Depth and Contact Prediction

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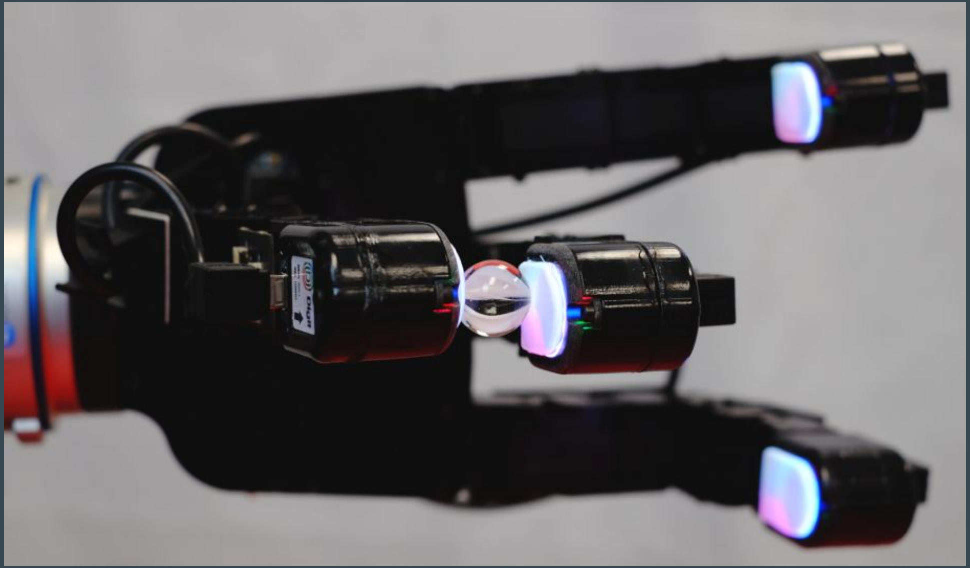
Introduction

In this project, we use deep neural networks to predict 3D contact geometry from monocular images of a GelSight tactile sensor, which is also called vision-based tactile sensor. Specifically, we aim to acquire the inverse sensor model to reconstruct local 3D geometry from a tactile image.



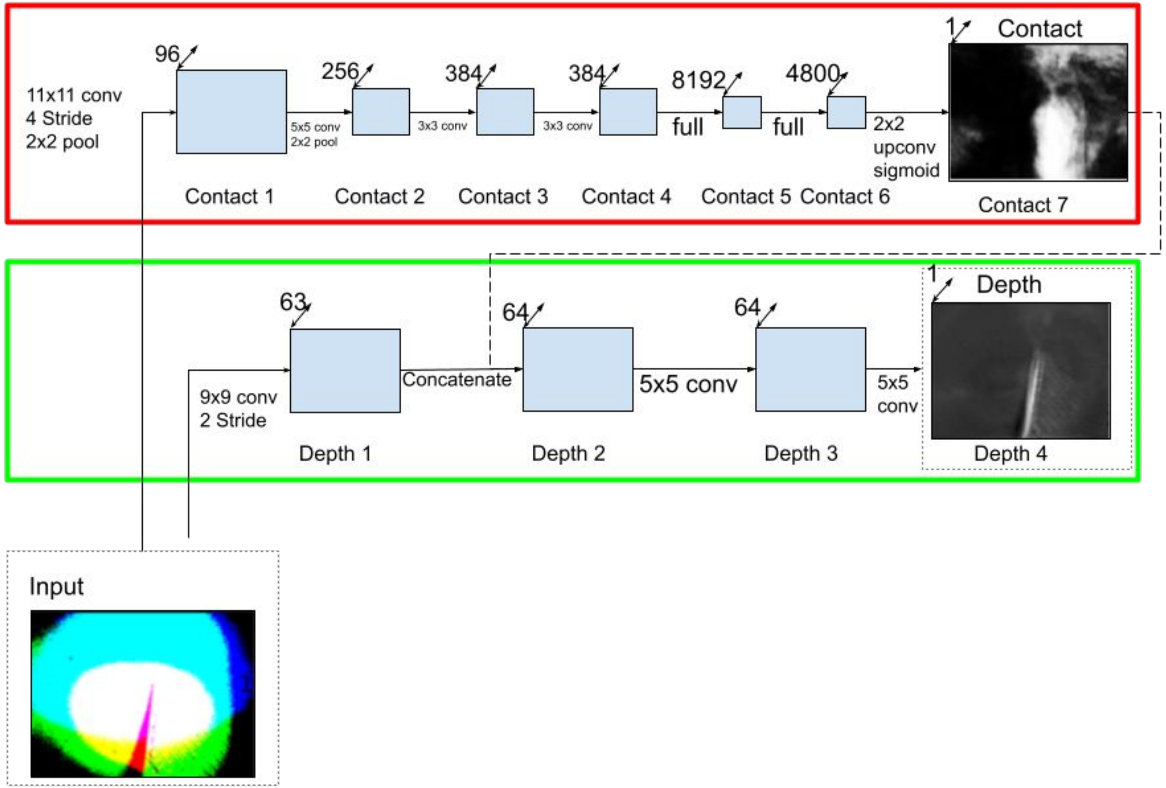
Literature Review

- Eigen et al. handle depth estimation by using two deep network stacks: Coarse and Precise [1]
- Laina et al. utilize CNNs to create depth mapping [3]
- Ma et al.'s model is a single deep regression network that learns directly from the RGB-D raw data [4]
- Godard et al. utilize a binocular stereo footage to train their singular convolutional neural network based on the constraints of epipolar geometry [2]
- Wang et al. find the depth of a scene, by first calculating the mapping of the image from color (RGB) to horizontal and vertical surface gradients and then applying a fast Poisson solver to integrate gradients and get the depth [5]

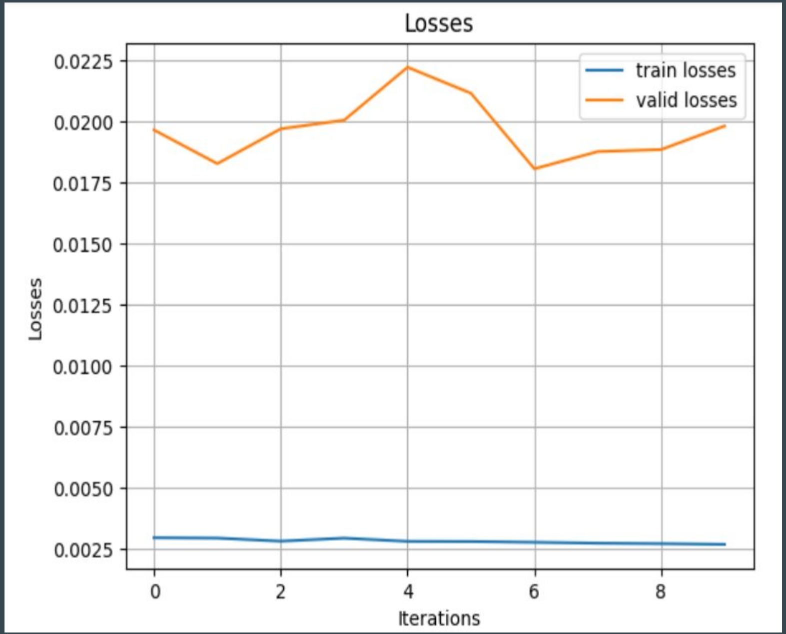
Experimental Setup

- 1000 training images
  - Tactile Image and Ground Truth Depth Image
  - Split 80/20 train/val
- Transforms:
  - Setting size to 240 x 320
  - Turning to PyTorch Tensor
  - Normalize Tactile Images
- Augmentations
  - We randomly rotated the images between -5 to 5 degrees
  - Random Horizontal Flip: Randomly flip the images horizontally with probability 50%

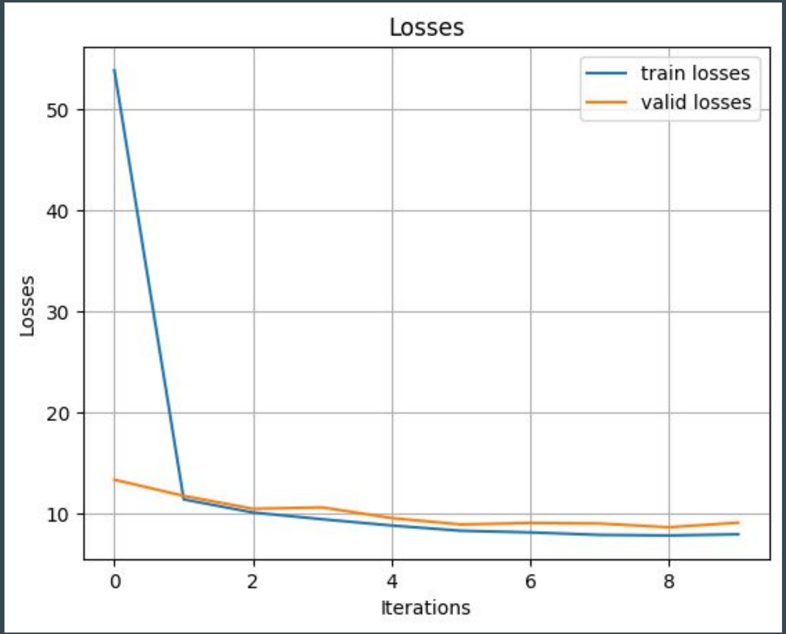
Methodology



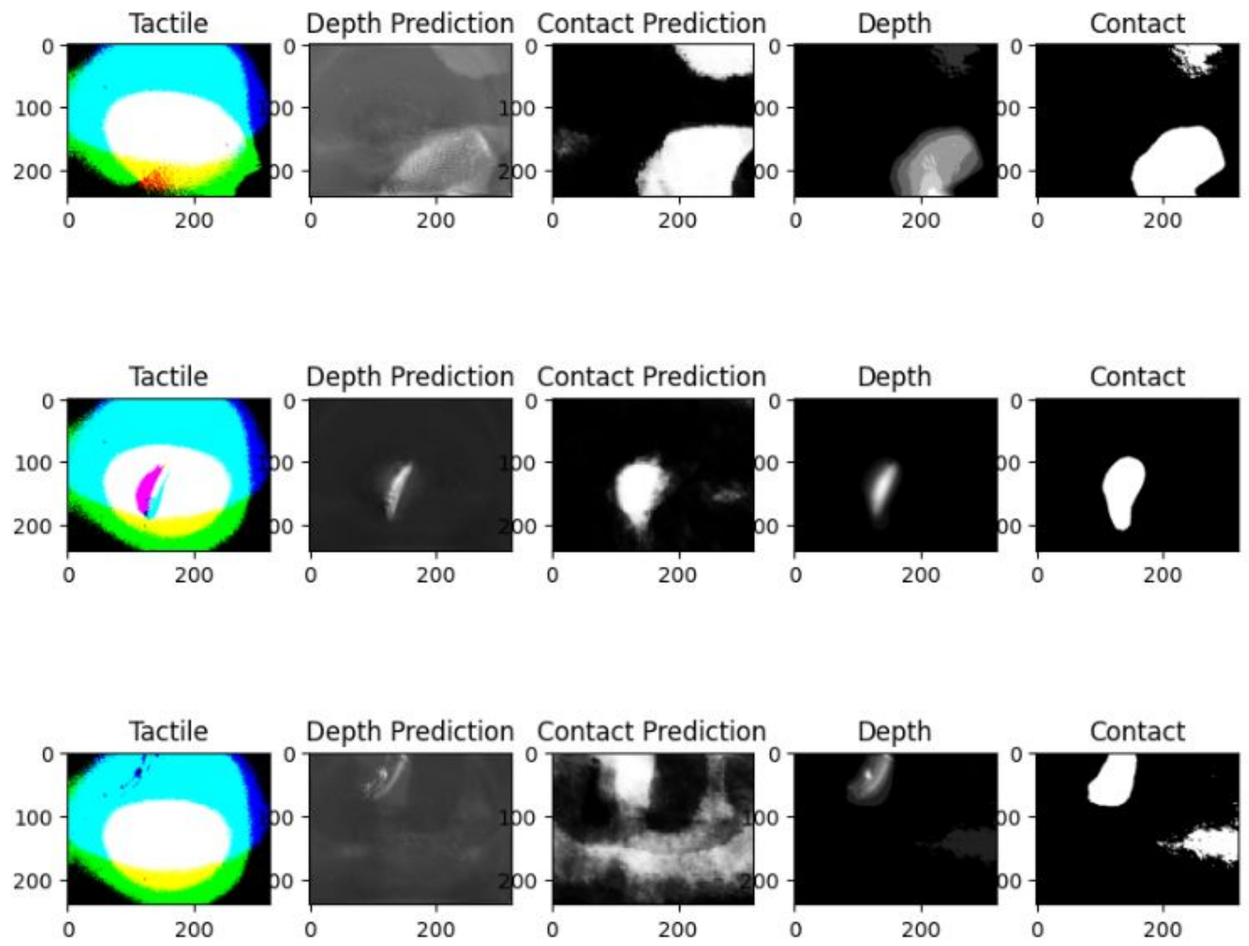
Results and Discussion



Loss Graph for ContactNet Model

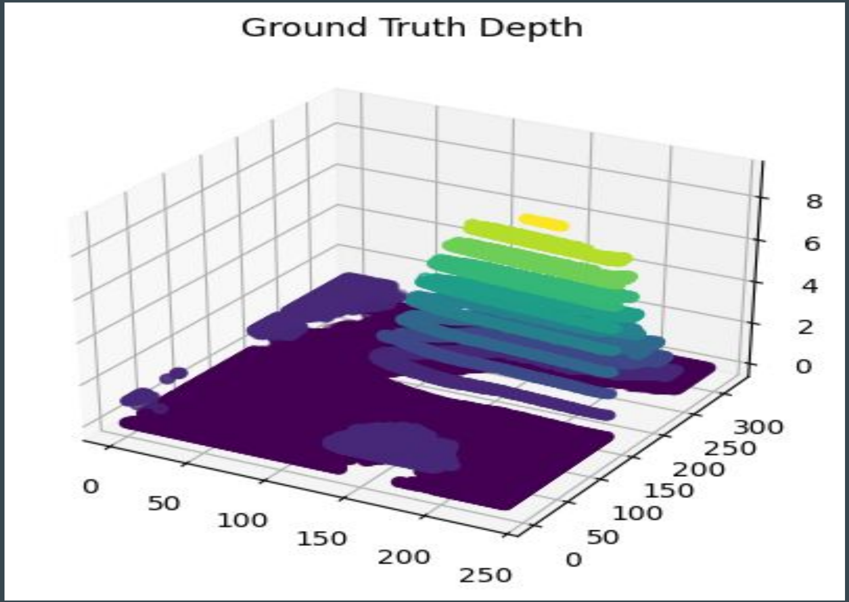


Loss Graph for TactileDepthNet Model

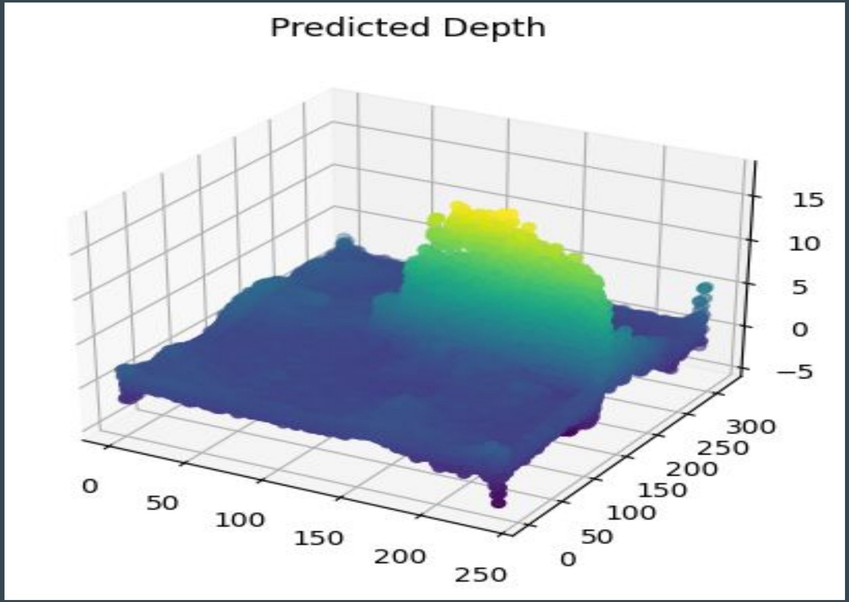


Tactile
Depth Prediction
Contact Prediction
Depth
Contact
0
100
200
0
200

Results and Discussion (Contd.)



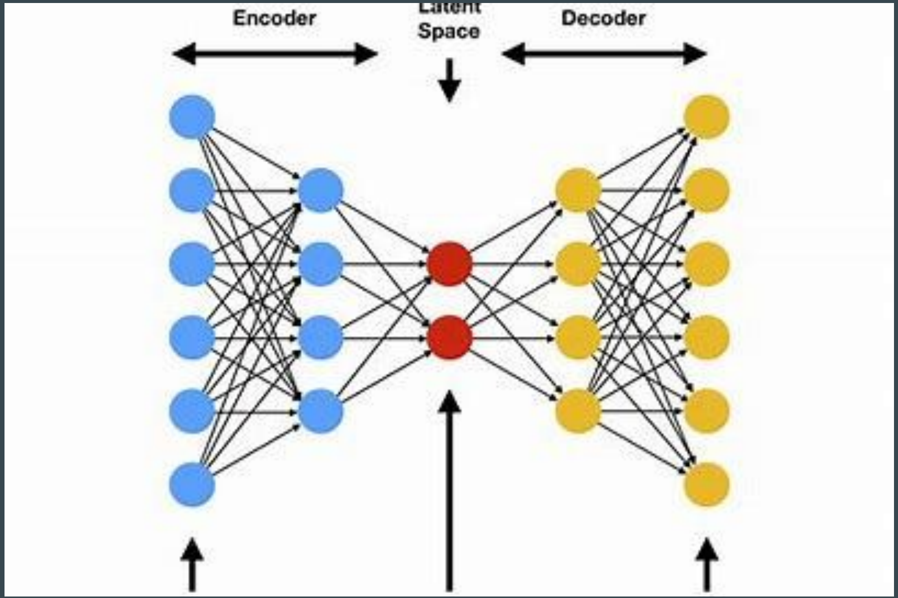
Ground truth depth corresponding to a tactile image



Predicted depth corresponding to a tactile image

Future Work

- Use different layer combinations.
    - Autoencoder idea
- Improve our models' robustness.
- Use different optimization techniques.



Takeaways

- Construction of Neural Networks in PyTorch
- Convolutional Neural Networks
- Effective loss functions used in depth estimation model training.
- Importance of image normalization
- The role of depth estimation in 3D Reconstruction.

References

[1] David Eigen, Christian Puhrsch, and Rob Fergus. "Depth Map Prediction from a Single Image using a Multi-Scale Deep Network". In: 2014. arXiv: 1406. 2283 [cs.CV].

[2] Cl ́ement Godard, Oisin Mac Aodha, and Gabriel J. Brostow. "Unsupervised Monocular Depth Estimation with Left-Right Consistency". In: 2017. arXiv: 1609.03677v3 [cs.CV].

[3] Iro Laina et al. "Deeper Depth Prediction with Fully Convolutional Residual Networks". In: 2016. arXiv: 1606.00373 [cs.CV].

[4] Fangchang Ma and Sertac Karaman. "Sparse-to-Dense: Depth Prediction from Sparse Depth Samples and a Single Image". In: 2018. arXiv: 1709 .07492v2 [cs.RO].

[5] Shaoxiong Wang et al. "GelSight Wedge: Measuring High-Resolution 3D Contact Geometry with a Compact Robot Finger". In: 2021.