Appendix B: 12 Design Steps

**1. Define a Problem**

My Engineering Physics capstone project is to design and create a robotic hand that resembles a human hand in size and method of actuation. The hand will be printed using a 3-D printer, so part of the project involves understanding and testing the capabilities of 3-D printers. The goal is to produce a hand that is capable of various grasping actions, able to apply enough force to lift objects, and has sensors.

Human hands are able to manipulate objects with remarkable dexterity and flexibility. Their effectiveness comes from, in large part, their large number of degrees of freedom of movement, and their sensing capabilities. The effectiveness of human hands motivates us to understand them, and replicate their traits in robotic hands to improve the robot’s ability to manipulate the world.

**2. Brainstorm**

Understanding the printer’s capabilities, its resolution, what structures can be printed, and if/how designs must be adapted to work in the printer.

Investigating tendon materials that will need to balance elasticity, strength, size, and weight.

Researching current finger and joint designs and how these can be adapted to suit the requirements of this project, then designing the fingers and joints.

Researching ranges of motion in human fingers, as well as forces applied by human muscles and positioning of muscles and tendons, to attempt to imitate these in the hand.

Designing sensing setups for detecting finger position, joint angles, and forces from objects; and designing fingers so that they support the mounting of these sensors.

Developing routing schemes for sensor data and power cables.

**3. Research**

Articles referenced above.

**4. Identify Criteria and Specify Constraints**

Final product should

* be approximately the size of a human hand
* have approximately the same number of degrees of freedom as a human hand
* be actuated
* have sensors in the joints and fingertips
* have low cost and production time

**5. Explore Possibilities**

Primary tradeoff issue involves what is built into the printed part and what is done to the product after printing. The advantage of printing attributes is that it reduces production time/effort. The disadvantage is that some parts that are printed have lower quality than their post-produced counterparts, or simply cannot be produced at all in the printer. Nearly every aspect of the design must be considered in this light. The tendons could be printed in flexible plastic, but finding a plastic that is flexible and resilient enough at the proper diameters is difficult. The holes for attaching and routing tendons can also be printed, but they may be obstructed by misprints or filler material. The sensors and wiring could even be printed, if conductive plastic is used, but this plastic takes time to produce and could have compatibility issues with the printer and other materials in the object. The joints of the finger can be printed so that they are already interlocking and inseparable, but this makes them inseparable and requires small clearances between the joint sections that can be fused by misprints or have rough surfaces that cause high friction in the joints.

**6. Select an Approach**

Done continuously.

**7. Develop a Design Proposal**

Material: ABS plastic. Standard for 3D printers. Strong and light. Non-toxic.

Manufacturing Method: 3D printing. This is inherent in the project; the goal is to 3D print a hand. The printer used at the beginning of the project was the University of Oklahoma Aerospace and Mechanical Engineering Dimensions 3D printer. Later in the project a Makerbot 2X was acquired and used for manufacturing several parts. The Makerbot 2X has a higher resolution, and more control over the printing process and materials used is possible. However, it is less reliable than the Dimensions printer, and as of the end of the project not all desired functionalities were available on the Makerbot printer.

**8. Make a Model or Prototype**

Several finger prototypes were constructed, analyzed, redesigned, and new prototypes produced. Additional complexity was added to each iteration.

**9. Test/Evaluate Design**

Test system set up – a stand for the finger with mounting spots for motors. No testing has been done yet, but it is expected that the analysis will be primarily qualitative (i.e. does the finger move as desired when actuated, range of motion, etc. as opposed to quantitative parameters such as torques, lifting strength, etc.). All testing until this point has been qualitative, related to desired motion of finger and fit of parts, and ability to route tendons properly.

**10. Refine the Design**

Several finger prototypes were constructed, analyzed, redesigned, and new prototypes produced. Additional complexity was added to each iteration.

**11. Create or Make Solution**

**12. Communicate Processes and Results**

Final report and PowerPoint presentation will be completed.