THE ANDREW & ERNA VITERBI
FACULTY OF ELECTRICAL ENGINEERING

SIPL
Signal and Image Processing Lab

TECHNION
Israel Institute of Technology

Low-Cost 3D Scanner for a Prosthetic Hand Digital Fitting

Guy Yoffe and Aviv Golan, Supervised by Shunit Polinsky

In collaboration with

Introduction

- Creating a prosthetic hand is a long, expensive, and complicated process due to the cost of the prosthetic components and the personal adjustment process.
- Kids aren't funded by the government and need to exchange their prosthetic hand often due to their growth. Thus, they need a low-cost prosthetic hand.

A 3D-printed prosthetic hand by e-Nable

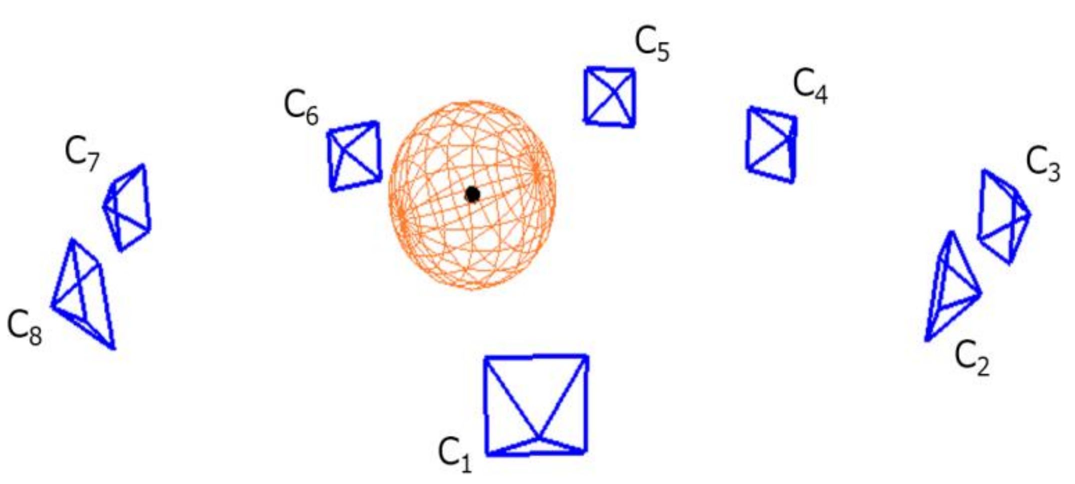
Goals

- Create a low-cost 3D scanner.
  - A small number of low-cost depth cameras.
  - Accurate and clean results.
  - An easy-to-use user interface.
  - Open-source.

Challenges

- Low-cost cameras outputs noisy and less accurate depth images.
- Small number of depth cameras.
  - Small overlap between cameras' fields of view.
- Moving scanned object – a moving hand.
  - Can cause noises and inaccuracies.

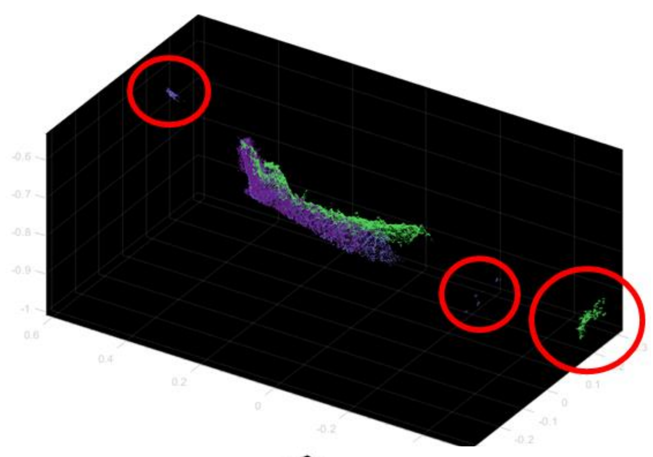
Calibration



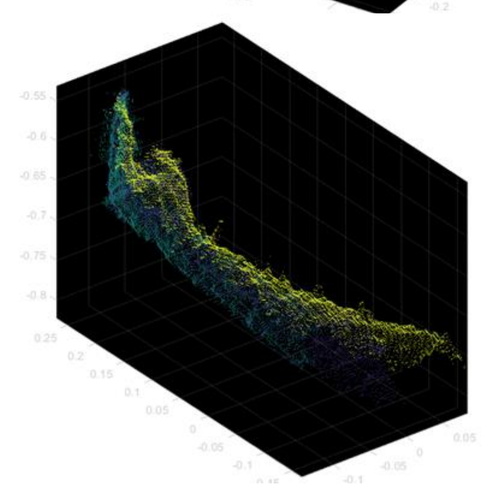
- Every depth camera captures a sphere simultaneously.
- Using MSAC the radius and the center of the sphere is found in each point cloud.
- The extrinsic transformation between each pair of cameras is taken to be the rigid transformation (only rotation and translation) that minimizes the MSE of the distances between the centers after the transformation.

Segmentation

- The hand is expected to be the biggest object in the point cloud.
- Done by taking the biggest cluster in the point cloud.
- Removes far-from-hand noises.



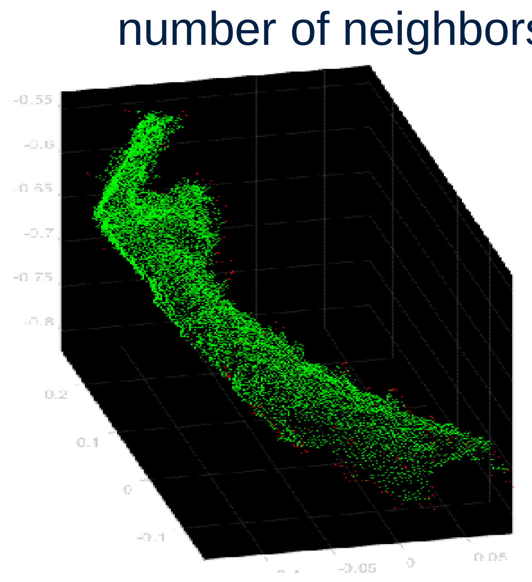
Point cloud of a hand before segmentation



Point cloud of a hand after segmentation

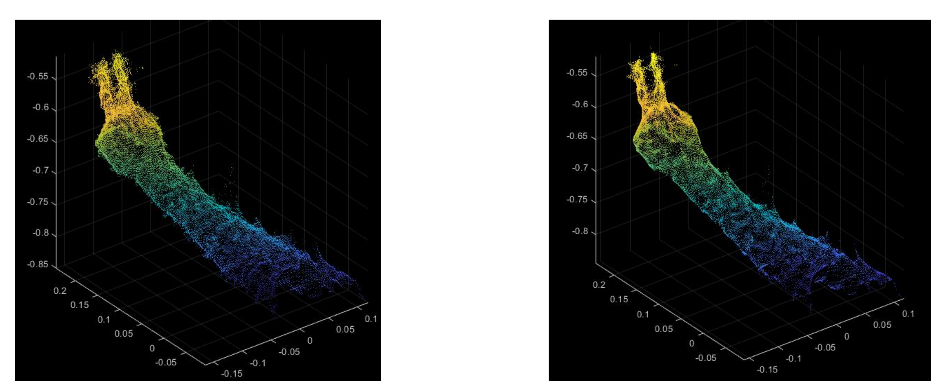
Denoising

- Neighbors Filter
  - Removing the points that has the lowest number of neighbors.



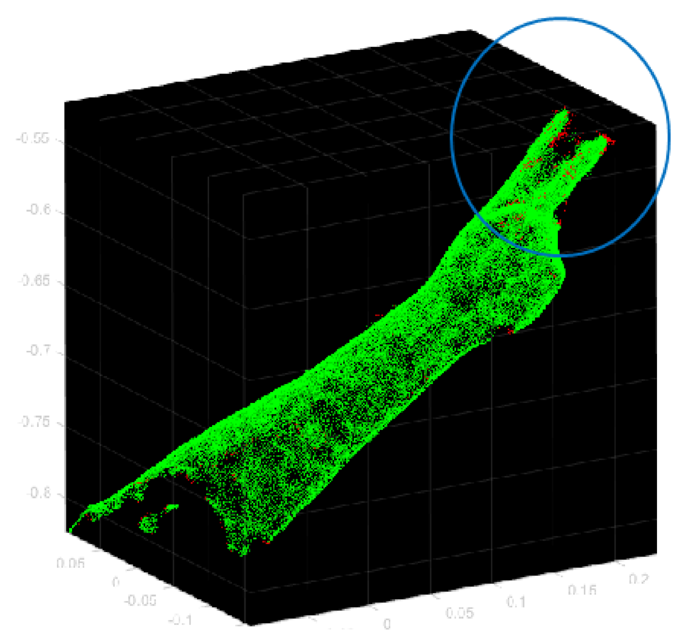
A point cloud after neighbors filter. The points that are considered as noise are colored in red.

- Guided Filter
  - edge and sharp-shape preserving filter.
  - Assumes that the surface is linear about each point and minimizes the MSE of the projection error and the L2 regularization.



A point cloud before (left) and after (right) the guided filter.

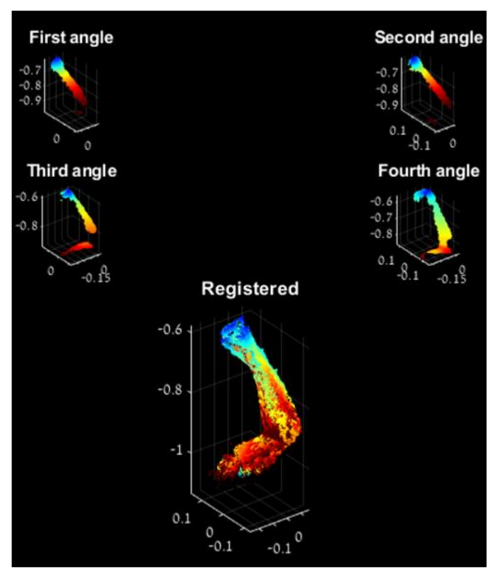
- Boundary Filter
  - Removing points that are far from the centroid of their nearest neighbors.



A point cloud after boundary filter. The points that are considered as noise are colored in red.

Registration

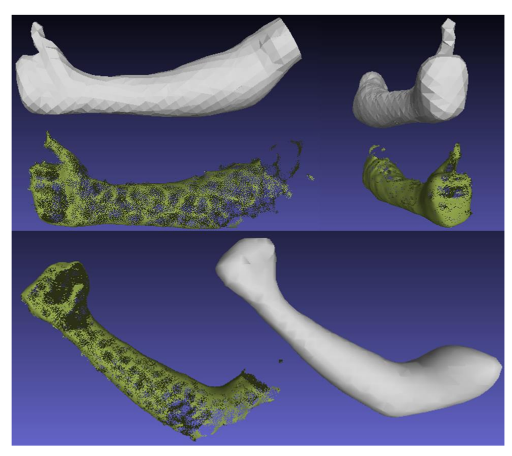
- Combine all the merged point clouds from every round using the calibration, segmentation and noise reduction to single accurate and detailed point cloud.
- Using ICP algorithm - find the rigid transformation between every couple of point cloud that minimize the MSE between matched point of the point clouds after the transformation.



ICP algorithm demonstration over 4 point clouds of a hand from different angles

Reconstruction

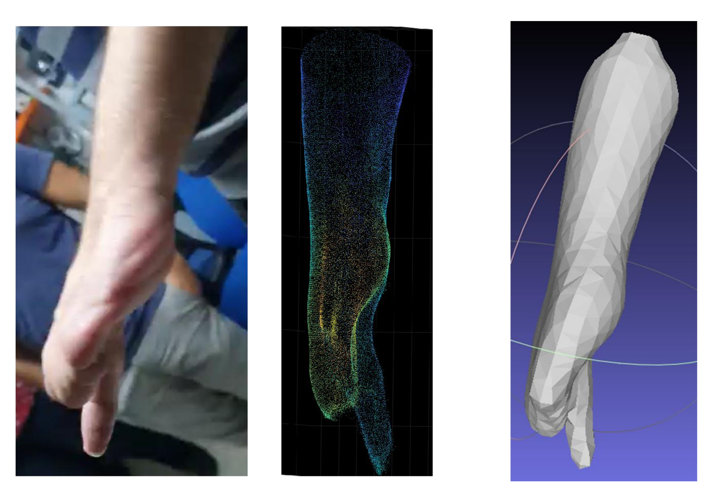
- Convert the final point cloud to 3D mesh.
- Using the Poisson Surface Reconstruction algorithm using the point cloud's normal.



Poisson Surface Reconstruction results on point clouds of hands

Results

- Experiments were done on several patients with a residual limb.



An RGB image, the final point cloud and the final mesh of a residual limb

Conclusions

- Successfully built low-cost 3D scanner with three Intel RealSense SR300 cameras.
  - Successful calibration, segmentation, noise reduction, registration and reconstruction.
  - Create 3D mesh of a scanned point clouds of a residual limb.
  - System with two GUI's – one for the algorithm and one for plane-cut.

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