Tabletop Robotic Arm

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Abstract

This team was tasked to the problem of building a robotic arm to demonstrate to incoming students and current students what engineering entails at SFA. The robot must fit on the top of a standard table and lift a 0.5-pound object. The customer specified a 5 to 6-axis robot that was able to reach about 2 feet in its range. The team began by designing a robot to fulfill the requirements of the customer. After a design was selected, the process of fine tuning the design and the prototyping of the design began. Multiple different analyses and changes took place in the making of the design, including writing a code for the robot to be able to move properly about the ranges of motion for each joint. Finally, testing of the product took place once a product was created, allowing the team to identify inadequacies and strengths throughout the design.

Design Choices

The conceptual designs generated by the team consist of an arm made up of 5 unique segments, including a base and a claw, each controlled via a stepper or servo motor depending on the type of motion desired. The electrical components are to be controlled by a Raspberry Pi as the primary processor which will be interfacing with a PCB. Additionally, a videogame controller of some kind will be used to control the arm manually. The mechanical concept design is currently based on a 4 servo-1 stepper design as indicated using decision matrices.

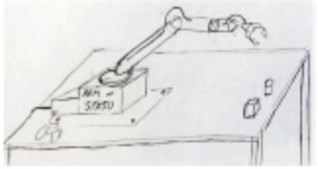

Figure 1. Conceptual Design for Robotic Arm

			4-Servo 2-Stepper			6-Servo			6 Stepper		
Design Criterion	Weight Factor	Units	Magnitude	Score	Rating	Magnitude	Score	Rating	Magnitude	Score	Rating
Material Cost	0.17	$/lb	11.3	6	1.02	11.3	6	1.02	11.3	6	1.02
Manufacturing Cost	0.17	$	500	10	1.7	500	10	1.7	500	10	1.7
Reparability	0.06	Experience	Good	6	0.36	Great	9	0.54	Good	6	0.36
Durability	0.06	Experience	Good	6	0.36	Good	6	0.36	Good	6	0.36
Aesthetic	0.12	Experience	Great	9	1.08	Great	9	1.08	Great	9	1.08
Reliability	0.12	Experience	High	9	1.08	Fair	6	0.72	Fair	6	0.72
Method of Control	0.18	#	2	10	1.8	2	10	1.8	2	10	1.8
Responsiveness	0.12	ms	42	7	0.84	42	7	0.84	42	7	0.84
					8.24			8.06			7.88

Figure 2. Decision Matrix

Methods and Materials

To determine the stepper motor holding torque requirements, static analysis was applied to the arm while fully laterally extended to simulate the maximum possible loading condition. With these new parameters from the static analysis, the motor selection is still currently in progress. On the software side of things, inverse kinematics will be implemented to handle the motor control and ensure movement happens in a linear fashion, which has been simulated within a purely virtual environment (Processing IDE). Forward kinematics is where the hand or claw of the robotic arm is dependent on the base segment. While inverse kinematics will have the end or parent segment dictate the other child segments of the arm.
Through different design for manufacturing and assembly methods chosen, the design was optimized and allowed for an easier manufacturing process and assembly. An example of this is shown in the figure below.

Part #	Description	Finish	Cost	Qty
001	PLA	Grey	$25.00	1
002	18HM18-0904S Stepper Motor	Unfinished	$58.79	1
003	Digital Servo (4-pk)	Unfinished	$28.99	1
004	16-Channel PWM Servo Controller Module	Unfinished	$8.99	1
005	Raspberry Pi 3 Model B 2 GB	Unfinished	$43.00	1
006	Plexiglass 20" X 24" X 1/8"	Unfinished	$38.80	1
007	2"X2"X.5" Wood	Unfinished	$24.76	1
008	22 Gauge Wire Solid Core Hookup Wires	Unfinished	$13.99	1
009	Xbox Controller	Unfinished	$58.00	1
010	Bushing	Unfinished	$3.94	1
011	ELEGOO 120pcs Multicolored Dupont Wire	Unfinished	$6.98	1
012	Adafruit TB6612 1.2A DC/Stepper Motor Driver Breakout Board	Unfinished	$6.95	1
013	AC-DC Switching Power Supply 5V 20A 100W	Aluminium	$39.99	1
014	5T 20 Awg 15-FT 12/3 Heavy Duty	Blue	$21.99	1
015	Zener Diodes Kit	Unfinished	$11.99	1
016	Rg Sleeve (#6)	Unfinished	$6.80	1
017	20A Switch SPST 3 Pin Rocker Switch	Unfinished	$12.36	1
018	Fuse 3 Amp	Unfinished	$5.10	1
019	Inline Fuse Holder ATC/ATO	Unfinished	$10.99	1
	Total Cost		$380.47	

Figure 4. Bill of Materials

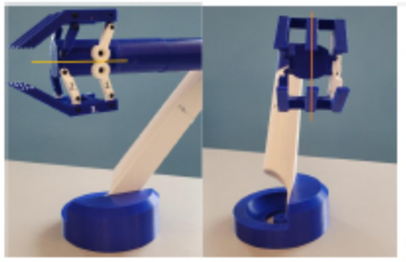

Figure 5. DFA - Simplified Claw Design

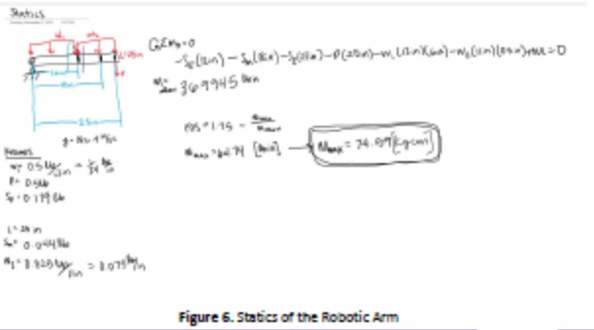

Figure 6. Statics of the Robotic Arm

Results

Through the final assembly of the project, the team discovered strengths and weaknesses throughout the design. One strength was the controlling interface, which included an inverse kinematics algorithm and code to handle the manual controller. The design of the robot is a strength because it is meant to be optimized for transport and demonstration of the electronics throughout the design to other students. A weakness discovered through testing of the robot revealed that there was a miscalculation of the stall torque needed in the servo that lifts the arm located at the base and sourcing of the servos was not reliable. Figure 6 pictures a modified static analysis which reveals the new stall torque to be about 75 kg cm. To supply this, a new power supply will be purchased that supplies a voltage and current necessary for powering the servos properly. This will allow the robot to be able to pick up a half pound block and the claw to be able to have a firmer grip on the object.

Figure 6. Final Assembly of Robotic Arm

Discussion

The capstone team has worked to develop a model and a functional prototype that can move a 2 cubic inch block approximately 2 feet in a 360° range of motion surrounding the arm. Additionally, the robot should be capable of being controlled by an operator or functioning autonomously as a "display model" for current or prospective students to view at their leisure. The target market for this product is almost exclusively educational, as it will not be large enough or strong enough to be used in any real industrial applications.

Conclusions

To further progress this robot, the team will return through the summer months and finish the project, with the new power supply and servos, so the SFA Physics, Engineering, and Astronomy Department can utilize it to show incoming students and current students.

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Team Members

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