DEVELOPING A 3D MODEL OF THE TONGUE AND MOUTH TO ASSESS PRESSURE GENERATION WHEN SWALLOWING

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Abstract

Dysphagia, the inability to swallow correctly, is a problem that can lead to a number of negative health conditions such as pneumonia, dehydration and malnutrition. The client, Dr. JoAnne Robbins, researches the causes of and treatments for dysphagia. Dr. Robbins requires a tongue model that can accurately and precisely be used to test liquids and foods, and is compatible with the equipment needed for pressure measurement devices. The design is a silicone tongue that features a 3-banded, T-pin design which utilizes computer-controlled servo motors for actuation.

Problem Definition

Motivation

- Dysphagia (difficulty swallowing) affects a large number and variety of people [1]
  - Aging
  - Neurological disorders
  - Muscle disorders
- Can lead to complications
  - Pneumonia, Malnutrition and dehydration
- No current devices to study dysphagia or swallowing
- Current focus: tongue

Background

- Swallowing requires complex muscle movement
  - Intrinsic muscles, extrinsic muscles
- Swallow occurs in two phases
  - Horizontal phase, vertical phase
- Current devices: AnTon model, robots in Japan
  - Not swallowing motion

Figure 1. AnTon model [3]

Problem Statement

- Goal to develop actuating tongue model
- Must go through full range of swallowing motion
- Must apply accurate pressure to bolus/oral cavity
- The tongue must be able to simulate degeneration of muscles common in dysphagia

Design Criteria

- Sturdy design for daily use
- Waterproof and easy to clean
- Able to swallow hot/cold samples
- Stain-protected material
- Proper pressure distribution and mechanics
- Must mimic human swallowing motion and timing (0.5 sec)

Swallowing

Figure 2. MRI scan of stages of the swallowing process [2]

Final Design

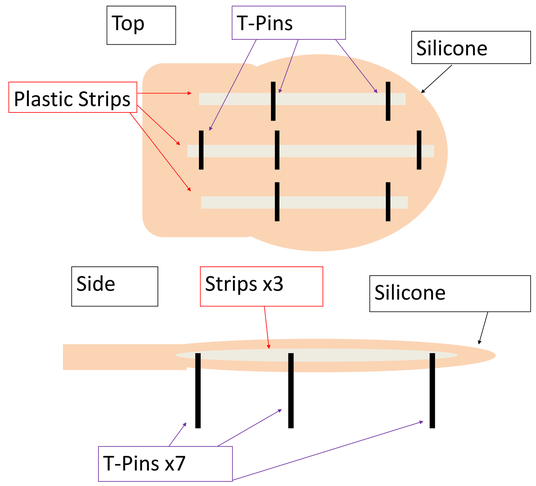


Figure 3. Layout of 3 strip, 7 pin final design

Model Design

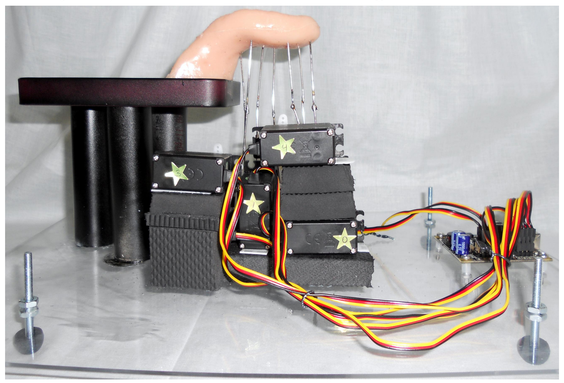
- Changed mesh and cable design to T-pin and reinforcing strip design(shown at left)
- Revised methods for forming negative alginate mold and forming silicone
- Used thinner grade silicone with pigment
- Made negative clay model thinner and more lifelike

Automation

- Seven servo system
  - Attached to t-pins extended with solder
- Phidgets microcontroller
- Solid base
- Java program to allow individual servo movement or concerted movement

Results

"I think it looks really amazing. Your team did a great job this semester and brought the project forward nicely with innovative ideas." Jackie Hind
"Nice job…you have made it come a long way." JoAnne Robbins



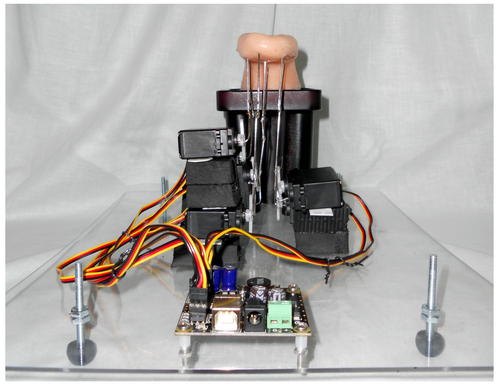


Figure 4. Final design side (left) and front (right) views

Parts List and Cost

Item	Cost
1 Quart Ecoflex 00-10 Silicone	$ 30.10
3 lb. Alginate Molding Material	$ 21.83
T-pins and plastic	$ 0.00
Sculpey modeling clay	$ 11.00
8 Hitec HS-422 Servos	$ 79.92
Phidgets AdvancedServo 8-motor	$ 87.70
Total	**$ 230.55**

Future Work

- Design oral cavity and throat model
  - Simulate realistic properties of tissues
  - Mechanical throat muscle contraction
- Create additional actuation point/angle to further tongue movement towards back of throat
- Provide tongue movement for disease models
  - Code for swallow with varied paralysis
- Develop a more user friendly program interface
  - Integrate on-screen buttons for commands
- Further testing
  - Quantify pressure exerted by tongue
  - Verify function with varied bolus substances

References

1. "Dysphagia." Mayo Clinic. Mayo Clinic, 2011. Web. 3 May 2012. http://www.mayoclinic.org/dysphagia/.
2. JoAnne Robbins, Ph.D.
3. Hofe, Robin and Moore, Roger K., "Towards an investigation of speech energetics using 'AnTon': an animatronic model of a human tongue and vocal tract, Connection Science, 20 (4): 319-336, December 2008.
4. Takemoto, Hirononri. "Morphological Analyses of the Human Tongue Musculature for Three-Dimensional Modeling." Journal of Speech, Language, and Hearing Research. ProQuest Research Library. Web. 3 May 2012.

Acknowledgements

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