Integrating Visual and Tactile Feedback for Enhanced Object Manipulation

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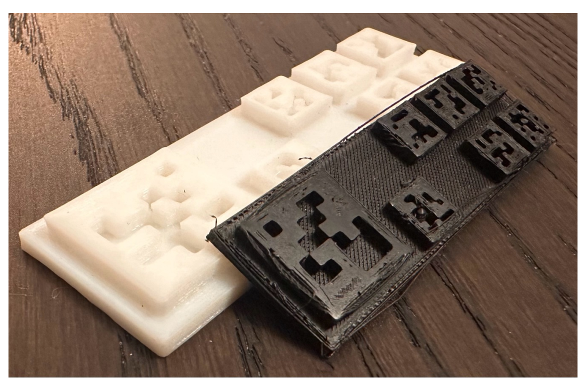
INTRODUCTION

- A current challenge in the field of robotics is understanding how to teach robotic arms to automatically grasp and manipulate objects.
- One of the main issues is training robots to grasp objects without visual servoing.
- Alongside my mentor, I have developed a novel technique that uses visuotactile markers to enable robots to grasp objects using tactile feedback when visual recognition is unavailable.
- These unique markers encode information on how to correctly grasp a variety of objects.



3D Printed Visuotactile Markers

OBJECTIVES

- Design and 3D print unique visuotactile markers that will be placed on an assortment of objects.
- Develop computer vision and control algorithms to allow for detection of the visuotactile markers and for visual servoing of robotic arms.

THEORY

- **3 Assumptions:**

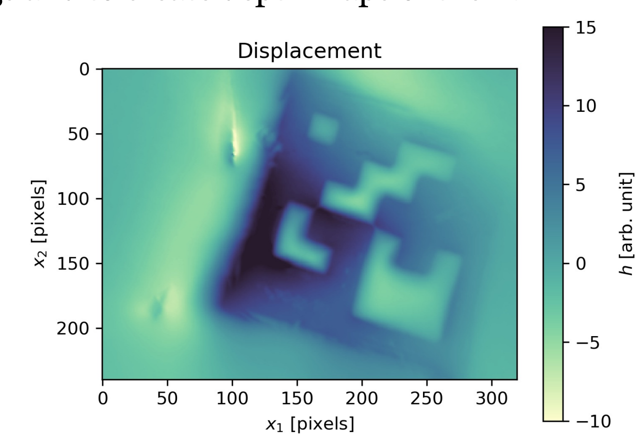
  1) We assume the object has a maximum linear and angular velocity.

  2) We assume the marker is a rigid body.

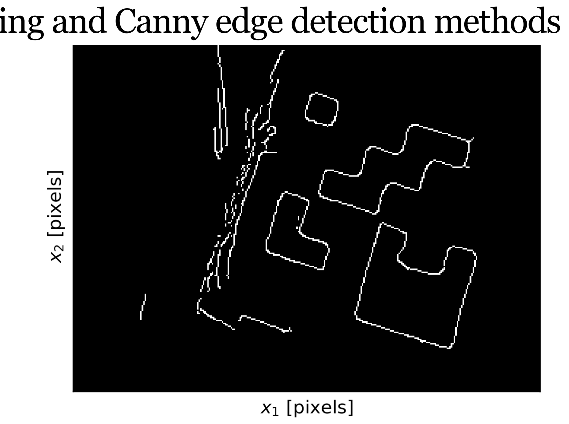
  3) We assume that we have access to the marker's state while it intersected the sensing plane at some prior point in time.

METHODS

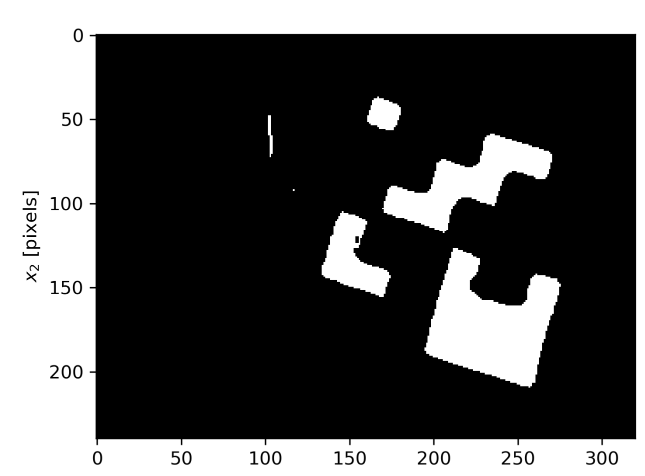
- At the start of the project, I was provided CAD designs in Fusion360 of the visuotactile tags by my mentor.
- I 3D printed the visuotactile tags, created molds, cured them in UV resin, and then sanded the markers.
- We used the GelSight Mini sensor to visualize the visuotactile tags and to create depth maps of them.



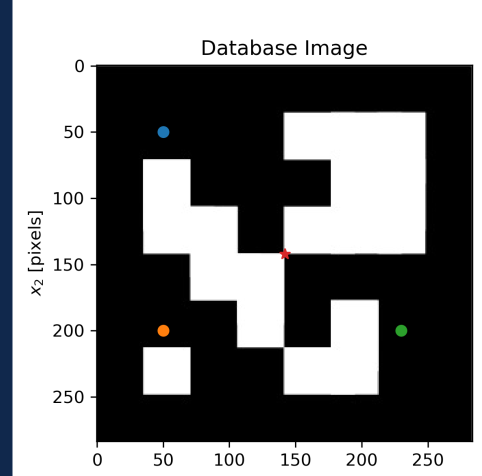
- After creating depth maps, we settled on the Savitsky-Golay filtering and Canny edge detection methods for noise filtering.

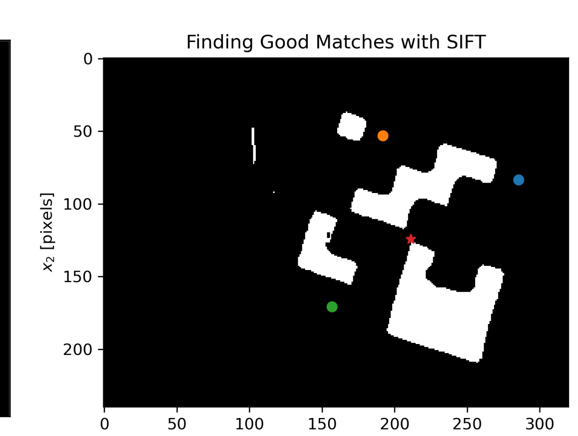


- We determined only the tags within the marker—not the border of the marker—needed to be preserved for recognition.
- Then, we performed dilation to preserve the edges of each tag, and we then applied flood-fill and contouring to fill in each tag.



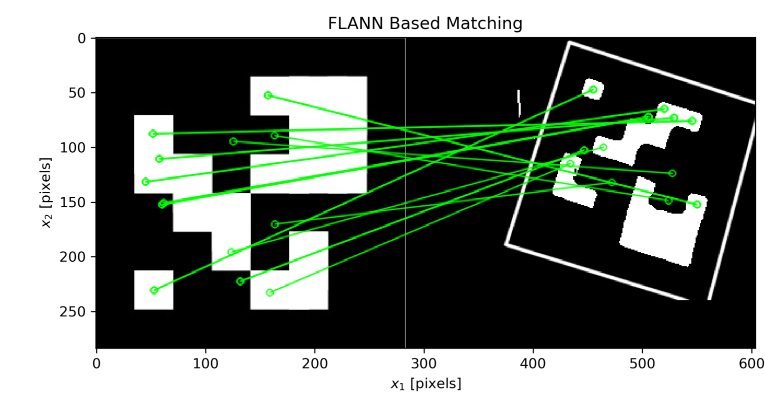
- We were able to identify good matches in the flood-fill image and match them to the database image using Scale-Invariant Feature Transform (SIFT).



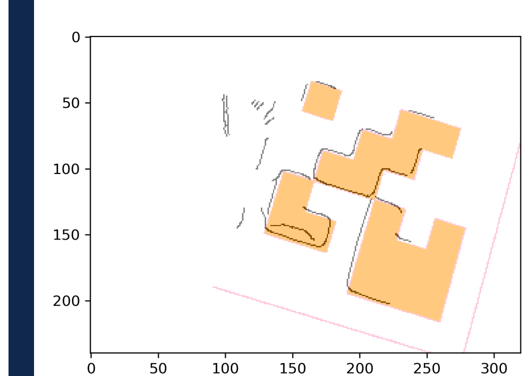


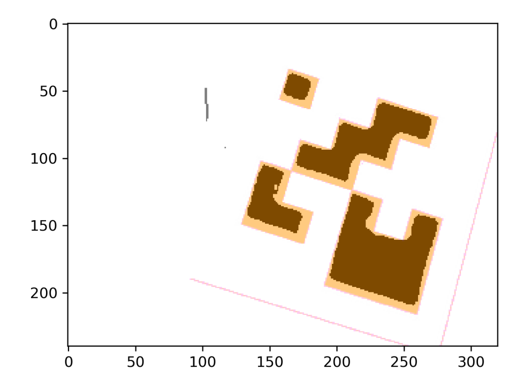
RESULTS

- We successfully used Scale-Invariant Feature Transform (SIFT), FLANN-based matching, and homography transforms to map features in the database image to the flood-fill image.

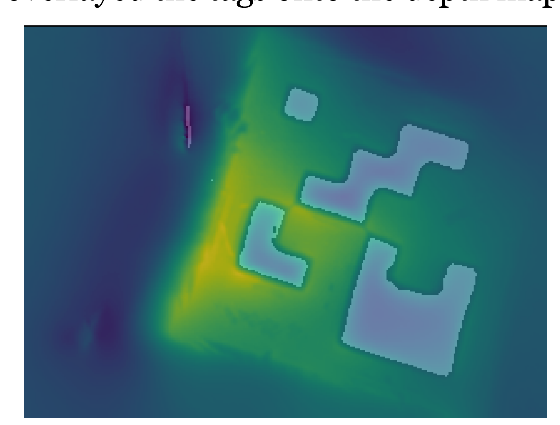


- We overlayed the database tags onto the edge-detection and flood-fill images.

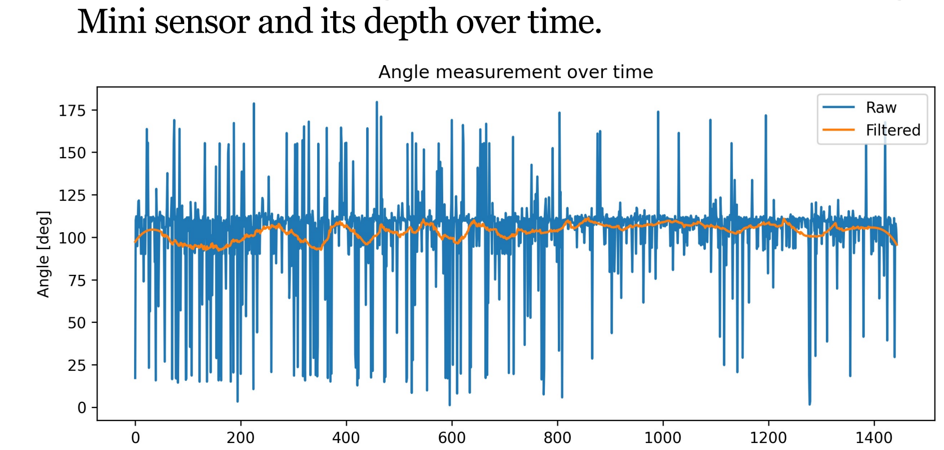


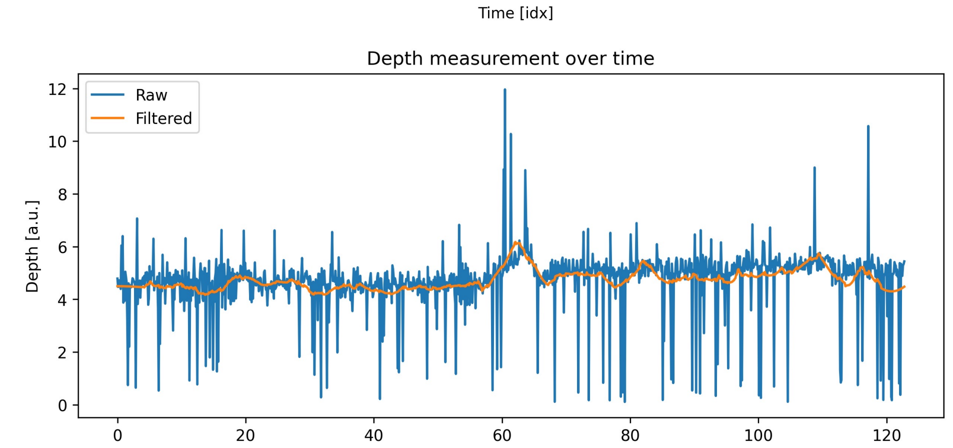


- Then, we overlayed the tags onto the depth maps.



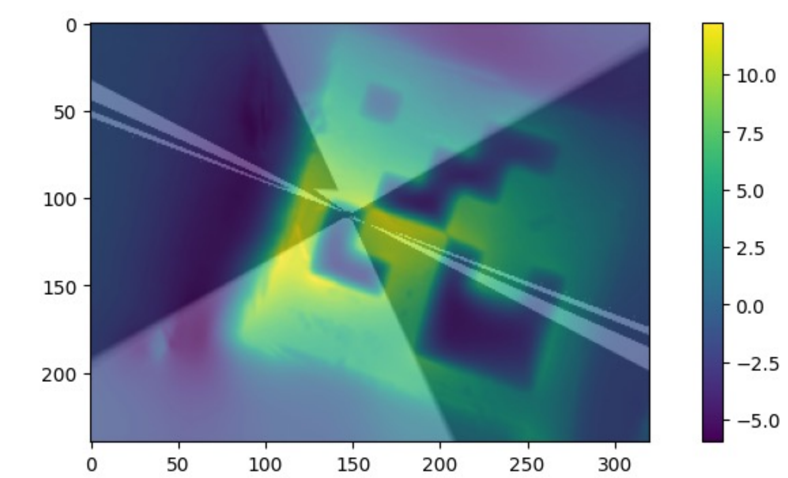
- We calculated the angle the marker made with the GelSight Mini sensor and its depth over time.





FUTURE WORK

- We discovered that not every timestamp has enough unique features to construct a correct homography transform.



- Future work consists of creating an algorithm that takes the last successful homography transform and uses it as an initial parameter for the next timestamp.
- Finally, we intend to integrate this work with a robotic platform.

CONCLUSION

- We successfully created computer vision algorithms to allow for recognition of visuotactile markers by the GelSight Mini sensor.
- Our visuotactile markers can be identified in real-time based on their unique tags.
- With future integration with a robotic platform, we aim to have our markers used in a variety of settings—from tool detection in spaceflight to automating robotic surgery.

ACKNOWLEDGEMENTS

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