Robotic End-Effector

Colton Workman, Jake Murphy, Robert Shields, Thomas Wudyka

Mechanical Engineering, University of New Hampshire, Durham, NH 03824

Advised by John Roth

Introduction

Retrieve objects of irregular geometry during unmanned missions in space, deep sea and hazardous environments.

- •Ancient/Fragile Artifacts
- •Salvage of Technological Value
- •Space Debris and Satellites

The end-effector must contour to object geometry

Methodology and Strategy

Two interchangeable contour strategies that cater to the mission have been developed by the team

Method 1: Resistively heat PLA using an internal nichrome wire and press onto artifact taking its shape

PLA Pucks contour onto irregular objects allowing for secure grip

Pros
- Rapidly deployable
- Requires one robotic arm to operate
- "Micro contouring" giving strong grip

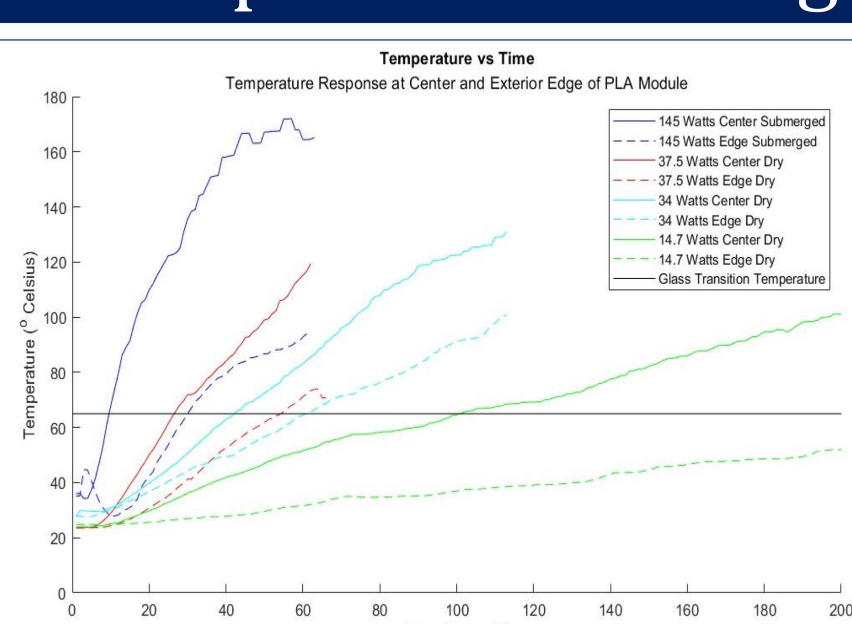
Cons
- Capacity to harm fragile objects
- Difficult to remove from closed geometries
- Large power draw in cold environments

Method 2: Scan the object and 3D print end-effectors that match the geometry

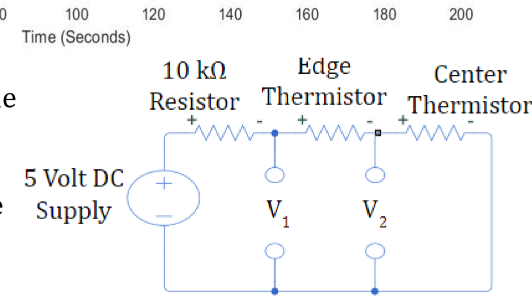
Pros
- Reliable
- Deep contours possible
- Variety of printing material options
- No risk of sticking to object

Cons
- Scanning not always possible
- Time consuming
- Requires scanner, 3D printer, and clamp systems
- Requires significant stability

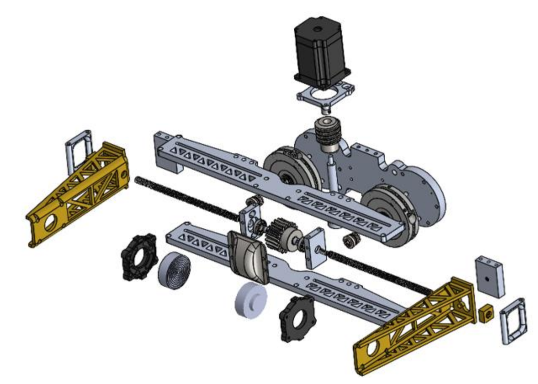
PLA Puck Temperature Testing

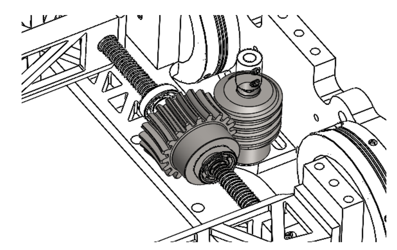


Testing of PLA Puck heat time including thermistor setup, outgassing and results from underwater test, and voltage divider circuit

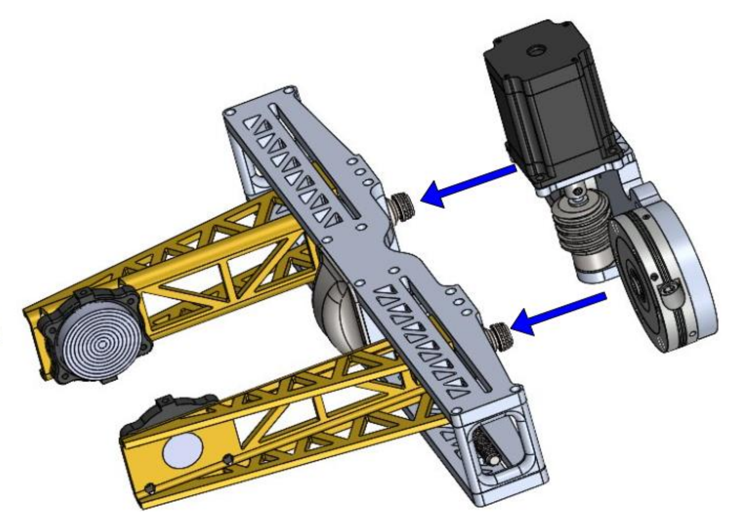


System Overview- CAD and Mounted System

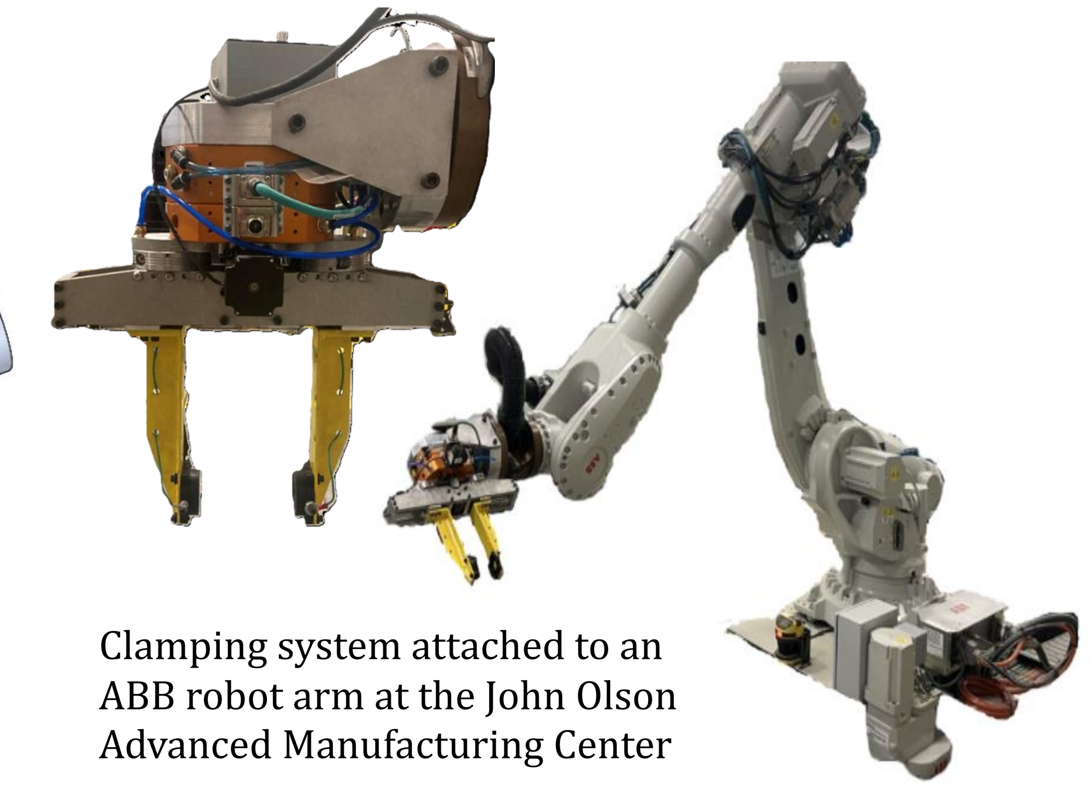




Worm gear robotic arm to clamp power transmission

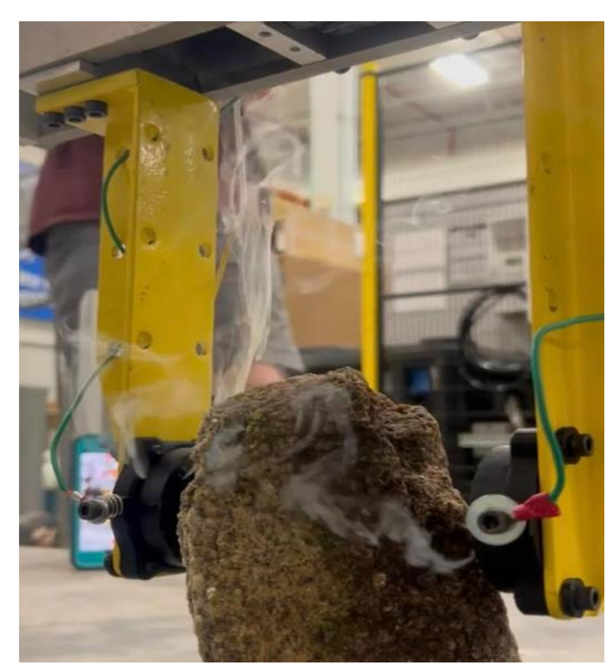


CAD Assembly showing pneumatic Schunk connectors allowing clamp to be detached from robotic arm for a hand-off between transport systems



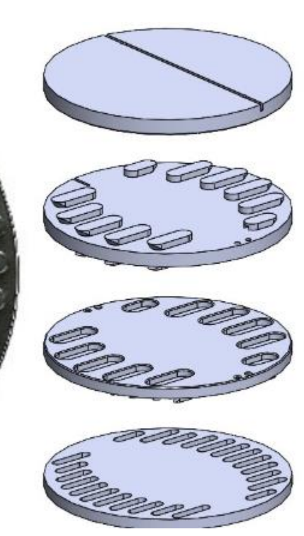
Clamping system attached to an ABB robot arm at the John Olson Advanced Manufacturing Center

Resistively Heated PLA Pucks Method

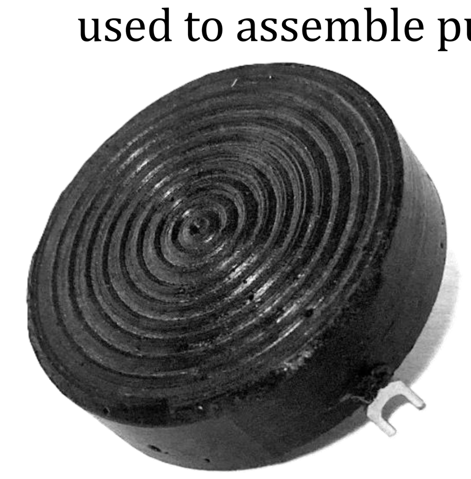


Resistive Heating of PLA pucks

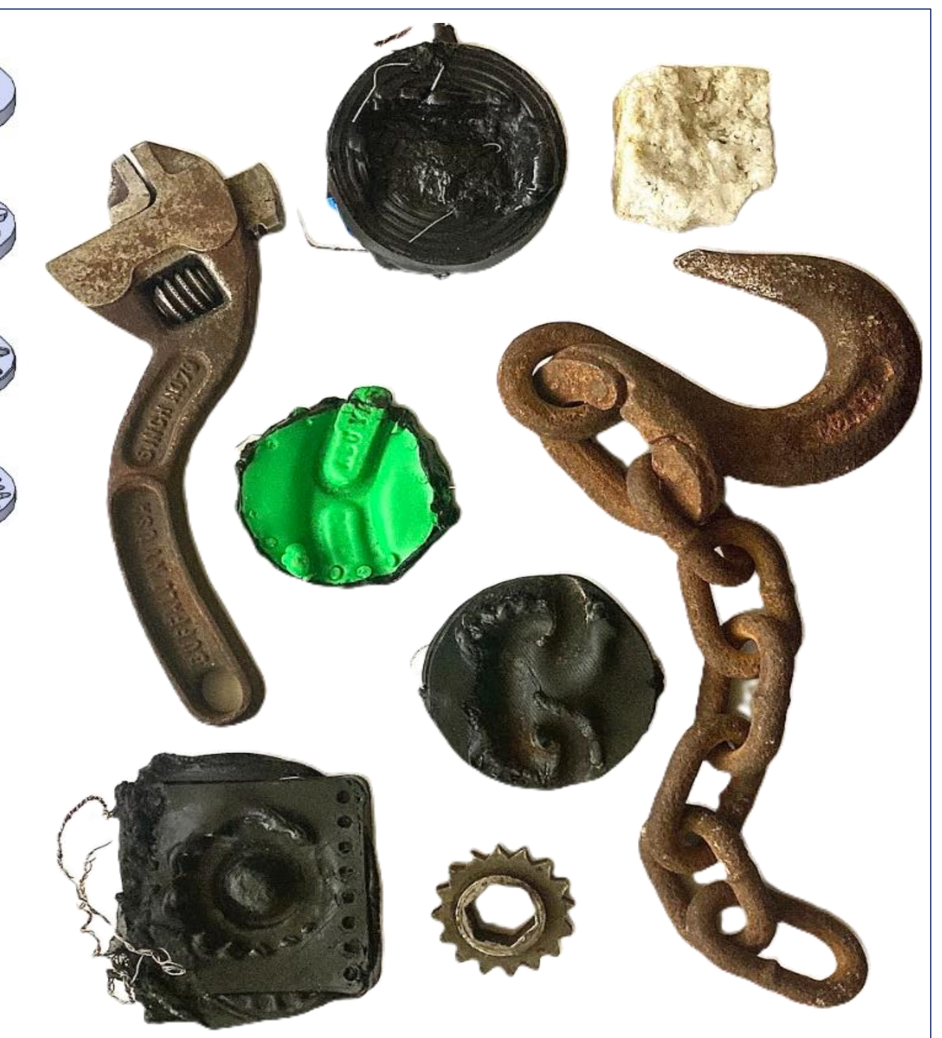
Cross section of PLA pucks showing nichrome wire matrix



PLA plies wired with nichrome used to assemble puck



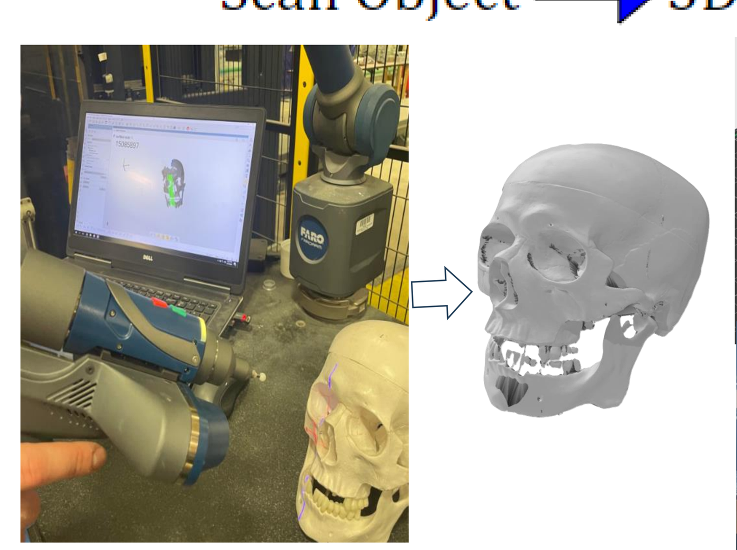
PLA Puck after heated compression of assembled plies



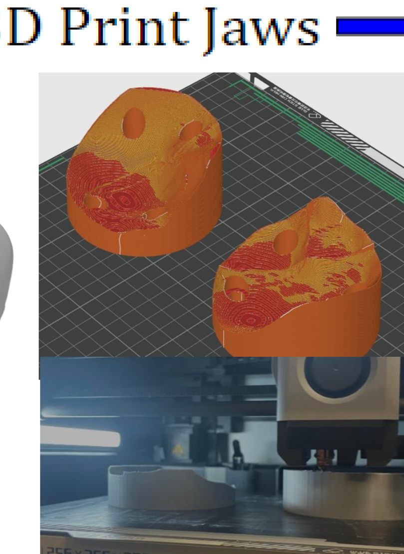
Contoured PLA pucks once removed from retrieved artifacts

Scan and Print Method

Scan Object → 3D Print Jaws → Clamp



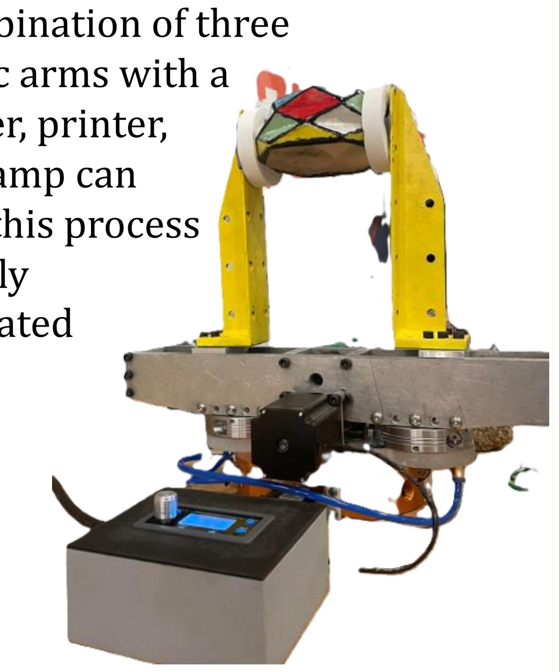
3D rendering achieved via scan of artifact



Printing of PLA end-effectors matching artifact geometry

Robotic arm picks up delicate artifact with contoured end-effector

A combination of three robotic arms with a scanner, printer, and clamp can make this process entirely automated



PLA Puck Manufacturing Methods

1. Print or injection mold PLA Plies
2. Thread nichrome wire through designated path
3. Run current through wires and compress layers to seat wires
4. Heat under compression to form solid module

Mold used for heated compression

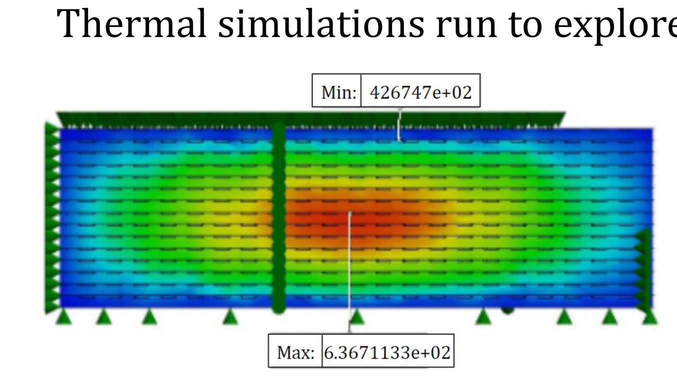
Trials and Tribulations

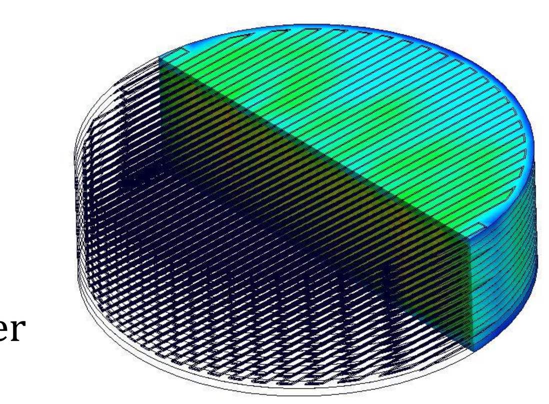
Issues During PLA Puck Development (from left to right)

- Delamination between layers before solid puck development
- High-temp PLA escaping through skin layer due to extreme temperature gradient
- Void nucleation within solid puck solidification process
- Burning of PLA puck surface changing thermoplastic properties

Simulations for PLA Puck

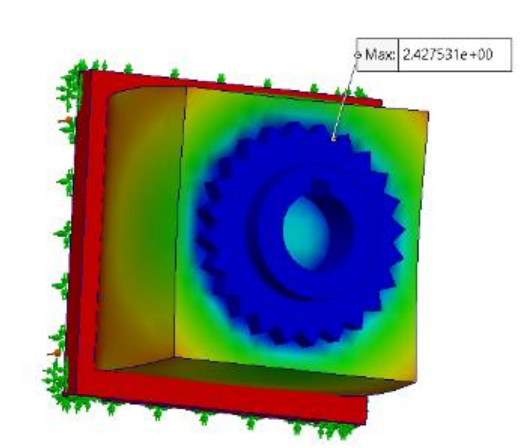
Thermal simulations run to explore scalability of PLA puck





Temperature gradient observed after 10 seconds of heating (Kelvin)

Non-linear deformation analysis simulating maximum stresses observed on fragile artifacts during PLA hot compression



Maximum Stress of 2.34 MPa which is much less than the yield strength of porcelain

Comparison of experimental test with simulation

Acknowledgements

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