Department of MECHANICAL ENGINEERING
THE UNIVERSITY OF UTAH

NASA Robotic Test Stand Arm

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Introduction

The purpose of this project is to improve on the work of a previous capstone team that built a robotic arm to assist in the operation of a hydraulic material testing machine. The Robotic Arm system is designed to load and unload coupon specimens from the grips of the testing machine. In order to increase the level of safety and automation of this robot, user interfacing features such as natural language processing, a graphical user interface (GUI), and computer vision were implemented.

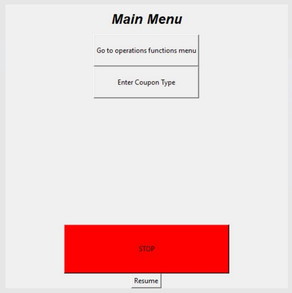
A major focus of this project is the automation of the material testing procedure. Rather than a human manually placing coupons in the testing stand, the robotic arm must load the coupons with accuracy, precision, and repeatability.

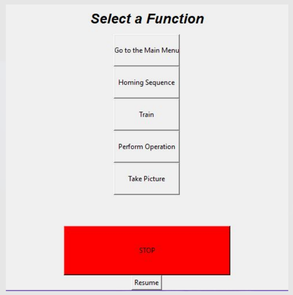
The Robotic Test Stand Arm project is sponsored by the National Aeronautics and Space Administration (NASA).

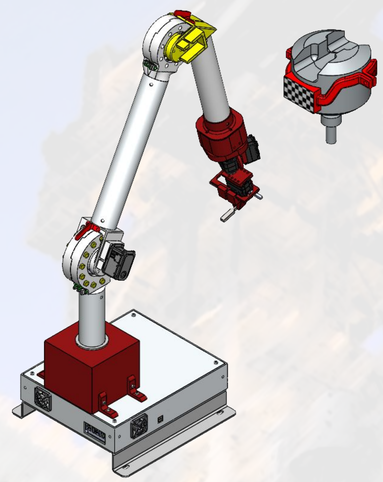
Project Requirements

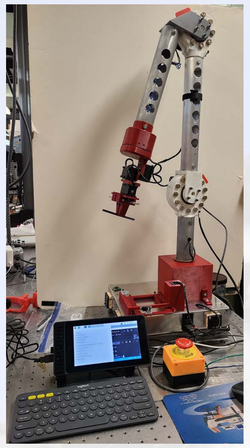
	Requirement	Specification	Unit
User Safety	Emergency shutoff button readily and easily visible and available.	If the emergency shutoff is pressed, the robot will stop moving within 30ms.	ms
	Operate at a speed that will not cause harm to the user and environment.	The maximum speed the robot tool can move is 10cm/s.	cm/s
	Only allow torque within the motor specifications	If motor torque on any motor exceeds 5.5Nm, operation stops	Nm
Automation	Able to autonomously retrieve coupon geometry	The robot will use computer vision to compute geometry within 3% of true value	mm
	Able to autonomously realign the coupon in the testing stand	The robot will place the coupon within 0.5 deg of vertical	deg
	Store all coupon data.	Store coupon data using the Hierarchical Data Format	mB
User Int. (UI)	Have a graphical user interface (GUI) where buttons link to certain actions by the robot.	The robot can be controlled using a 7” touchscreen display resulting in proper action beginning in 1 second	s
Accuracy	Able to detect and process voice commands.	Any voice commands from 30dB to 90dB will be detected and processed by the robot	dB
	Able to reach position with less error than a human operator.	The coupon will be placed within 0.5mm of the center of the testing stand.	mm
	Place a coupon into the testing stand vertically and in the center of the stand.	The robot will place the coupon within 0.5 deg of vertical in the stand.	deg
Repeatability	The Robot Arm must be able to repeatedly place coupons in the testing stand	The robot can place at least 5 coupons in a row in the testing stand	# of coupons

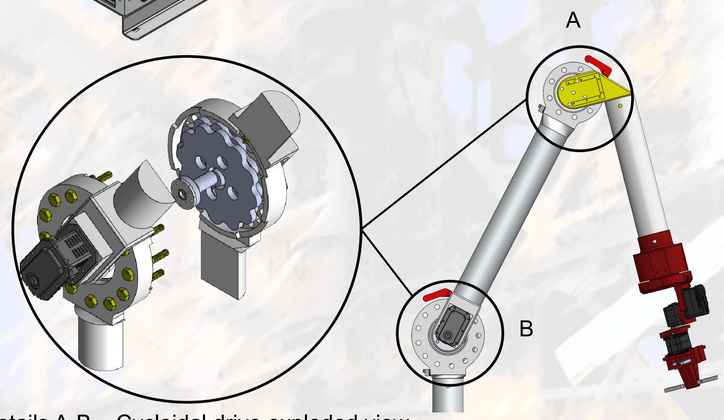
User Interfacing - GUI











Details A-B – Cycloidal drive exploded view

Project Phases

Phase 1 (Spring 2021) :
- Changed microcontroller interface from Arduino Mega to RaspberryPi 4
- Ported kinematics controls algorithms from C++ to Python

Phase 2 (Summer 2021) :
- Designed cycloidal gear systems and replaced previously designed gears

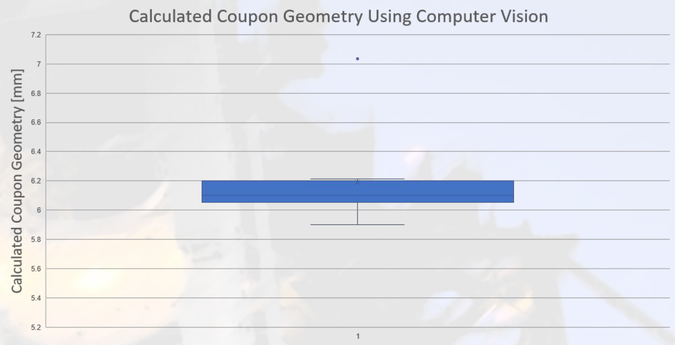
Phase 3 (Fall 2021)
- Implemented motor calibration sequence
- Implemented computer vision method to obtain coupon geometry
- Introduced Graphical User Interface (GUI)
- Implemented natural language processing
- Completed repeatability testing via digital image correlation

Computer Vision and Digital Image Correlation Testing

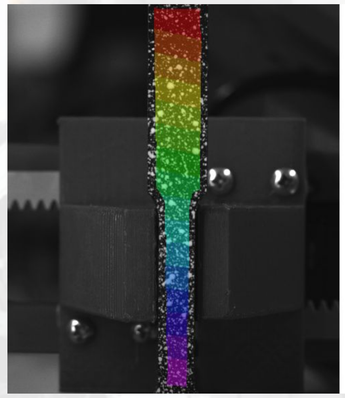
In order to validate our work, we employed two different tests. To ensure the Computer Vision was correctly detecting the geometry of the testing coupon, we measured the coupon manually, then used the Computer Vision to get the dimensions. The generated results were then compared to the manual result and statistics were generated.

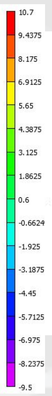
To confirm the repeatability of the robot, we used a Digital Image Correlation test. This test used computer software to determine translation of the coupon as well as deviation from pure vertical. A reference coupon was manually placed, then the robot arm was moved into the reference position with the coupon 38 times. Using the paint splattered pattern on the coupon, the software is able to determine displacement by comparing the trial image to the reference image.

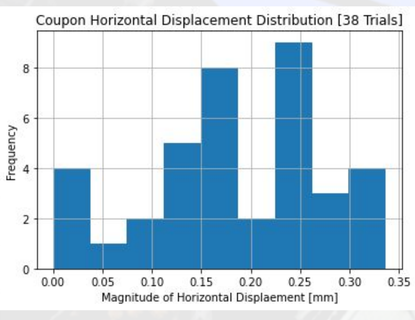
Test Results

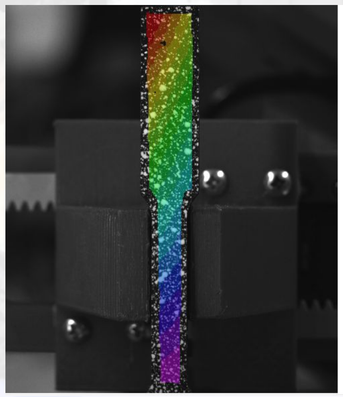


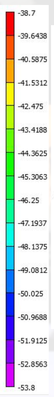
Computer Vision test results for calculating coupon geometry while in testing stand. The true coupon geometry was 6.19mm, and the mean value in this test was 6.17mm. This is an error of 2.71%.

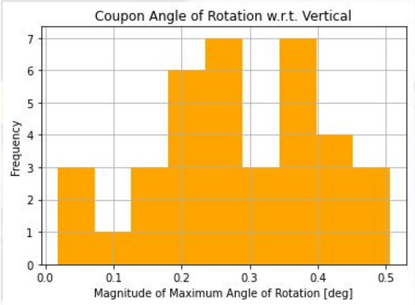












Above are sample contour plots of the Digital Image Correlation test. The scale on the right side of each image is in thousands of an inch (1/1000”).

Conclusion

The group successfully met the goals of the project. The repeatability was confirmed with digital image correlation. We were able to get well below the 1 mm of horizontal shift with a result of about .33 mm on average. We also were able to control all of the movements of the robotic arm with the new kinematics algorithms and GUI. The software allows the user to easily modify instructions, as well as more complex motions if necessary.

Future Work

For future work, the next group will work on interfacing the Robotic Arm with the hydraulic tensile test machine. The Robot will be able to autonomously load and unload coupons and collect coupon test data for future analysis.