Fortis Manus

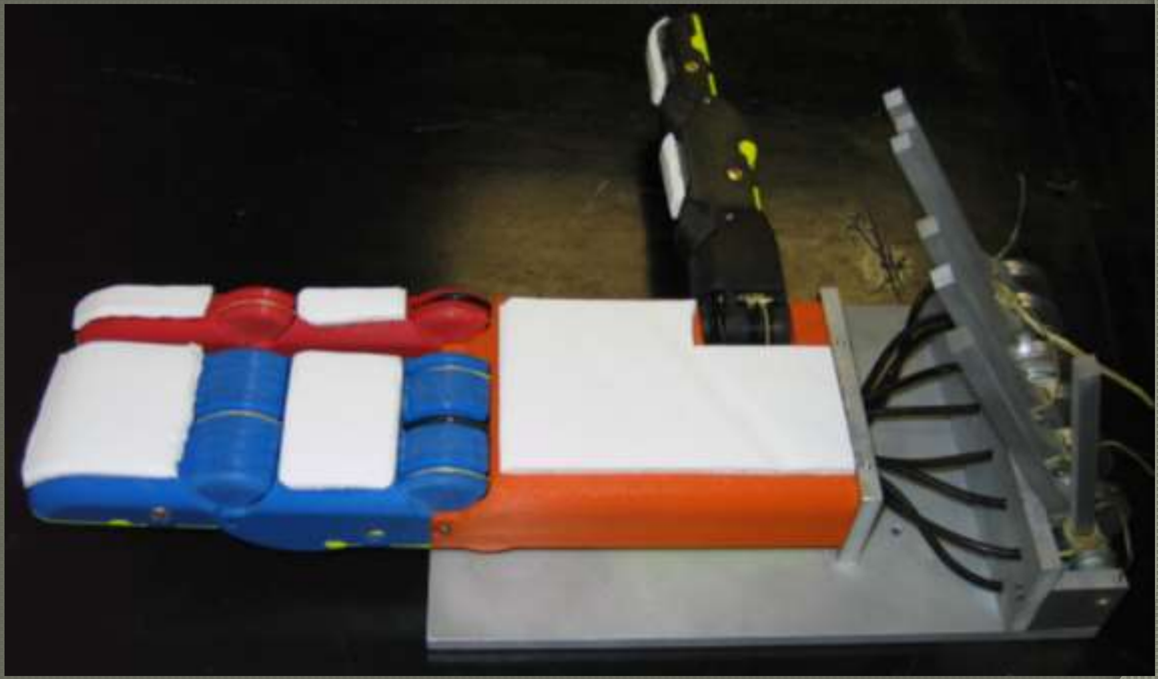
Hand-Like Manipulator

Entendre Biotech

Chris Harbers - Daniel Mosiman - Bridget Schabron

Overview

- Project Background
- The Design
- Fabrication Methods
- Design Evaluation
- Conclusions



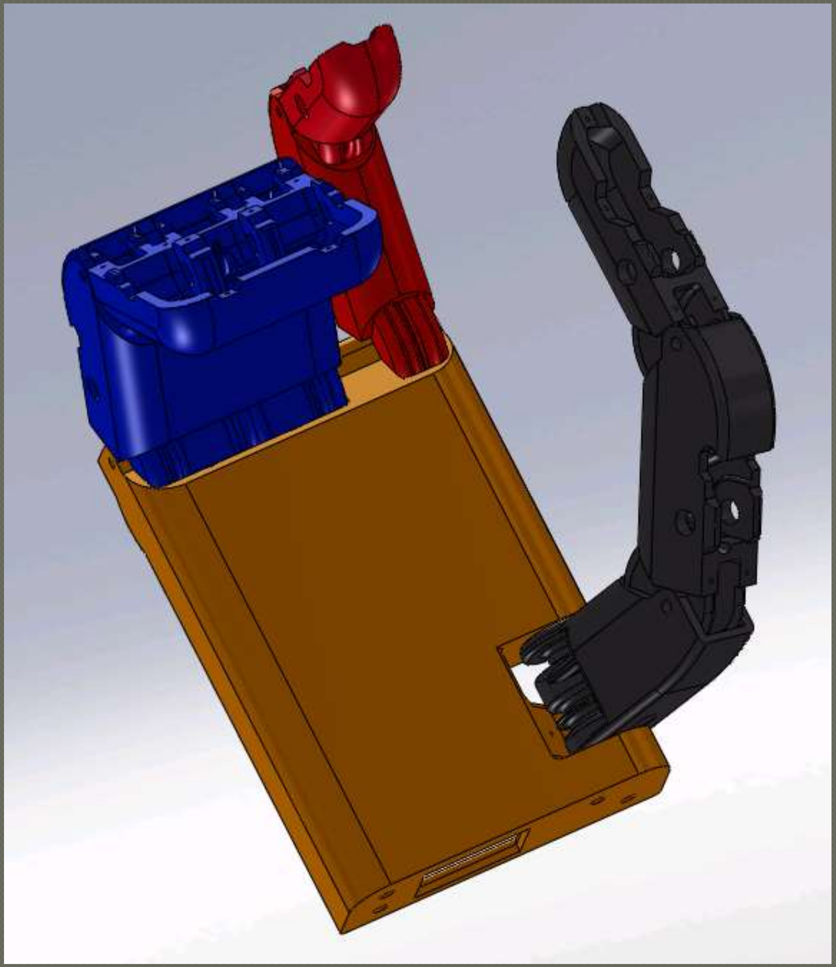
Project Background

Project Description: Design a robotic manipulator to emulate the functions of a human hand

The Design

Fortis Manus was designed to:

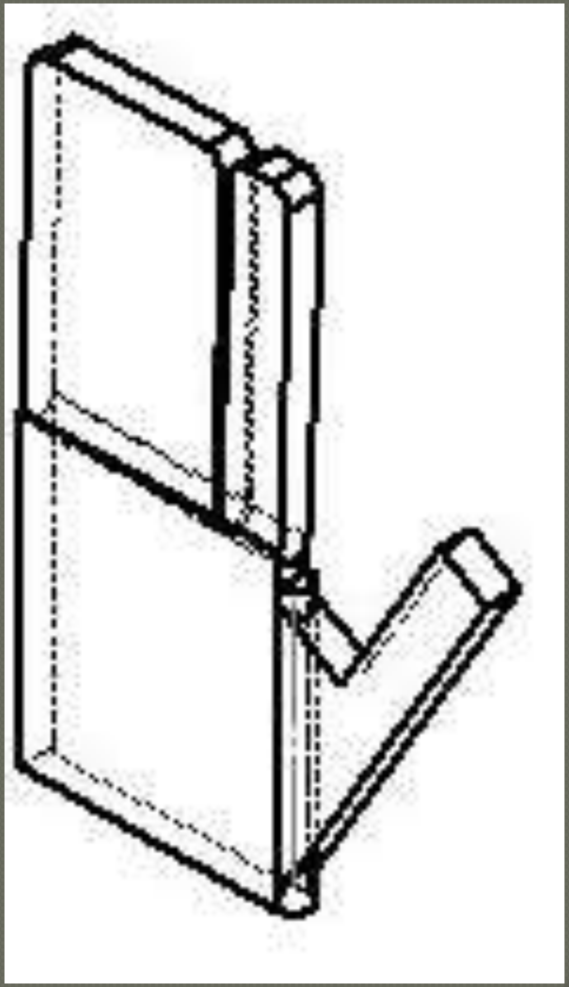
- be similar in dimension to a human hand.
- provide gripping functions comparable to a human hand.
- have the ability to perform in adverse environments.
- have the ability to manipulate a range of objects.



The Design – Three Phalange Design

Fortis Manus has three phalanges:

- Dexterous phalange
- Gripping phalange
- Thumb phalange

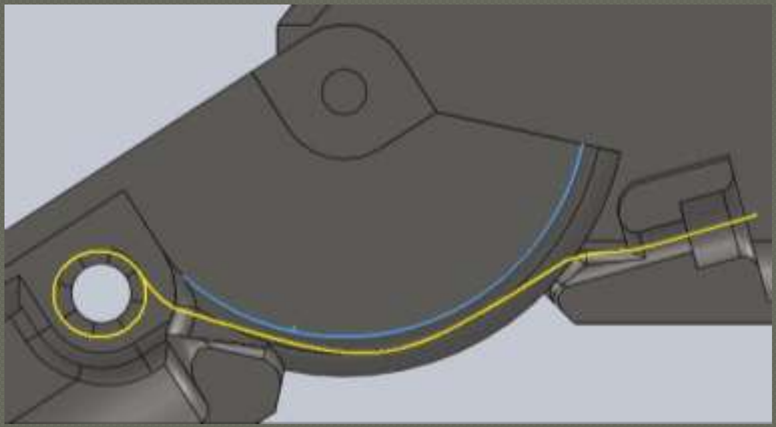


The Design – Joints

Joints between phalange sections accommodate angular deflection of 90°

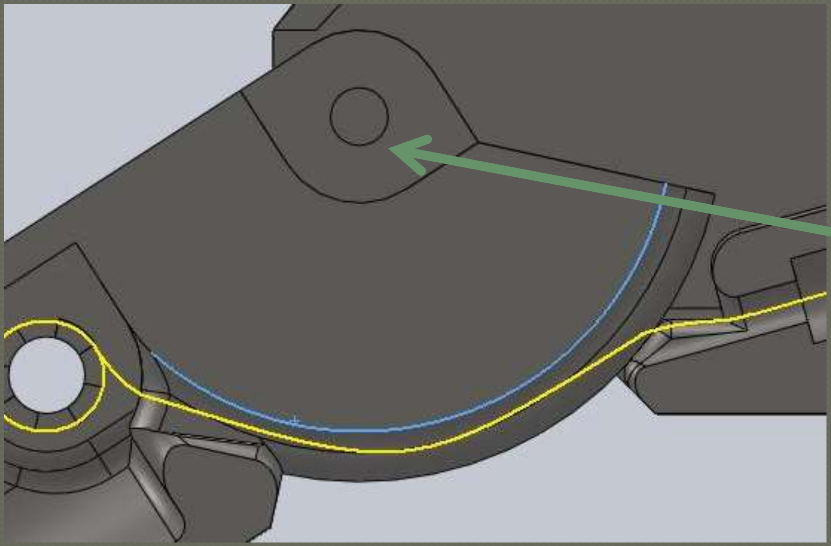
Shape of the joints ensures a constant radii for cable-pathing

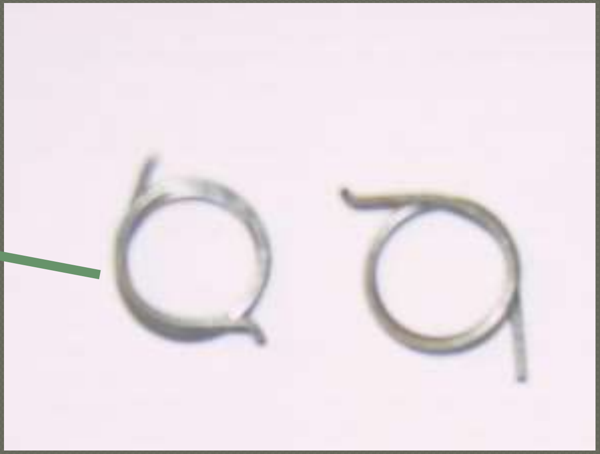
Palm-side joints allow for both cable and sheathing to safely pass through



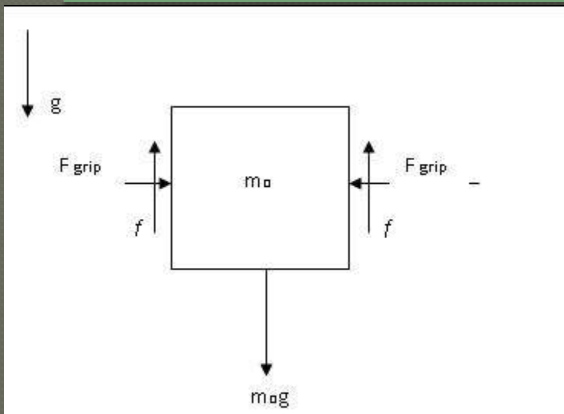
The Design – Locomotion

- Torsional springs within each joint act to return phalanges to open position
- Each spring was specified to resist gravity to keep hand open in any orientation

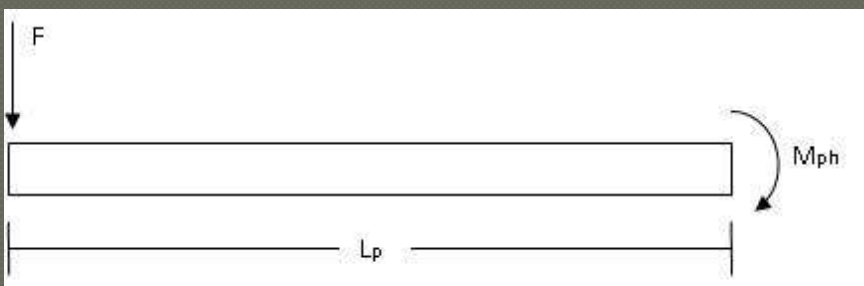




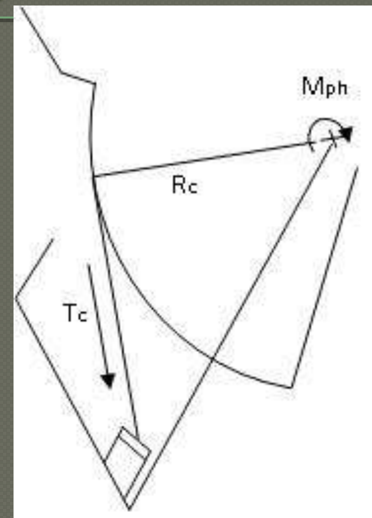
The Design - Locomotion



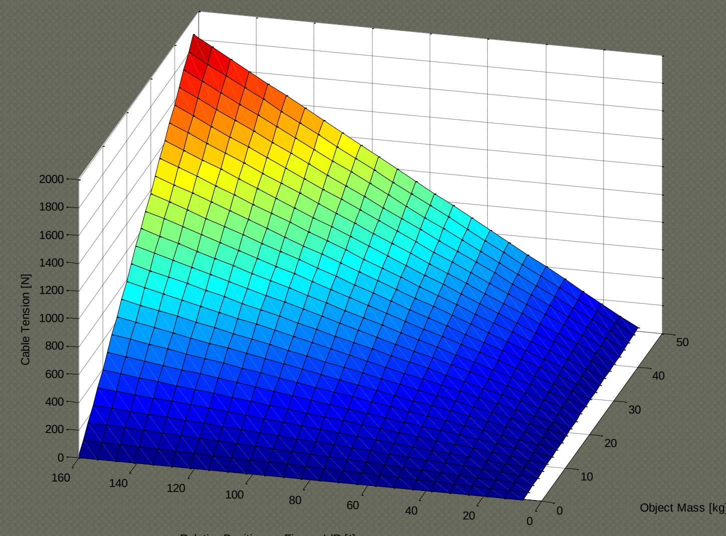
$$F_{grip} = \frac{m_o g}{2\mu_s}$$



$$M_{ph} = F_{grip} L_{ph} = \frac{m_o g L_{ph}}{2\mu_s r_c}$$



$$T_c = \frac{M_{ph}}{r_c} = \frac{m_o g L_{ph}}{2\mu_s r_c}$$

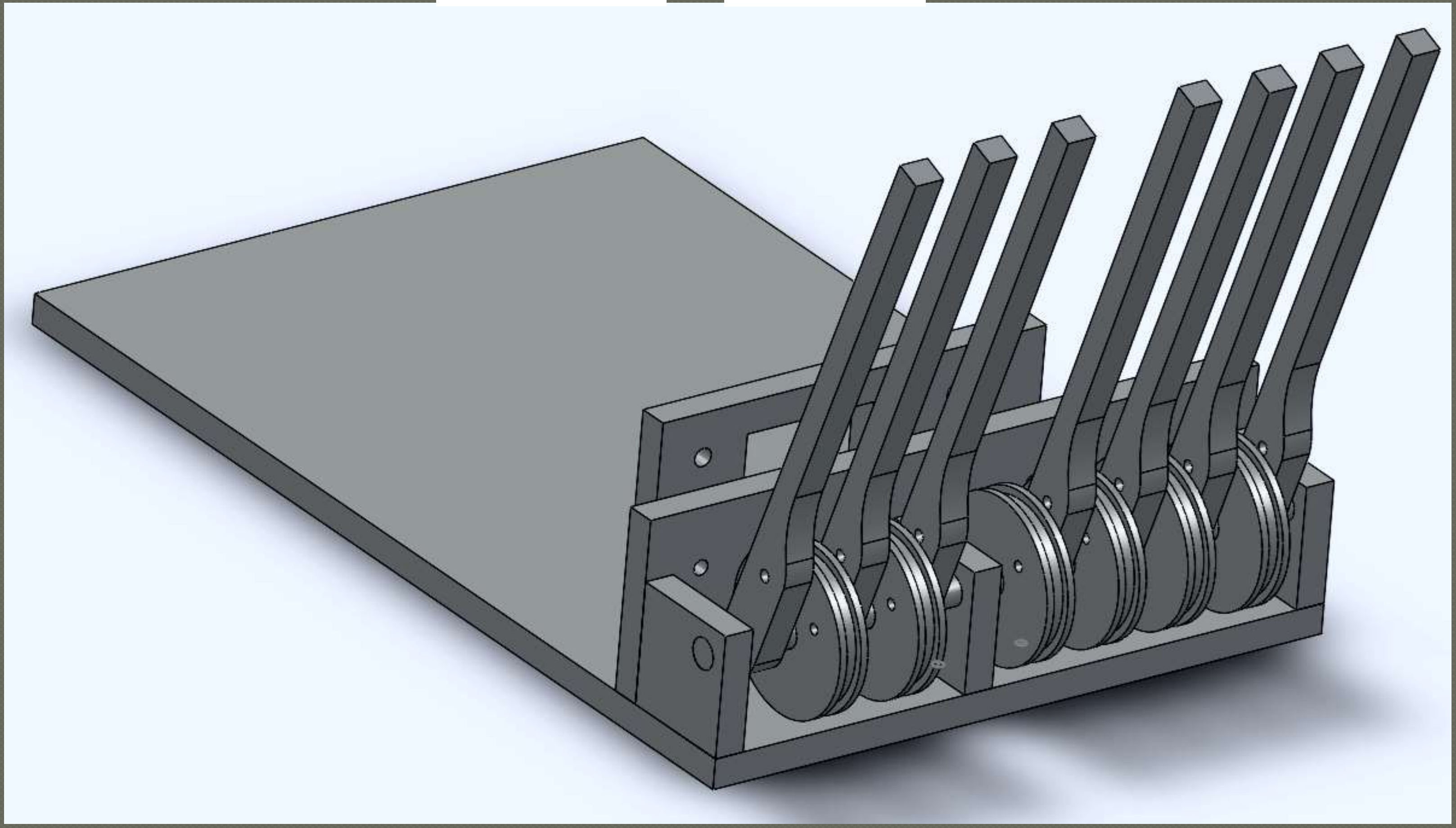


The Design – Locomotion

The lever box

$$\frac{M_{ph}}{R_{ph}} = T_c = \frac{M_l}{R_l}$$

$$R_l = \frac{M_l}{M_{ph}} R_{ph}$$



The Design – Material Selection

Stainless steel for structural components

Steel was chosen also for springs, rods, and pins

Wrap mandrills are made from brass

K49 Kevlar as a cable material

Nylon housing was chosen for sheathing material

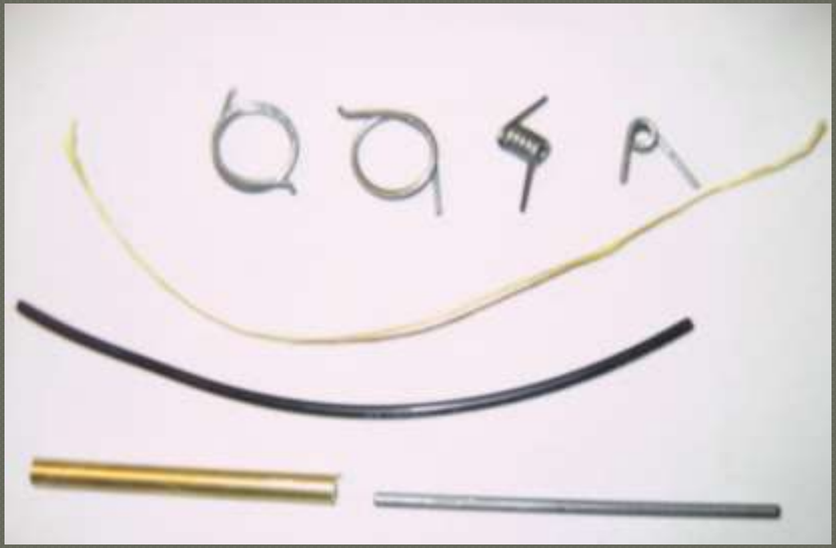
The Design – Material Selection

Silastic E RTV Silicone Rubber was chosen to coat palm-side faces of Fortis Manus for its:

- High tear resistance, 110 ppi
- Tensile Strength, 800 psi
- Durometer Hardness, 37 Shore A
- High coefficient of friction, 1.81 on dry surfaces
  - 0.63 on wet and dusty surfaces
- Non-toxic once cured
- Pliable

Manufacturing Methods

- With the exception of fasteners all parts were fabricated in-house:
  - Phalange Sections
  - Cables and Sheaths
  - Springs
  - Rods, Pins, and Mandrills



Manufacturing Methods

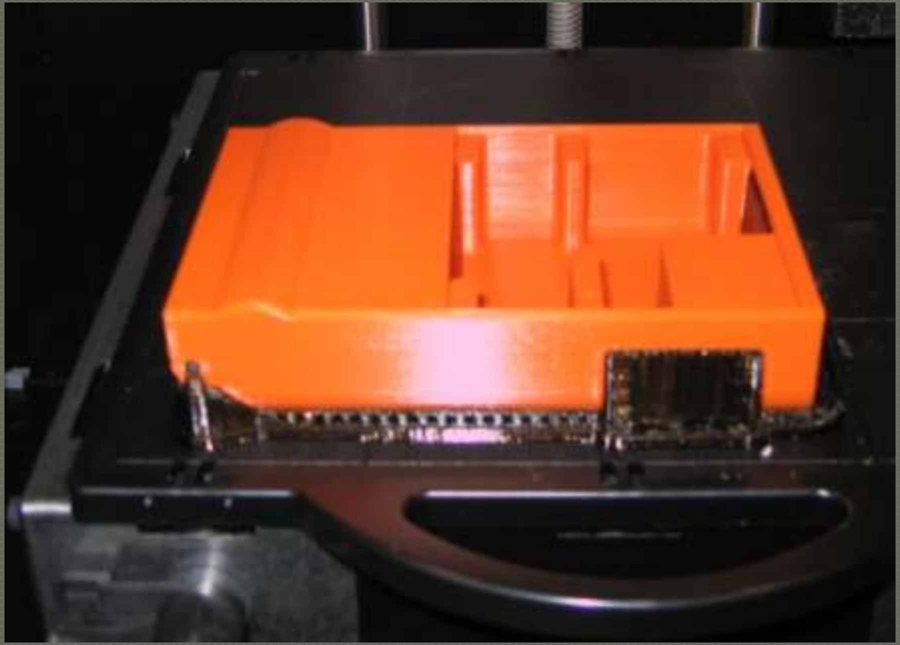
Dimension Elite 3D Printer

Purchased with the aid of University of Wyoming Engineering Fund for Enrichment (UWEFE)

Prints layer by layer

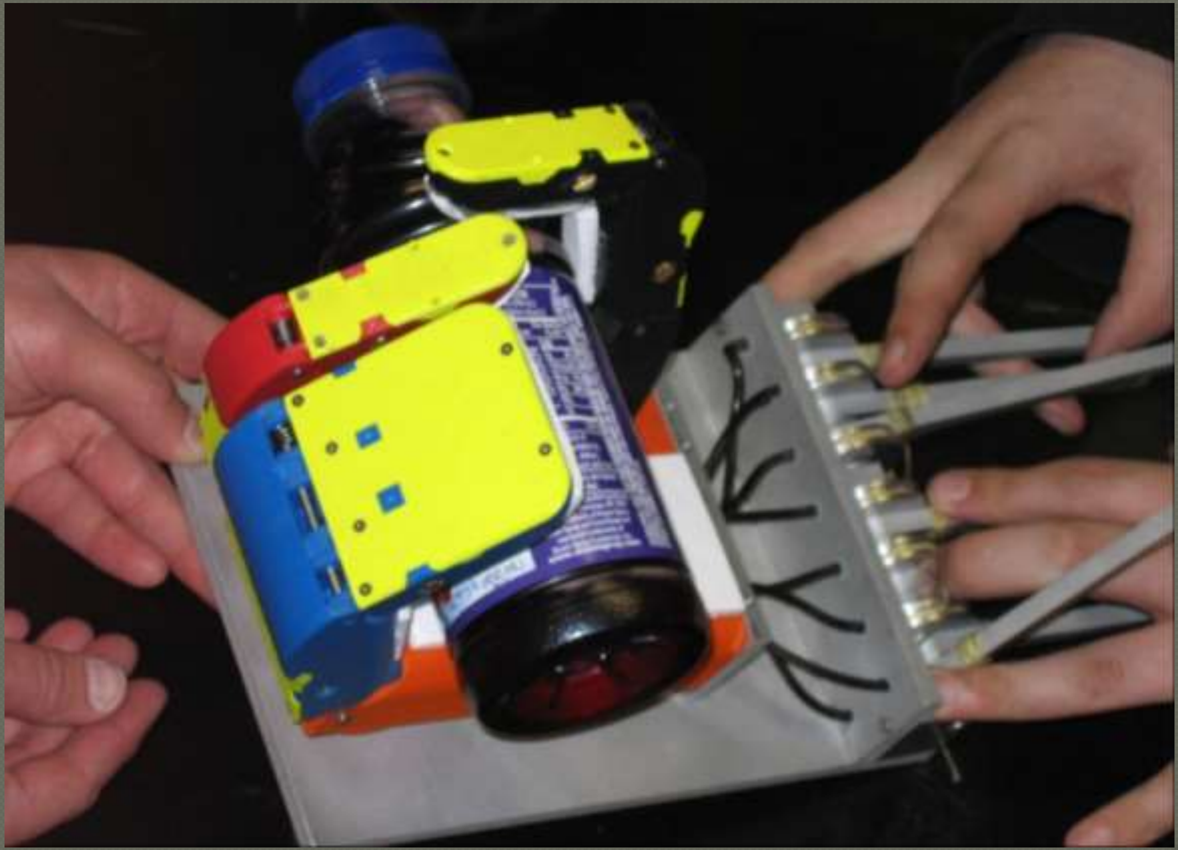
0.007 inch layer thickness

Manufacturing Methods



Design Evaluation – Testing

Fortis Manus was tested by attempting to grasp various objects



Design Evaluation - Testing

Design Evaluation – Pitfalls of the Design

- Cable/Sheath Friction
- Sheath Strength
- Gripping Material (Silicone) Adhesion
  - Adhesive needed
- Part Complexity
  - Fabrication by machining not feasible
  - Anisotropic material properties of printed medium

Schedule

	Task Name	Duration	Start	Finish	Predecessors
1	Revise Index Design	5 days	Mon 1/11/10	Fri 1/15/10	
2	Revise Grip Design	3 days	Sat 1/16/10	Mon 1/18/10	1
3	Revise Thumb Design	3 days	Mon 1/18/10	Wed 1/20/10	
4	Design Done--Present to Shop	0 days	Wed 1/20/10	Wed 1/20/10	3
5	Safety Rough Draft	7 days	Thu 1/14/10	Wed 1/20/10	
6	Revise Whole Design	3 days	Thu 1/21/10	Mon 1/25/10	4
7	Final Safety Plan	3 days	Thu 1/21/10	Mon 1/25/10	5
8	Broader Societal Impact Draft	8 days	Mon 1/25/10	Wed 2/3/10	
9	Final Broader Societal Impact Statem	5 days	Thu 2/4/10	Wed 2/10/10	8
10	Turn in Design to Shop	0 days	Mon 1/25/10	Mon 1/25/10	6,7
11	Prelim. Cable Drive Design (Mech.)	20 days	Tue 1/26/10	Mon 2/22/10	
12	Test Adhesion	2 days	Tue 1/26/10	Wed 1/27/10	
13	Develop Mat. Mold	11 days	Thu 1/28/10	Thu 2/11/10	12
14	Order Parts--Get Parts In	14 days	Tue 1/26/10	Fri 2/12/10	10
15	Manufacture Thumb	8 days	Tue 1/26/10	Thu 2/4/10	10
16	Assemble Thumb	1 day	Fri 2/5/10	Fri 2/5/10	15
17	Coat Thumb	2 days	Fri 2/12/10	Mon 2/15/10	16,13
18	Manufacture Index	5 days	Fri 2/5/10	Thu 2/11/10	15
19	Assemble Index	1 day	Fri 2/12/10	Fri 2/12/10	18
20	Coat Index	2 days	Mon 2/15/10	Tue 2/16/10	19,13
21	Manufacture Grip	8 days	Fri 2/12/10	Tue 2/23/10	18
22	Assemble Grip	1 day	Wed 2/24/10	Wed 2/24/10	21
23	Coat Grip	2 days	Thu 2/25/10	Fri 2/26/10	22,13
24	Manufacture Palm	5 days	Wed 2/24/10	Mon 3/1/10	21
25	Assemble Palm	1 day	Tue 3/2/10	Tue 3/2/10	24
26	Coat Palm	2 days	Wed 3/3/10	Thu 3/4/10	25,13
27	Midsemester, Interim Report	7 days	Fri 2/26/10	Fri 3/5/10	
28	Assemble Palm and Phalanges	2 days	Fri 3/5/10	Mon 3/8/10	23,20,17,26
29	Final Cable Drive Design	14 days	Tue 2/23/10	Thu 3/11/10	11
30	Cable Drive Program	14 days	Tue 2/23/10	Thu 3/11/10	11
31	Build Cable Drive	3 days	Fri 3/12/10	Tue 3/16/10	29
32	Program Cable Drive	2 days	Wed 3/17/10	Thu 3/18/10	31,30
33	Test Hand	4 days	Fri 3/19/10	Wed 3/24/10	32,31,28
34	Revise Hand	12 days	Thu 3/25/10	Fri 4/9/10	33,32,31,28
35	Presentation	7 days	Tue 4/13/10	Wed 4/21/10	34
36	Practice Presentation	3 days	Thu 4/22/10	Sat 4/24/10	35
37	Research Day	0 days	Sat 4/24/10	Sat 4/24/10	

	Task Name	Duration	Start	Finish	Predecessors
1	Revise Index Design	5 days	Mon 1/11/10	Fri 1/15/10	
2	Revise Grip Design	3 days	Sat 1/16/10	Mon 1/18/10	1
3	Revise Thumb Design	3 days	Mon 1/18/10	Wed 1/20/10	
4	Design Done--Present to Shop	0 days	Wed 1/20/10	Wed 1/20/10	3
5	Safety Rough Draft	7 days	Thu 1/14/10	Wed 1/20/10	
6	Revise Whole Design	3 days	Thu 1/21/10	Mon 1/25/10	4
7	Final Safety Plan	3 days	Thu 1/21/10	Mon 1/25/10	5
8	Broader Societal Impact Draft	8 days	Mon 1/25/10	Wed 2/3/10	
9	Final Broader Societal Impact Statem	5 days	Thu 2/4/10	Wed 2/10/10	8
10	Theoretical Cable Drive Design (Mecl	20 days	Mon 2/22/10	Thu 3/18/10	6
11	Midsemester, Interim Report	7 days	Fri 2/26/10	Fri 3/5/10	
12	Lever Box Cable Drive Design	10 days	Mon 3/8/10	Fri 3/19/10	6
13	Order Parts--Get Parts In	14 days	Fri 3/5/10	Wed 3/24/10	
14	Test Adhesion	2 days	Mon 3/22/10	Tue 3/23/10	
15	Develop Mat. Mold	3 days	Wed 3/24/10	Fri 3/26/10	14
16	Print Hand Parts	2 days	Mon 3/22/10	Tue 3/23/10	6,7
17	Build Lever Box	8 days	Mon 3/22/10	Wed 3/31/10	12
18	Assemble Hand	3 days	Thu 3/25/10	Mon 3/29/10	13,16
19	Coat Hand	2 days	Tue 3/30/10	Wed 3/31/10	18,14,15
20	Test Hand	4 days	Thu 4/1/10	Tue 4/6/10	19,18,17
21	Revise Hand	5 days	Wed 4/7/10	Tue 4/13/10	20,18
22	Presentation	7 days	Tue 4/13/10	Wed 4/21/10	18
23	Practice Presentation	3 days	Thu 4/22/10	Sat 4/24/10	22
24	Research Day	0 days	Sat 4/24/10	Sat 4/24/10	

Budget

Part (Quantity)	Total Cost
Large & Small Mandrels, Steel	$ 8.50 ($ 4.25 apiece)
Cable Mandrel, Brass(4 ft.)	$ 8.99 ($ 2.25 per ft.)
Pins (4 ft.)	$ 4.99 ($1.25 per ft.)
Kevlar Cable (50 ft.)*	$ 0.75 ($ 0.015 per ft.)
Sheathing – Nylon Tube (25 ft.)	$ 4.40 ($ 0.18 per ft.)
Large & Small Spring Wire (12 ft.)	$ 12.72 ($ 0.10 per ft.)
Fine Screws, #0-80, ¼ inch, Flat Head (x100)	$ 10.35 ($ 0.01 apiece)
Setscrews, #0-80, ¼ inch, Hex Socket (x100)	$ 10.70 ($ 0.01 apiece)
Tap Set, #0-80 (x1)	$ 12.72
ABS Plastic for hand (16.7 in^3)**	$ 75.15 ($ 4.50 per in^3)
Lever box, ¼ inch Aluminum (6 lbs)**	$ 6.42 ($ 1.07 per lb)
Lever Box, Screws, 4-40, ½ inch (x15)	$ 2.55 ($ 0.17 apiece)
Silicone Rubber, 4 kg bucket (x1)***	$ 227.27
Gorilla Glue, 0.52 oz. Bottle (x1)	$ 8.99
Total Project Material Cost	$ 394.50

* - provided by Dr. Walrath
** - provided by Machine Shop
*** - provided by Dow Corning

Conclusions

- What did we learn?

- What can we improve on?

Thanks To:

- Dr. Walrath – Our Advisor
- Dow Corning – Providing Silicone
- UW EFE Council & Dean's Office – 3D Printer
- UW College of ENGR. Machine Shop – Donating Print Medium, Managing 3D Printer & Lever-box fabrication

QUESTIONS?