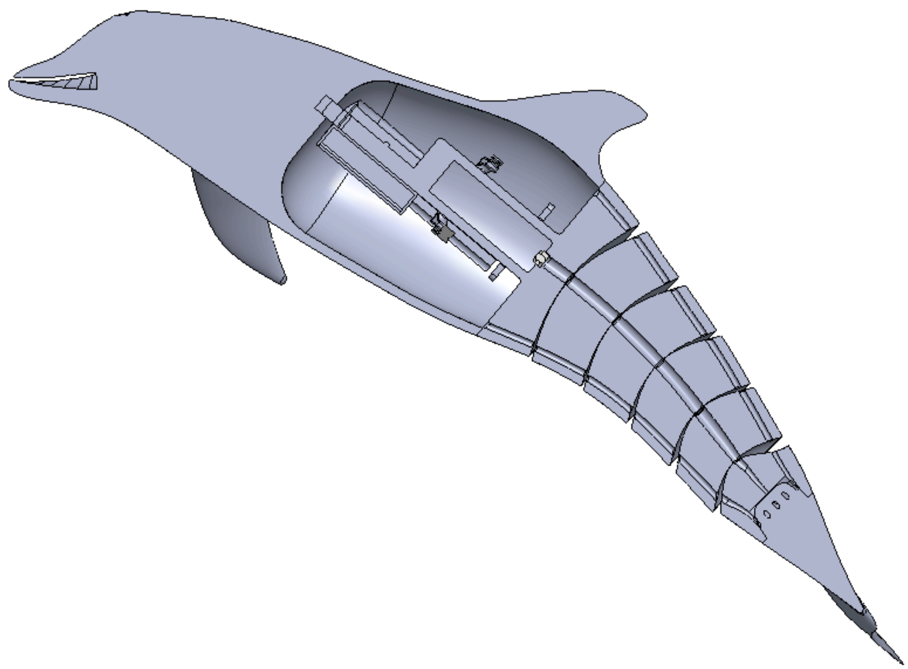

Figure 5: Inner Structure of Robot

Figure 4 shows the inner structure of the dolphin. There are five moving tail segments which can move about one another as controlled by four tendons running down the tail (and a center tendon to hold it together). Each segment actually consists of two domes with different curvature (like a small ball inside of a larger one) so that they will tend to roll on one another (Figure 5). This joint was inspired by the ball-and-socket joint, but adapted so that it could fit the very stretched elliptical cross-section of a dolphin without leaving large gaps between segments. This domed structure has the advantage that it works as an effective joint in both directions (up-down and side-to-side motion of the tail).

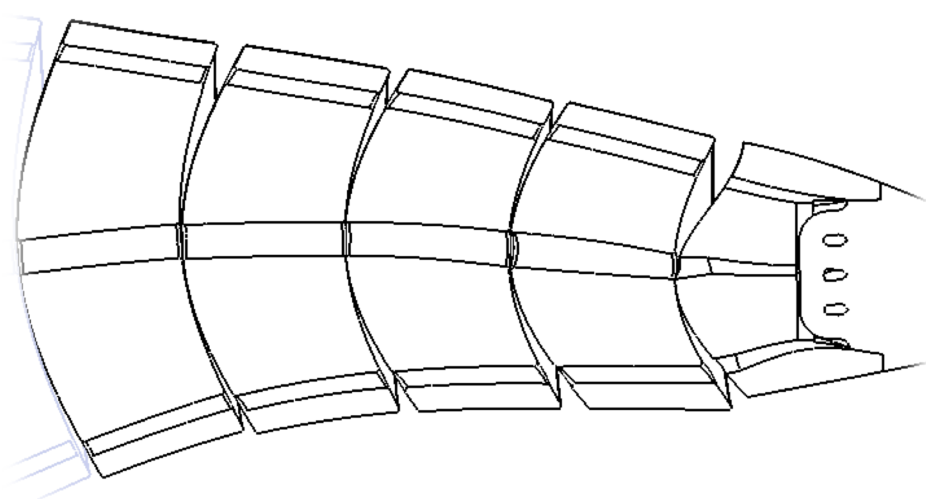

Figure 6: Shape of Tail Segments

Note that the final tail piece has a series of holes for attaching the tendons. It is this tensile force of the tendons that actually holds the whole actuation system together (see Figure 4).

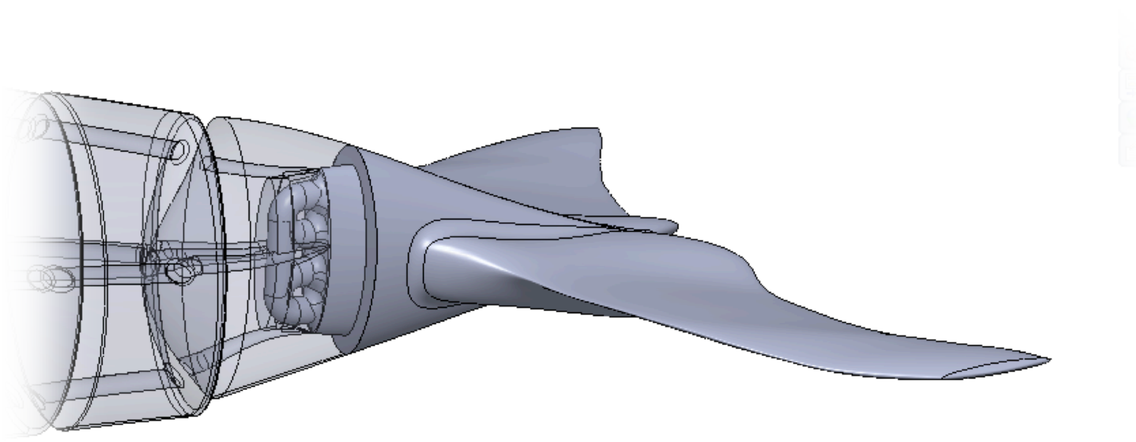

Figure 7: Tail Connection

On the other end of the actuation system is an integrated gearbox built into the first tail segment. This holds a series of gears from a Tamiya gearbox and rotates the arms of the cable cam drive, causing the tail to move in a given orientation. It also acts at the base that everything connects to.

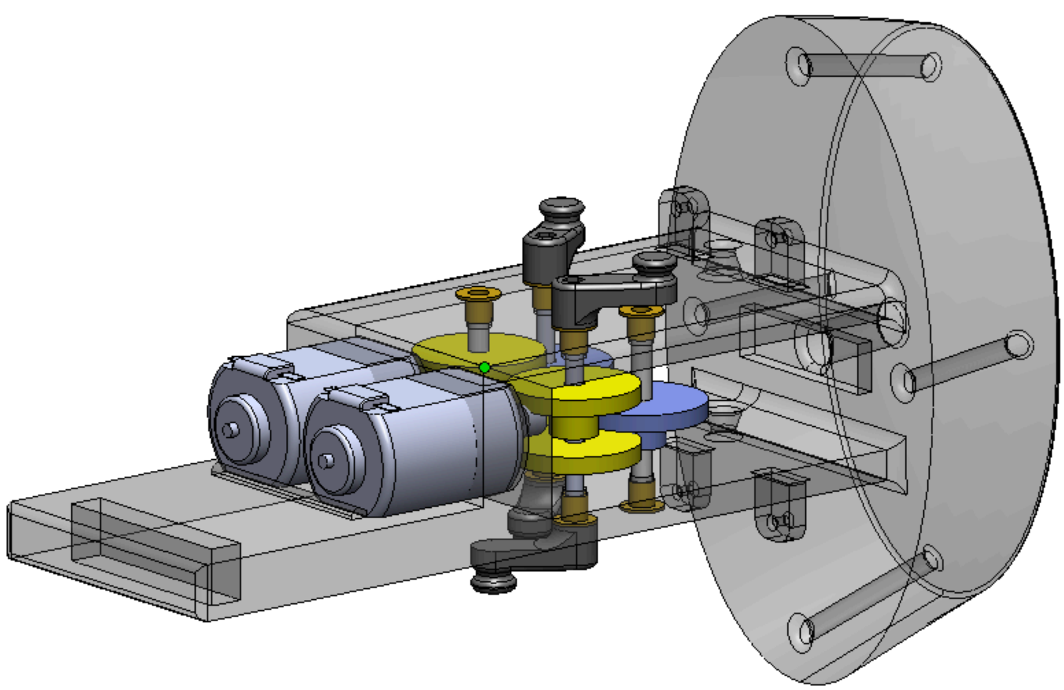

Figure 8: Integrated Gearbox

Like all of our past projects, there are common structures within the dolphin that we made. For example, each of the tail segments can be seen as a modified base plate. The tail fin is a "T," connected by a mortise and tenon joint to the rest of the tail. The gears are held within a box structure, and the outer shell is also a box. There are even some "C" channels that the gearbox slides into (Figure 9) that provide the friction hold that holds the outer shell on.

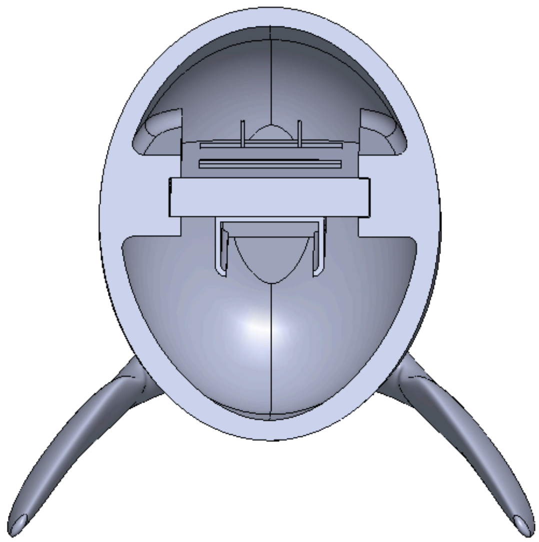

Figure 9: Inside the Shell

Power

The power system of the robot is relatively straightforward. There are two AAA batteries that provide a total of about 3 V to the system. These batteries can be easily switched out from their holders when they are running low. Based on external switches, this can either power one, two, or none of the two DC motors on board.

Transmission

Our robotic dolphin has an integrated gearbox (Figure 9) that uses components from Tamiya's commercial twin-gearbox set. It uses two DC motors (Tamiya FA-130). These motors have an advertized RPM of 6990-9100 and a stall torque of 4.6 gcm. In order to lower the speed and increase the torque to usable values, the motor output is put into a ABS plastic gearbox. In particular, power is transferred to a miter gear and some spur gears, which in turn rotate an arm that pulls on fishing line "tendons," causing the tail to move in the desired direction. The motor that controls the side-to-side motion has a 114.7:1 gear reduction and 0.25 in. arm, while the up-down motor has only a 38.2:1 reduction and a 0.45 in arm. Figure 11 shows the tendon path through the tail. Note that there are also special guide to control the cable cam so that it does not tangle around the gearbox.

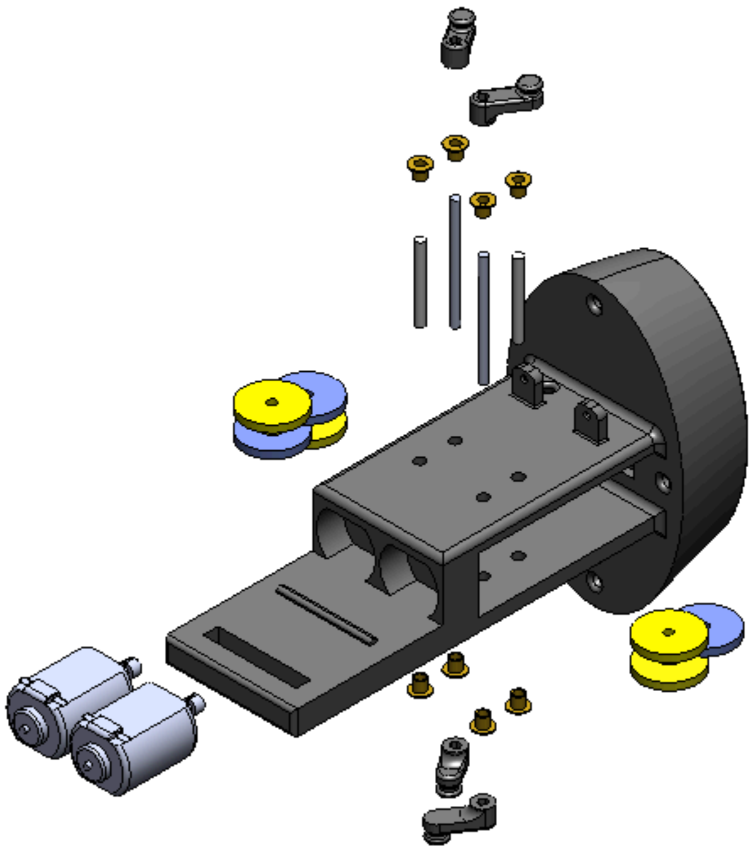

Figure 10: Exploded View of Gearbox

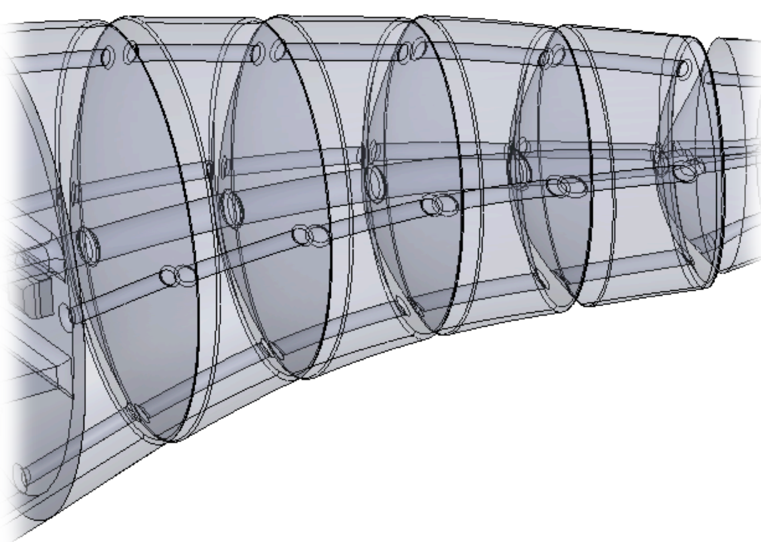

Figure 11: Tendon Path

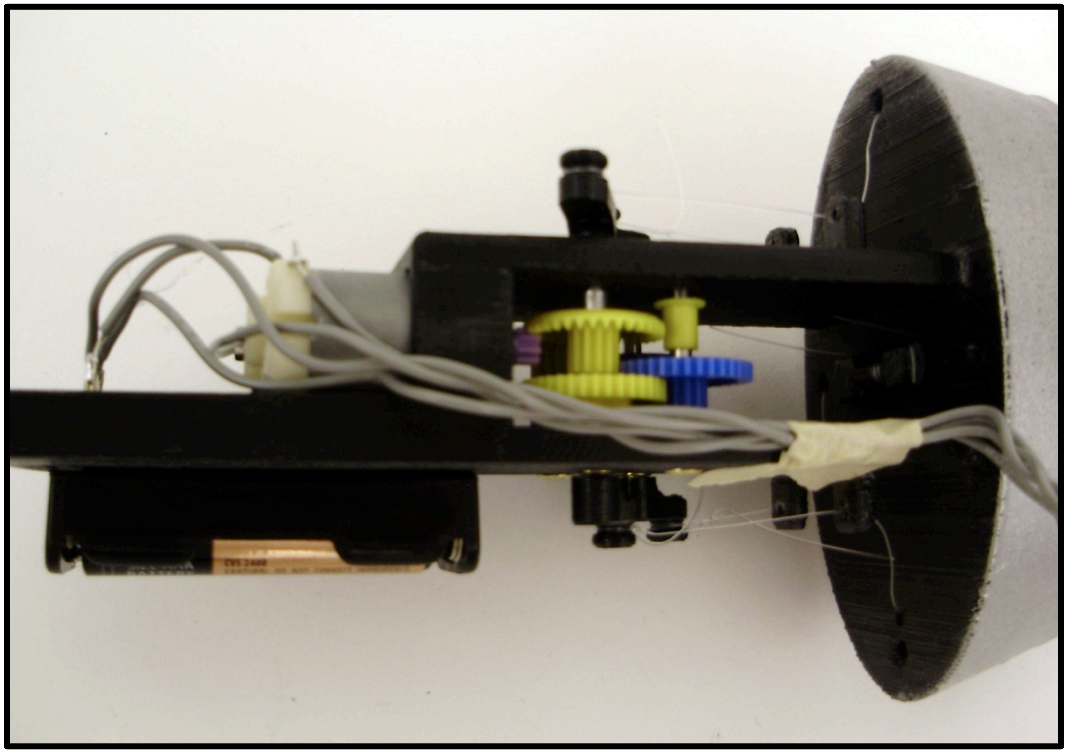

Figure 12: Assembled Gearbox in the Robot

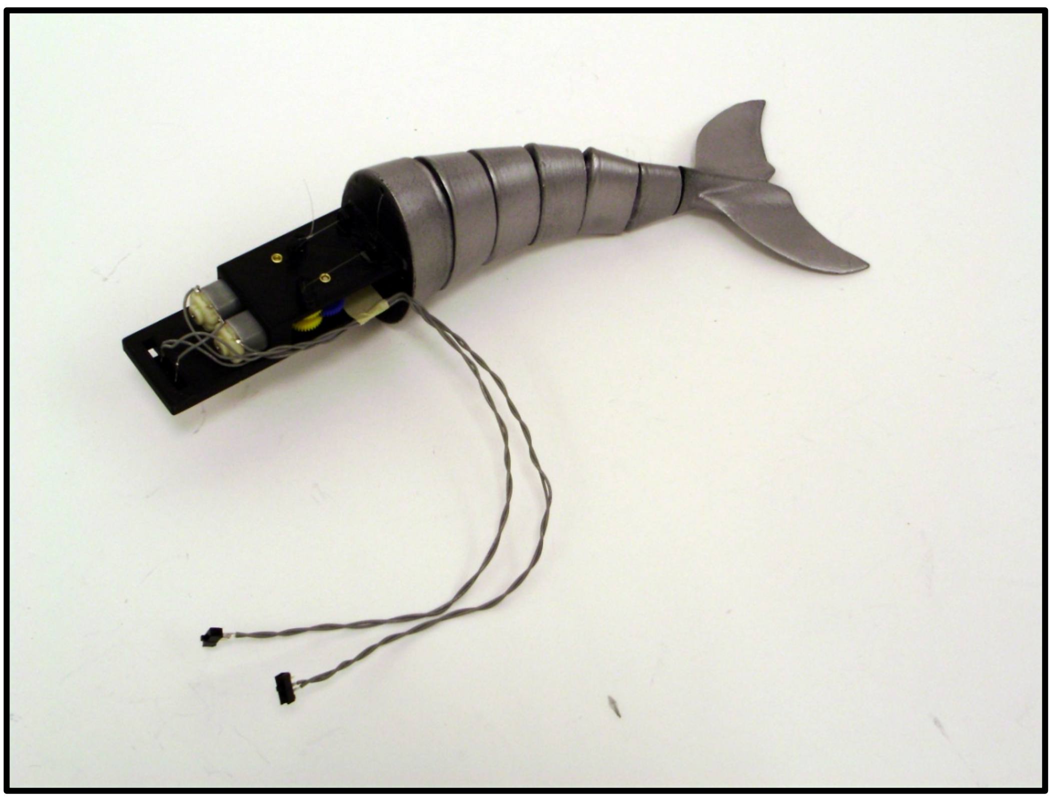

Figure 13: Full Tail Assembly

Conclusion

Through this project, we learned about several new prototyping techniques, including 3D printing and composite work. These are two very powerful tools for creating quality solutions in a short time frame. As an example, we were able to create a very successful, working prototype of a robotic dolphin in a very short time span despite errors in the print job and other delays.

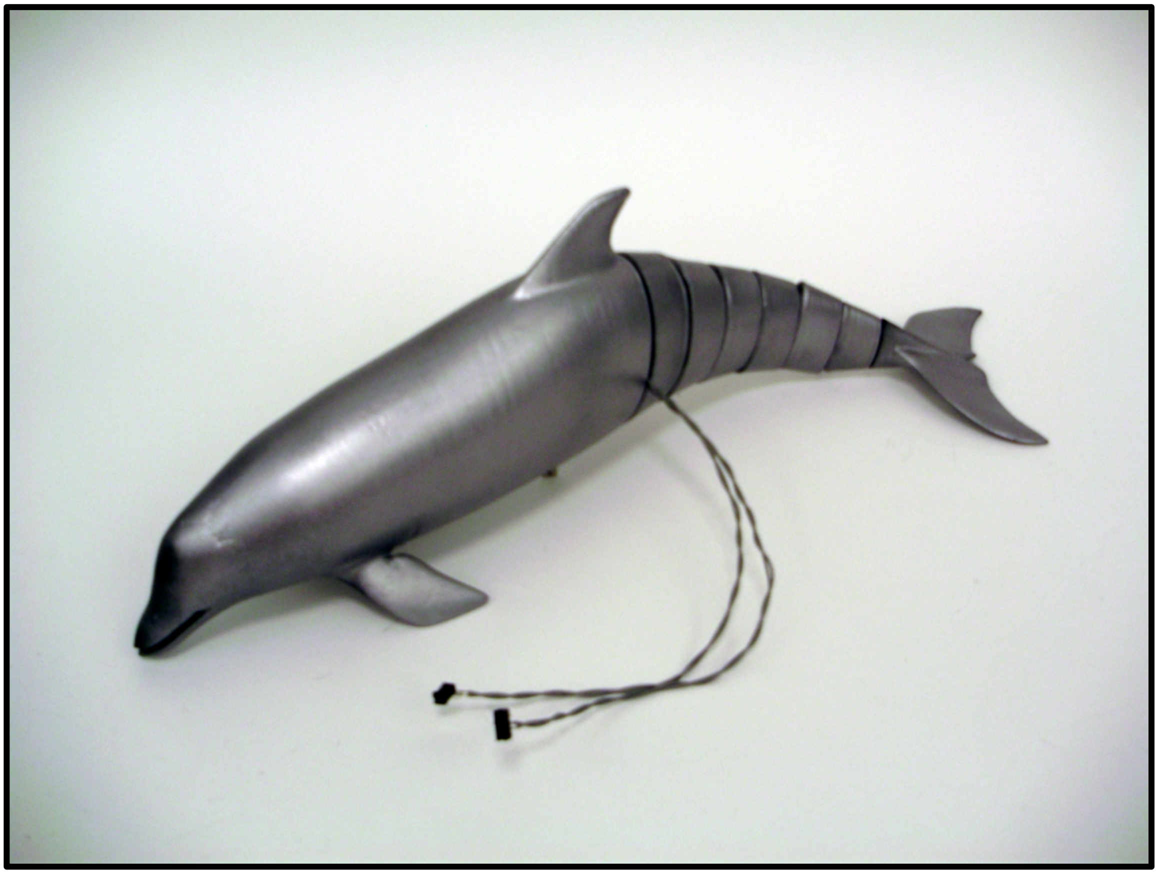

Figure 14: Assembled Robotic Dolphin

Appendix

If there are any questions about this report or my knowledge of the contained material, please email me at raphael.cherney@students.olin.edu.

Drawings

The attached package contains all necessary technical drawings to construct the robotic flying fish presented in this report.