NRI: Towards Dexterous Micromanipulation & Assembly

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PURDUE UNIVERSITY

XYZT Lab

Design Lab

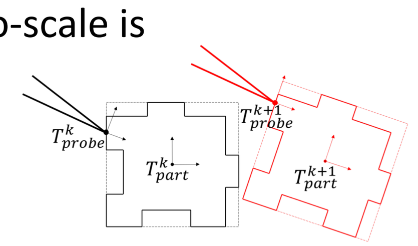
Motivation

- Perform fundamental research related to transitioning robotics manipulation from the macro-scale to the micro-scale
- Lay the foundations for new micro-robotic tools

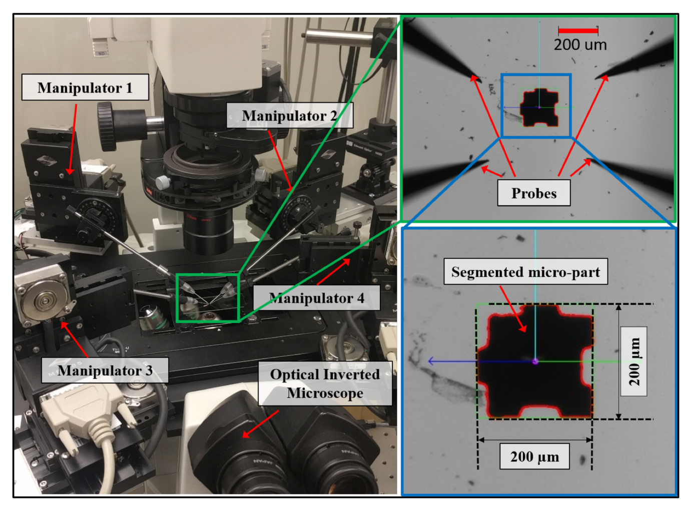
Micromanipulation Using a Learned Model

Goal

- Learn how to manipulate micro-parts
- **Challenge:** Multi-contact problem, friction, interaction dynamics at micro-scale is difficult to model



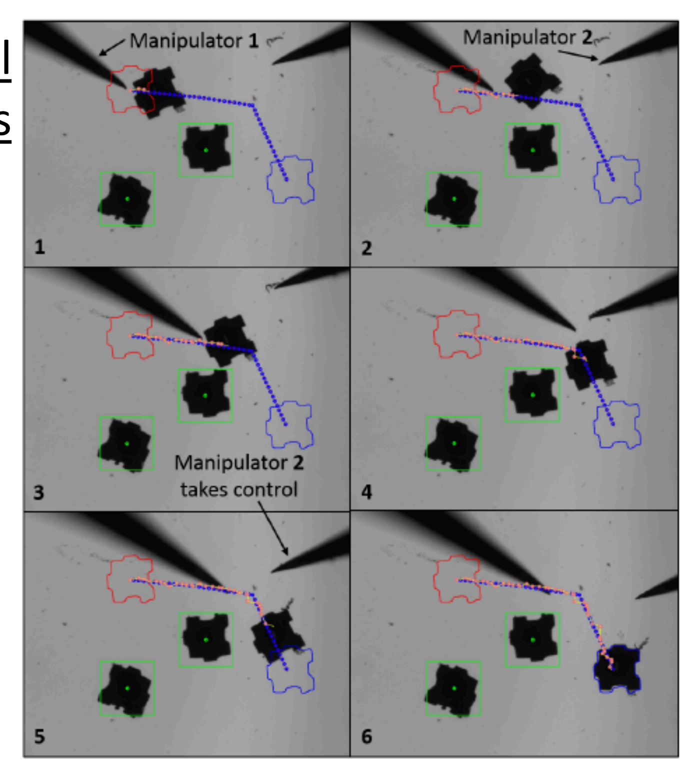
Testbed



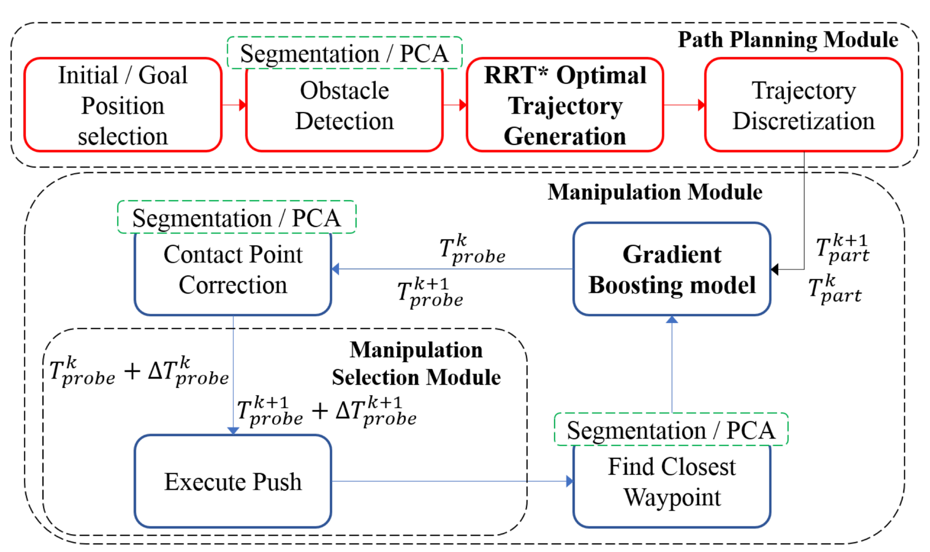
Micromanipulation Model

- Multi-target regression problem
  Gradient Boosting algorithm applied
- Input: initial and final configuration of part
- Output: Probe initial and final positions
- Separate model for each manipulator
- Contact modelled as a point contact

Experimental Results



System Work Flow



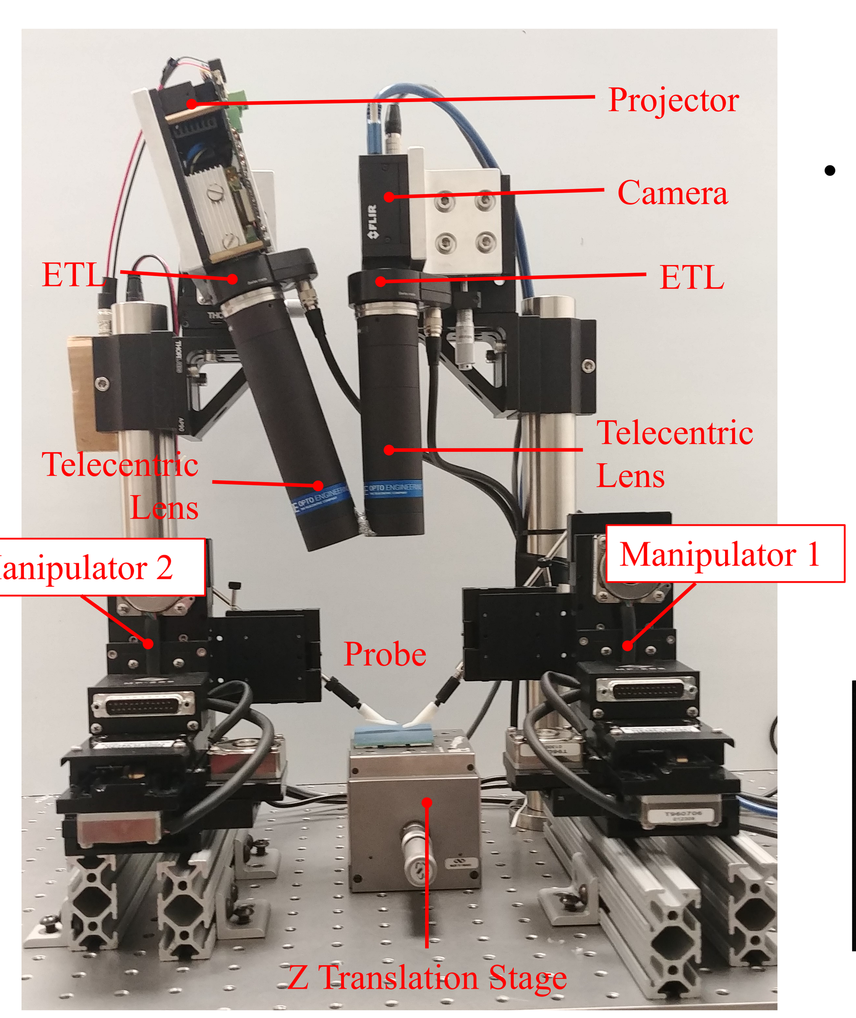
Goal 2

- Develop a multi-resolution 3D vision-system to provide sub-diffraction limit tracking for sensing in the micro-teleoperation and augmented/virtual reality system

Prototype 3D Vision System

- Telecentric and electrical tunable lenses (ETL) are employed to increase its resolution and depth of field
- System specifications:

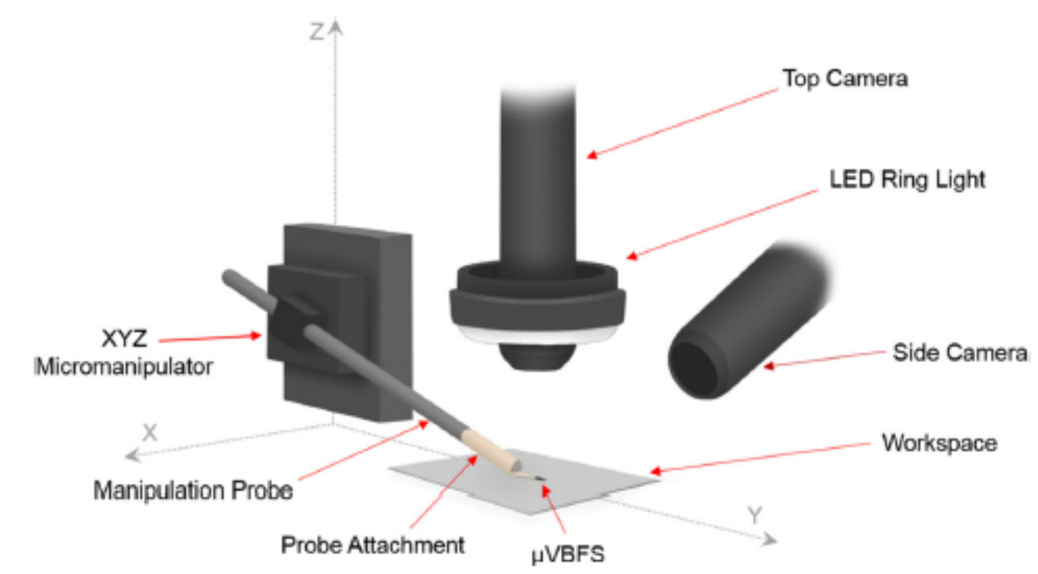
Parameter	Value
Pixel Size	2.18 μm
Field of View (FOV)	3.20 mm × 1.94 mm
Depth of Field	~0.7 mm (w/o focal sweep)
	~2.3 mm (w/ focal sweep)
Frame Rate	Max: 171 Hz (w/o focal sweep)
	100 Hz (w/ focal sweep)



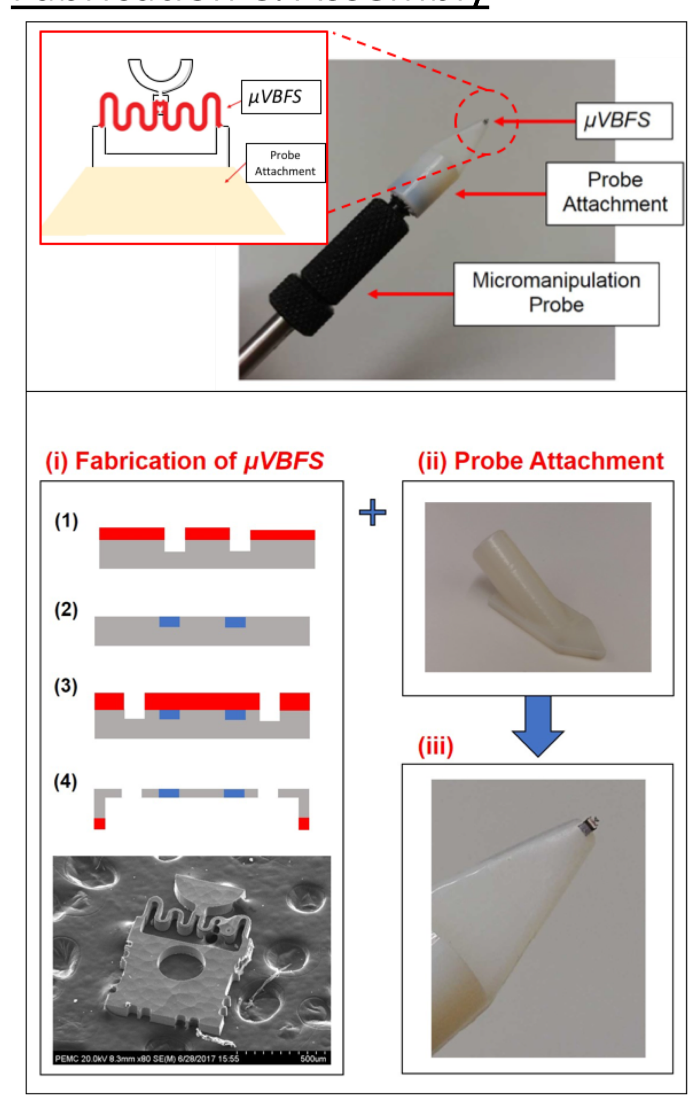
Vision-Based Micro-Force Sensing

Goal 1

- Develop a new class of manipulation probes for use as 3D vision-based micro-force sensors (μVBFS)

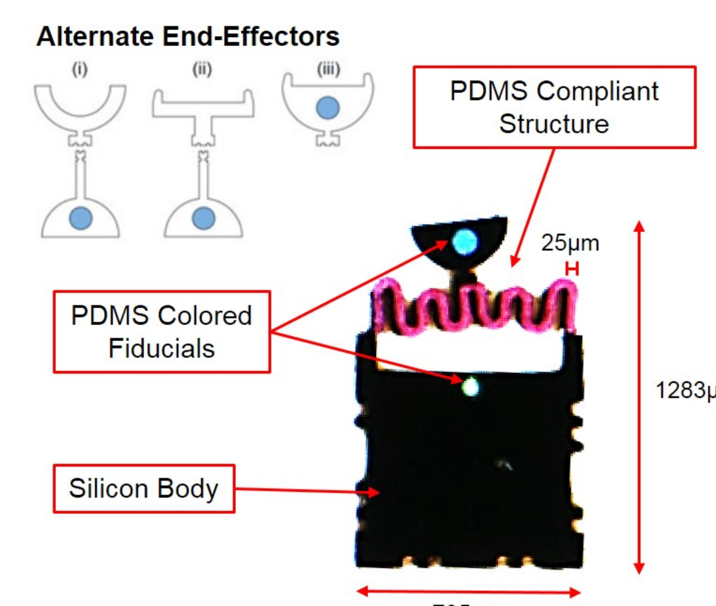


Fabrication & Assembly

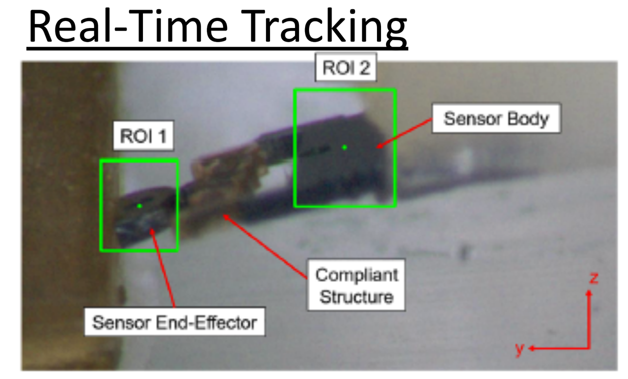


Updated μVBFS Design

- Alternative end-effector geometries for enhanced manipulation
- PDMS curing ratio tailored for desired force-sensing range
- Colored fiducials for color-based tracking of displacements/micro-force sensing
- Tracking at 20 Hz achieved
- Used to characterize stiffness of different hydrogel spheroids, which are typically used in 3D tissue engineered constructs

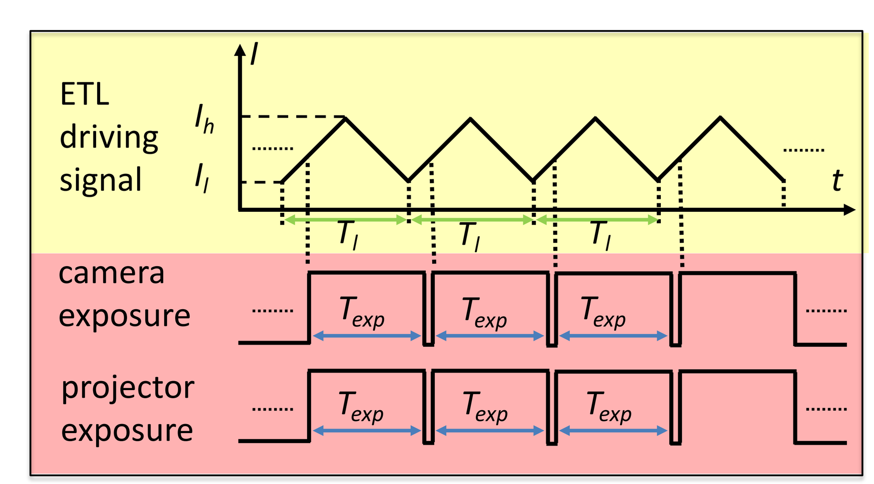


Real-Time Tracking

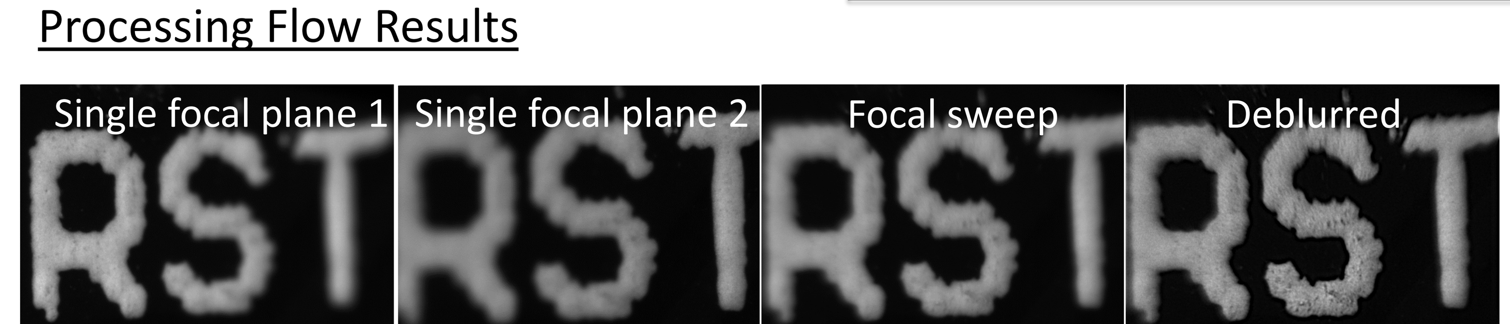


Focal Sweep Technique

- Change focal plane of the camera continuously during the exposure time with ETL, and then compute the all-in-focus image by Weiner Filter or Richardson-Lucy algorithm.



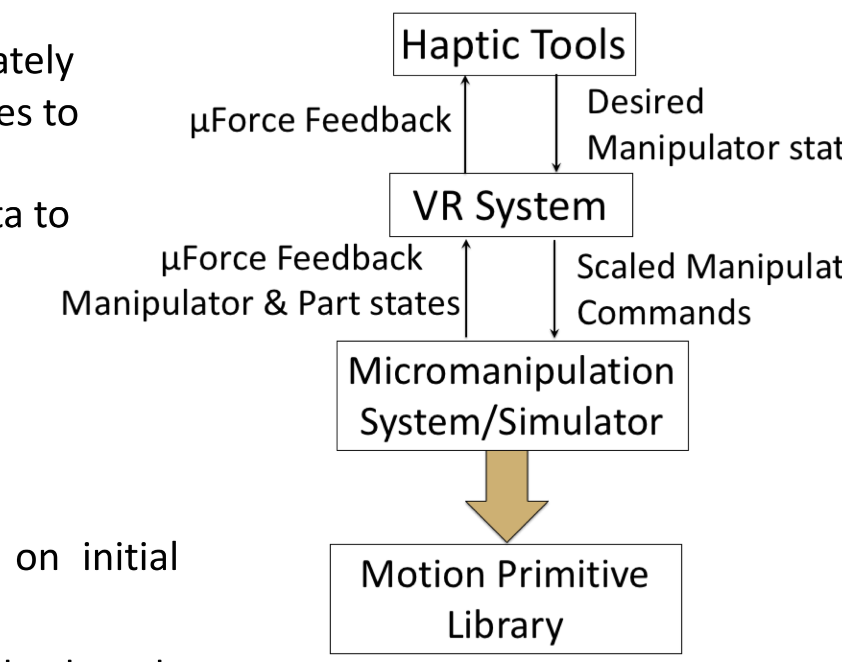
Processing Flow Results



Human-Robot Interaction

Goals

- Develop haptic tools/skins to accurately relay micro-scale manipulation forces to the teleoperator
- Capture manipulation and force data to develop new autonomous micromanipulation primitives



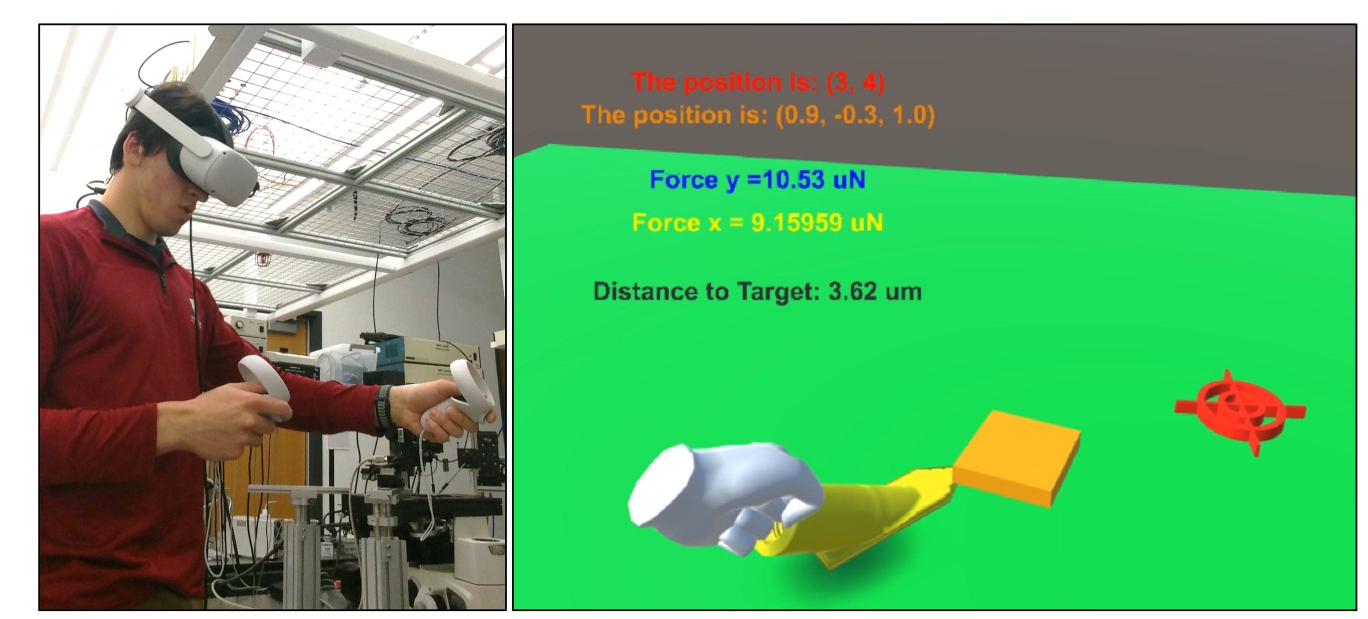
VR System

VR Scene Setup:

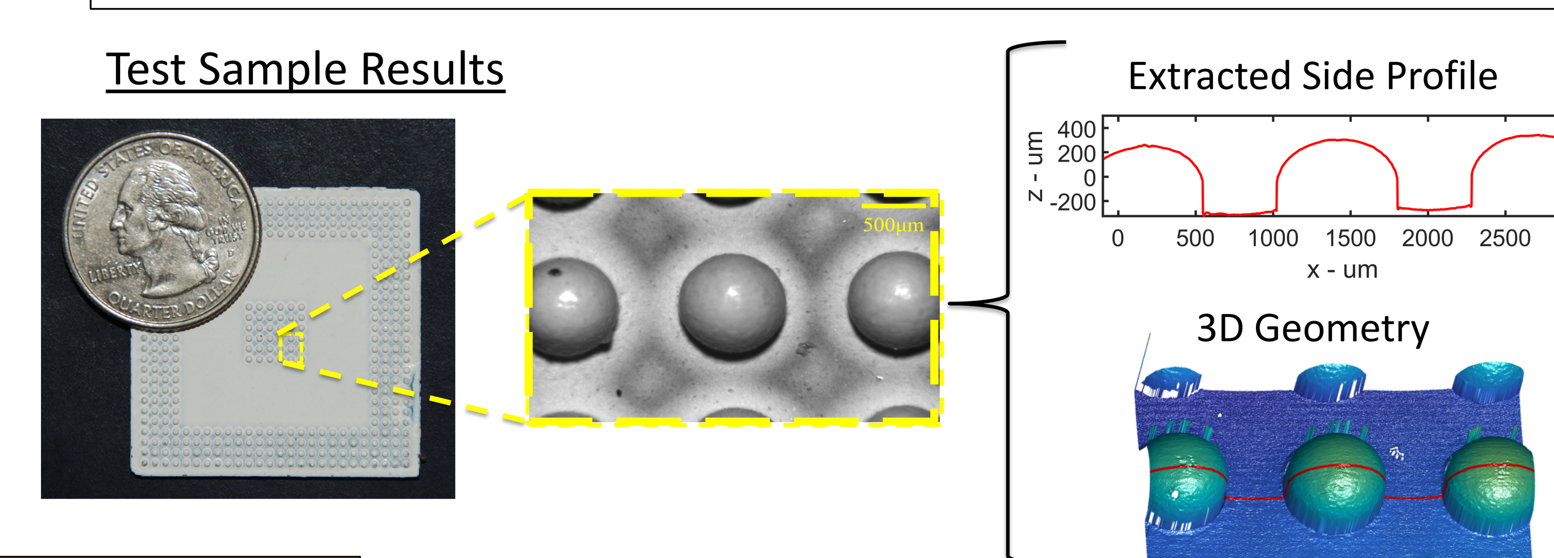
- Initializes the VR scene based on initial state of real system
- Identifies current states of parts, target, obstacles, and probes

VR Manipulation Capabilities:

- Able to pick up probes using Touch controllers and use them to manipulate the parts around the workspace.
- System logs movements for each probe and manipulator hardware system is able to replicate movements.
- For each instruction, the path is discretized and probe tracking algorithms compute forces for each discretized movement.
- If force is higher than the threshold force set by the user, movement halts automatically to keep manipulated objects safe.



Test Sample Results



Selected Publications

- V. Venkatesan and D. J. Cappelleri, "Path Planning and Micromanipulation Using a Learned Model," in *IEEE Robotics and Automation Letters*, vol. 3, no. 4, pp. 3089-3096, Oct. 2018, doi: 10.1109/LRA.2018.2849568.
- Sang Ho Yoon, Luis Paredes, Ke Huo, and Karthik Ramani. 2018. MultiSoft: Soft Sensor Enabling Real-Time Multimodal Sensing with Contact Localization and Deformation Classification. *Proc. ACM Interact. Mob. Wearable Ubiquitous Technol.* 2, 3, Article 145 (September 2018), 21 pages. DOI:https://doi.org/10.1145/3264955
- Xiaowei Hu, Guijin Wang, Yujin Zhang, Huazhong Yang, and Song Zhang, "Large depth-of-field 3D shape measurement using an electrically tunable lens," Opt. Express **27**, 29697-29709 (2019)

2021 NRI & FRR Principal Investigators' Meeting

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