Towards Dexterous Micromanipulation

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Design Lab
XYZT Lab

Motivation

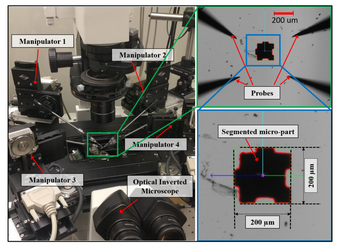
- Perform fundamental research related to transitioning robotics manipulation from the macro-scale to the micro-scale
- Lay the foundations for new micro-robotic tools

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

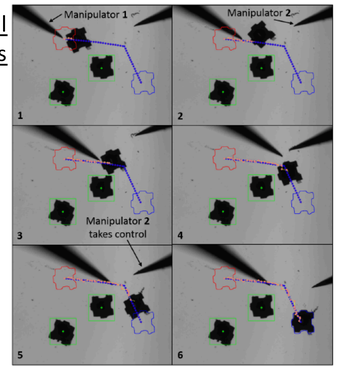
Testbed



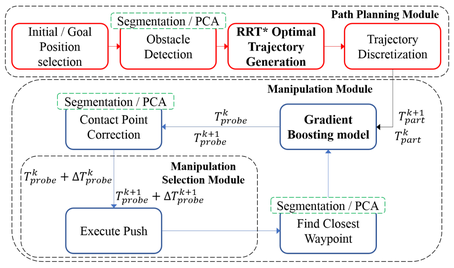
Micromanipulation Model

- 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

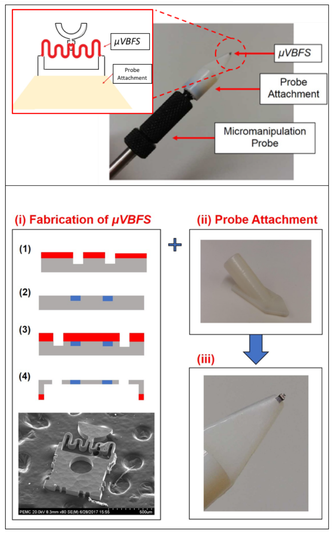


Vision-Based Micro-Force Sensing

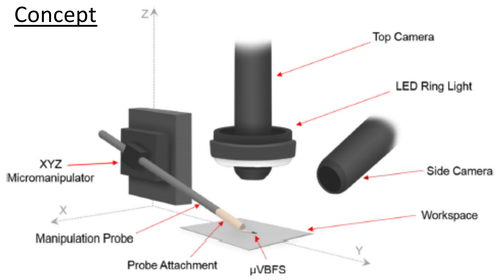
Goal 1

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

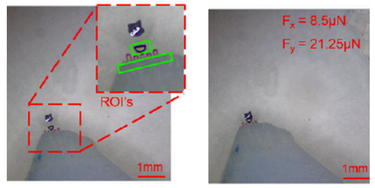
Fabrication & Assembly



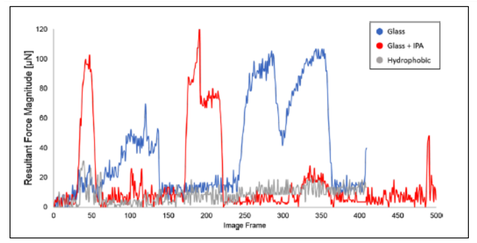
Concept



Experimental Results

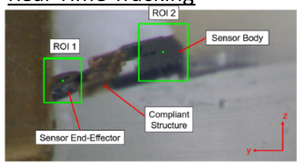


Case Study: Micromanipulation Substrate Design



- Study of the pushing forces required to manipulate micropart
- Three substrates were tested: glass slide, glass slide cleaned with IPA, glass slide with a thin hydrophobic gold layer
- Hydrophobic gold layer is the best at reducing uncertainties

Real-Time Tracking

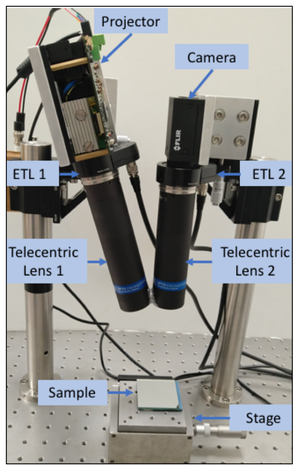


Goal 2

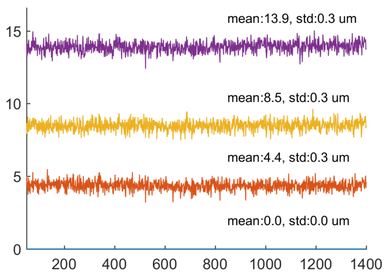
- Develop a multi-resolution 3D vision-system to provide sub-diffraction limit tracking for sensing in the micro-teleoperation and augmented/virtual reality system

Prototype System

- Camera and projector system
- Two electrically tunable lenses (ETL)
- Electronic synchronization between the camera and the projector
- The depth of field (DOF) of the system ranges from 300 µm to approximately 3 mm
- Able to resolve approximately 300 nm depth changes for diffuse white surface
- System spatial resolution (~ 2.3 µm), field of view (~ 4.4 mm x 2.9 mm), and depth resolution (~300 nm) meet the desired performance



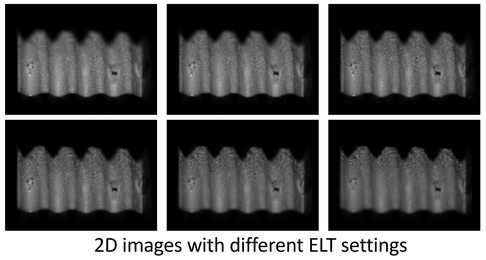
Resolution Verification



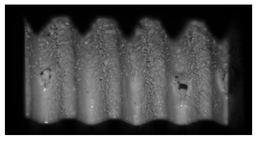
Next steps: develop software algorithms to

- Stack 3D images with different ETL settings to create an all-in-focus 3D image
- Achieve autofocus for the multi-resolution 3D imaging system
- Improve data capturing and processing speed to achieve real-time performance

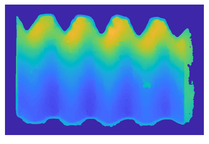
Preliminary Experiments



2D images with different ELT settings



All in-focus stacked image (3 mm)

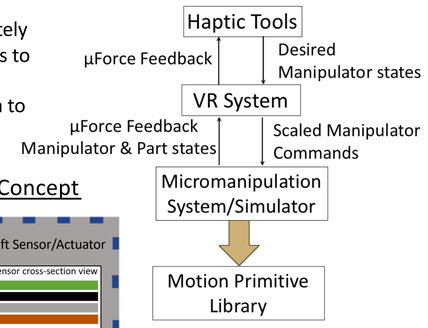


Rough 3D depth from ETL

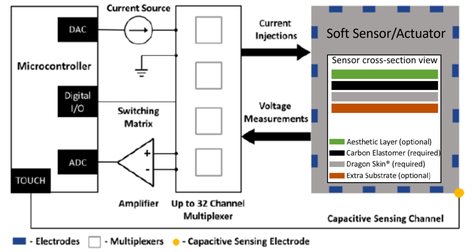
Human-Robot Interaction

Goals

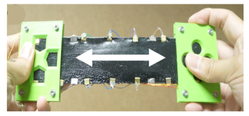
- Develop haptic tools/skins to accurately relay micro-scale manipulation forces to the teleoperator
- Capture manipulation and force data to develop new autonomous micromanipulation primitives



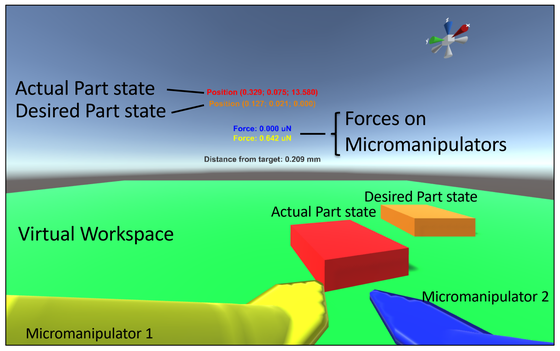
Multimodal Soft Sensor/Actuator Concept



Embedded Haptic Skin into Interaction Tool



Virtual Reality System



Outreach

Toy Design Workshop

- Two-week workshop for students in grades 7 and 8
- Combination of lecture-based and project-based classroom exercises
- Final team project – Storytelling Challenge incorporating at least 1 prior topic covered

Topics covered:

- How to sketch
- Strength of Materials
- Reverse Engineering
- Simple Vector Analysis
- Forces
- Newton's Laws of Motion
- CAD & Rapid Prototyping
- Basic Circuit Analysis

2020 National Robotics Initiative (NRI) Principal Investigators' Meeting
FEBRUARY 27 - 28, 2020 | ARLINGTON, VIRGINIA

Award ID#: 1637961