

Lunar Surface Image Segmentation



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George Washington University
Machine Learning II - DATS_6203_10
[GitHub Repo](#)



Joshua Ting



Going to the Moon!!

— — —

- Tasked to help land a lunar lander on the surface of the moon
- Many factors to consider in finding a safe landing location
 - Be nice to **not crash into rocks**
- Can we use ML/CV to help with this?

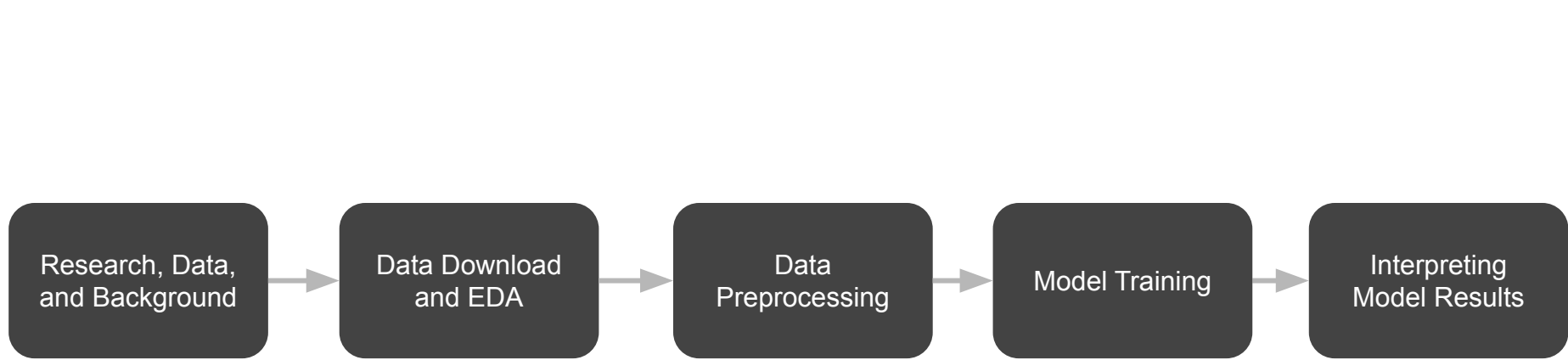


Figure 1: Lunar Surface⁴



Overview of Project Lifecycle

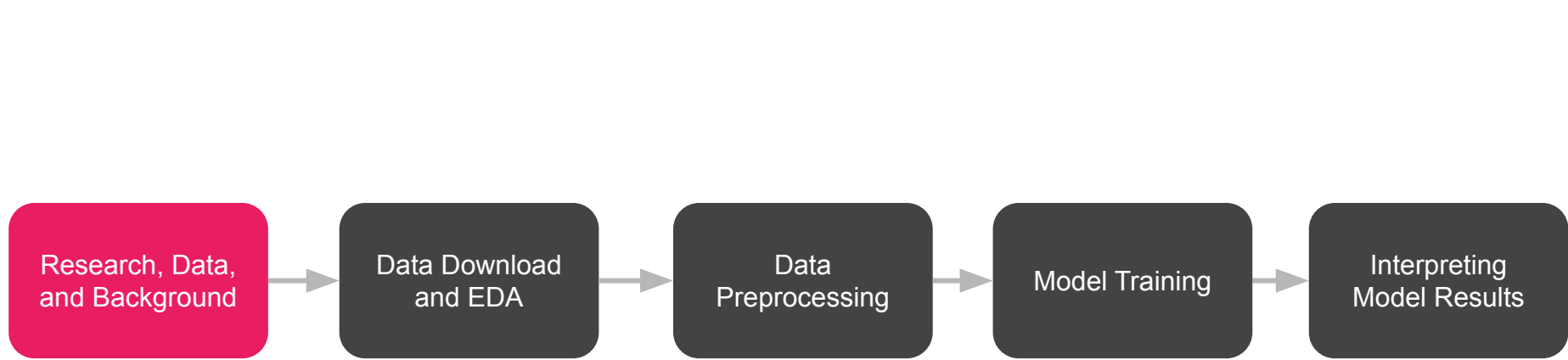
— — —





Overview of Project Lifecycle

— — —





Background

- Semantic Segmentation: **Classifying the class per pixel**

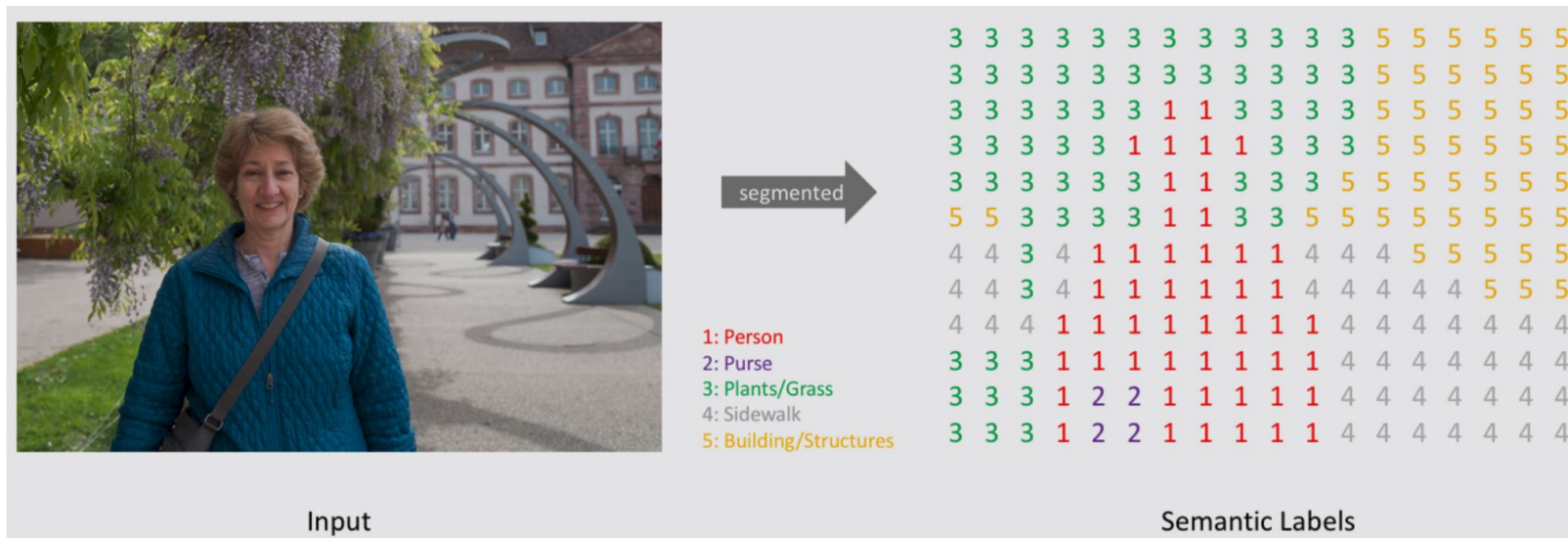


Figure 2: Overview of Semantic Segmentation⁵



Data Overview

≡ kaggle

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▲ 115

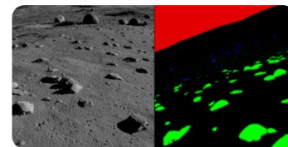
New Notebook

Download (5 GB)



Artificial Lunar Landscape Dataset

Photorealistic images of the Moon's surface with ground truth rock segmentation



Data Code (10) Discussion (1)

About Dataset

Context

It is often difficult to conduct any kind of machine learning experiment on lunar images because of their scarcity and lack of annotation. The goal of this dataset is to provide the general public with a sample of artificial yet realistic lunar landscapes, which can be used to train rock detection algorithms. Those trained algorithms can then be tested on actual lunar pictures or other pictures of rocky terrain.

Usability ⓘ

9.12

License

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Expected update frequency

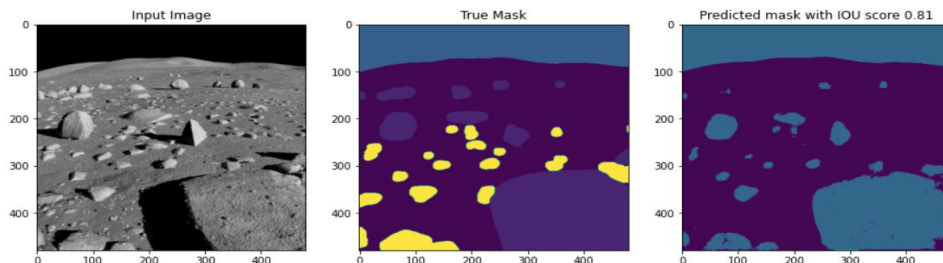
Never

Figure 3: Artificial Lunar Landscape Dataset from Kaggle³

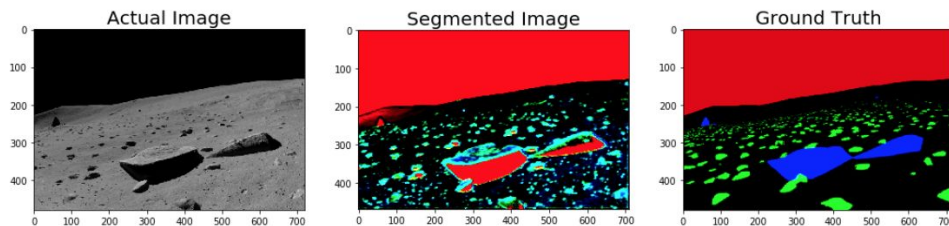


Prior Work on Dataset - Kaggle Notebooks⁷

- Gold: Tried VGG16 model



- Silver: Tried VGG16 model





Objectives and Contribution Goals

— — —

To build and train our **own U-Net** based architecture then compare results against a few **pretrained networks**



Dataset

— — —

- **Rendered Lunar Images:**

- 9,766 Images of Rendered Lunar Landscapes
- 9,766 Ground Truth Masks

- **Real Lunar Images for Testing:**

- 36 Images of Real Lunar Images
- 36 Ground Truth Masks

Dataset Split	Type	Percentage of Type
Train	Rendered	49%
Validation	Rendered	21%
Test - Rendered	Rendered	30%
Test - Real	Real	100%

Figure 4: Dataset Split



Rendered Image/Mask Example

— — —

Original:
render0034.png



Ground Truth Mask:
clean0034.png

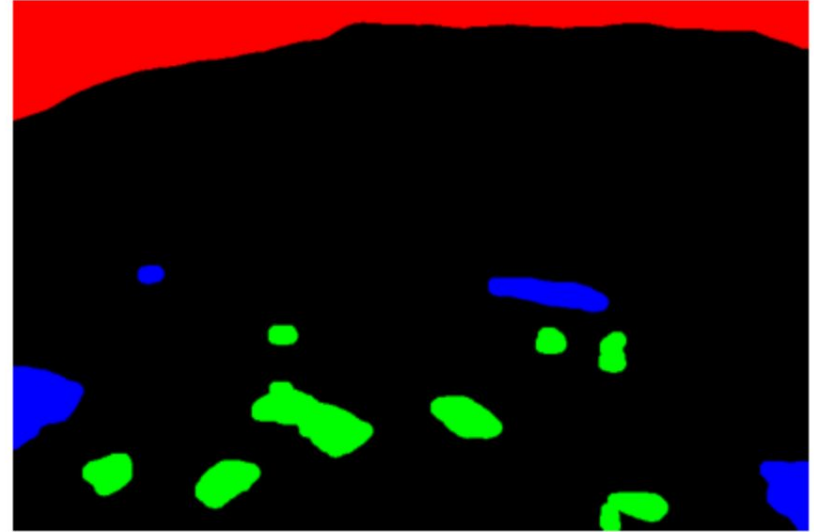


Figure 5: Rendered image and ground truth mask example³



Rendered Image/Mask Example w/ Color Key Labels

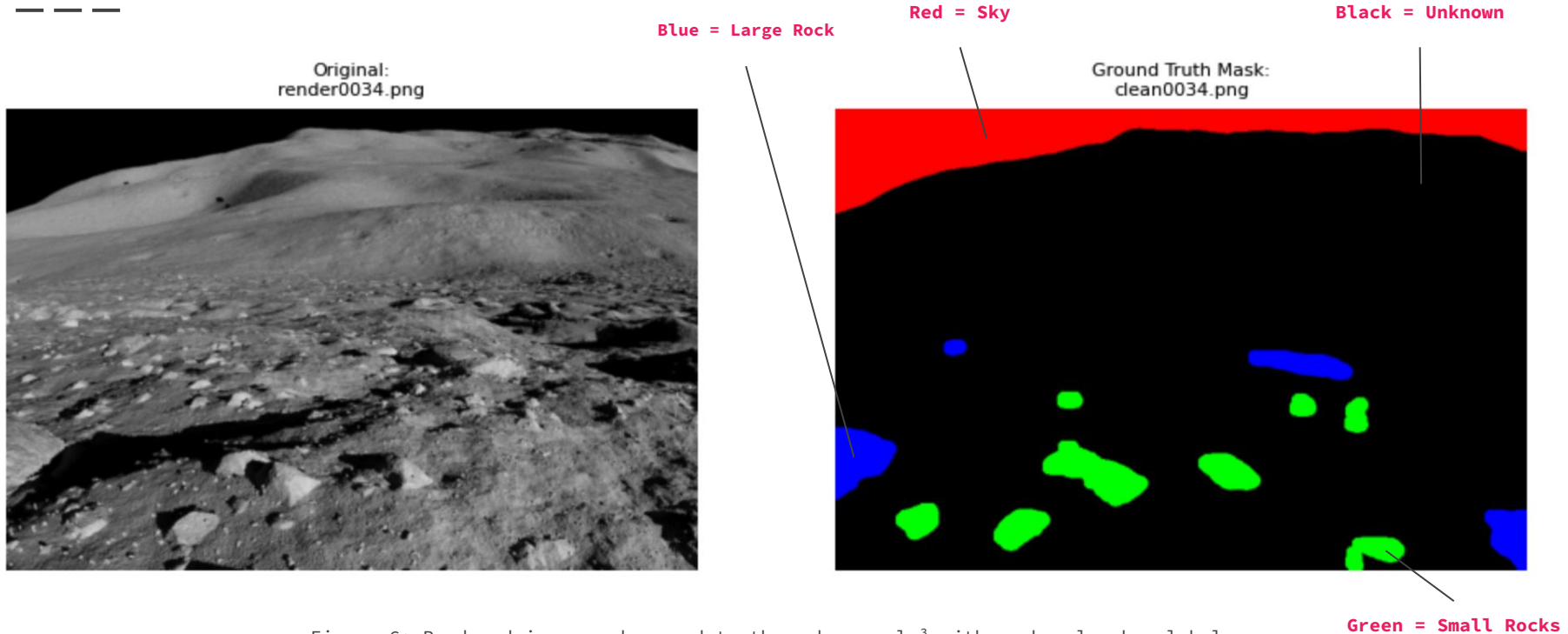


Figure 6: Rendered image and ground truth mask example³ with mask color key labels



Rendered Image/Mask Example II

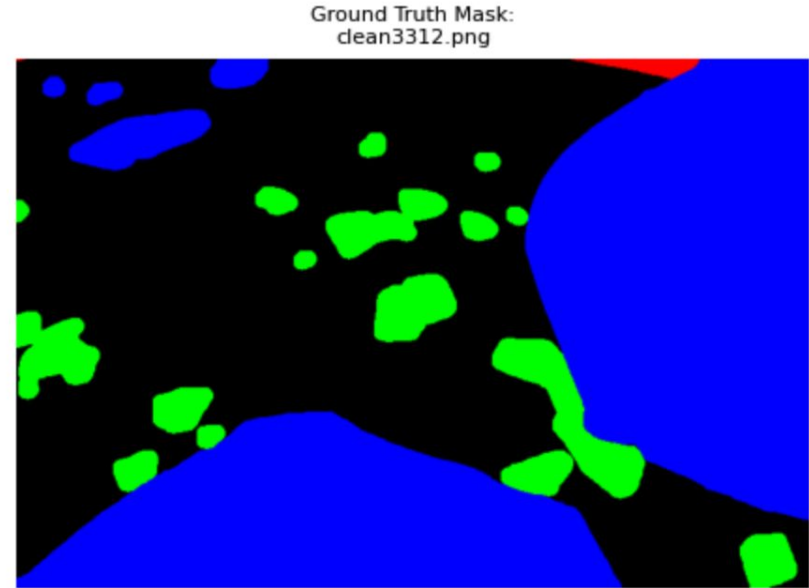
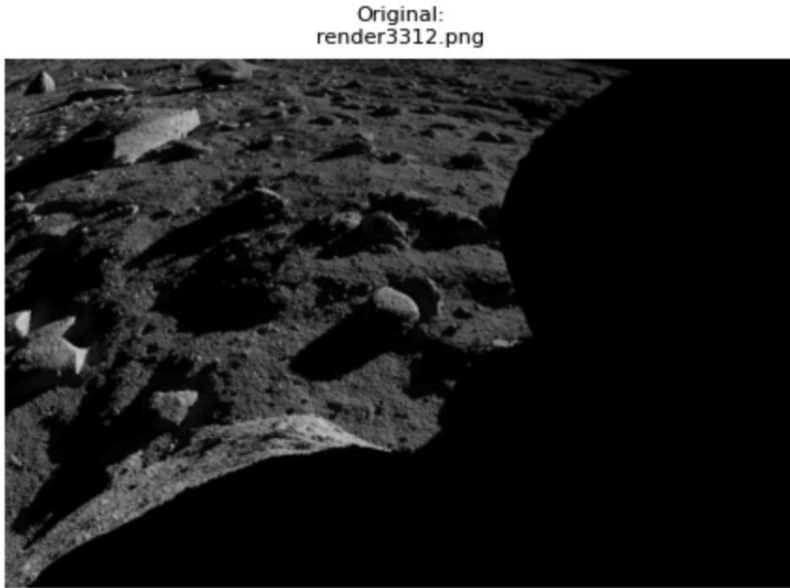


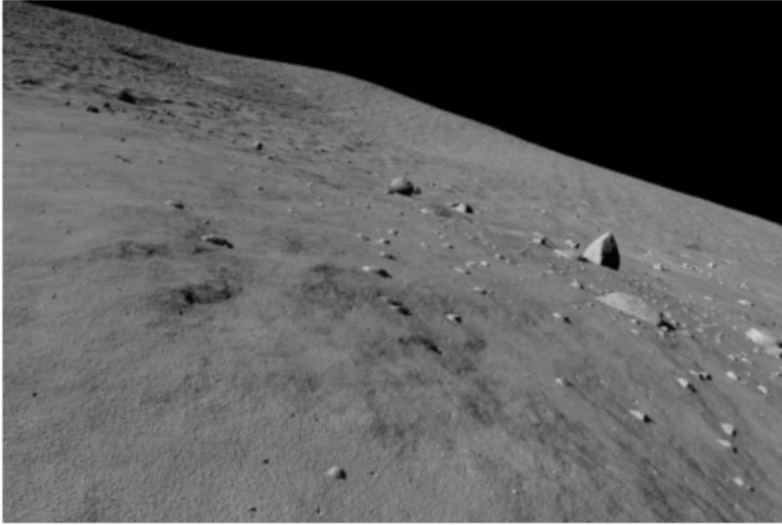
Figure 7: Rendered image and ground truth mask example³



Rendered Image/Mask Example III

— — —

Original:
render4798.png



Ground Truth Mask:
clean4798.png

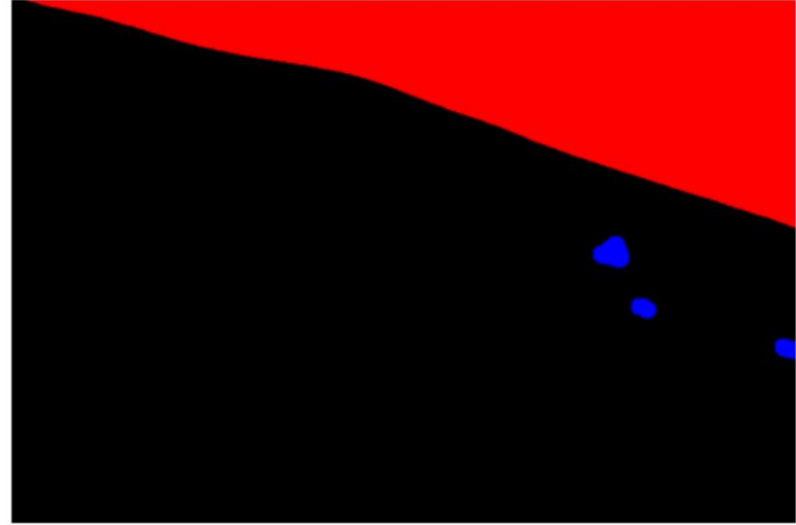


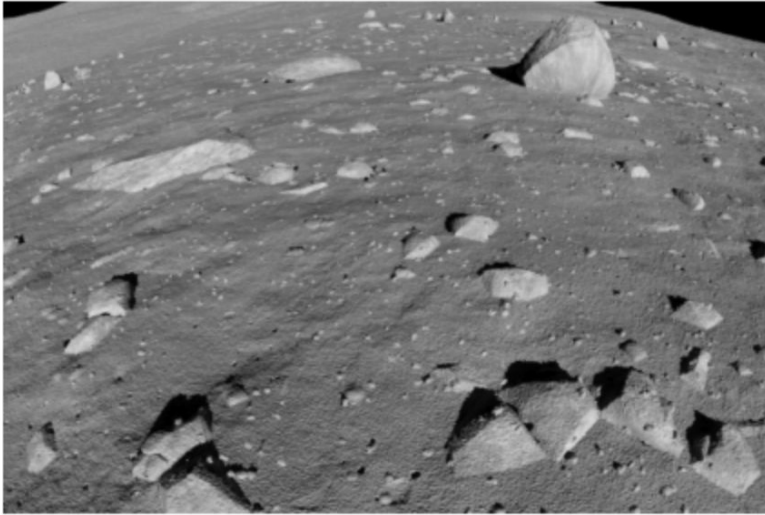
Figure 8: Rendered image and ground truth mask example³



Rendered Image/Mask Example IV

— — —

Original:
render6182.png



Ground Truth Mask:
clean6182.png

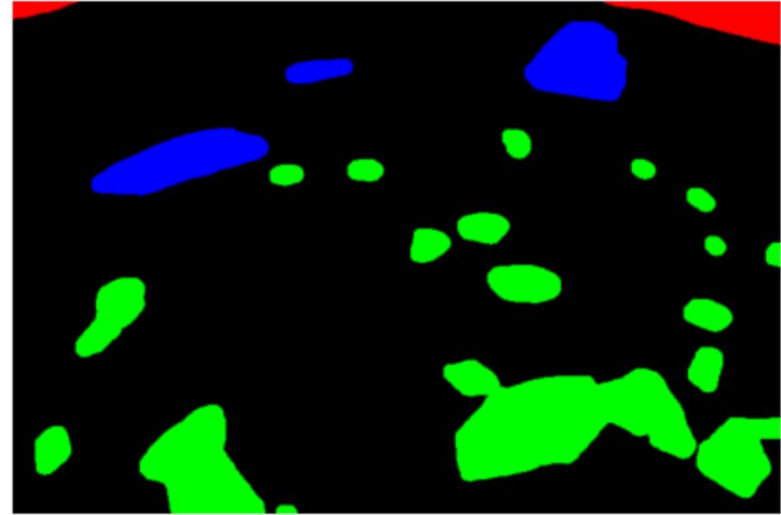


Figure 9: Rendered image and ground truth mask example³



Rendered Image/Mask Example V

— — —

Original:
render8455.png



Ground Truth Mask:
clean8455.png

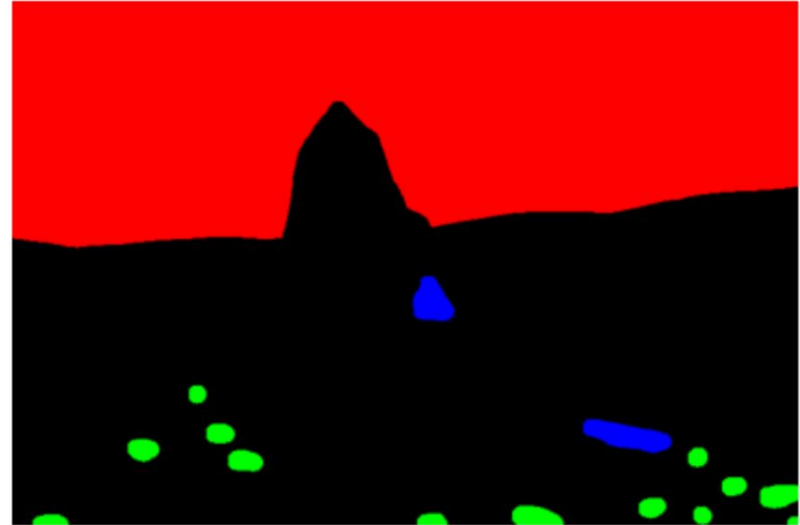


Figure 10: Rendered image and ground truth mask example³



Real Image Example

— — —

Original:
TCAM5.png



Ground Truth Mask:
g_TCAM5.png

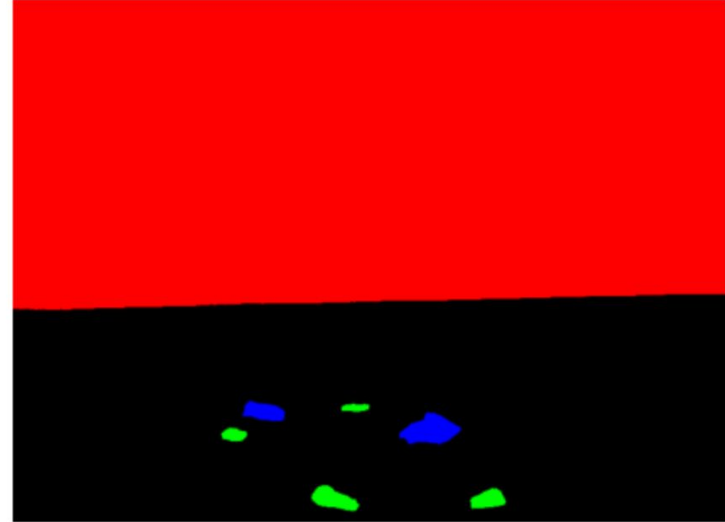


Figure 11: Real lunar image and ground truth mask example³



Real Image Example II

— — —

Original:
PCAM11.png



Ground Truth Mask:
g_PCAM11.png

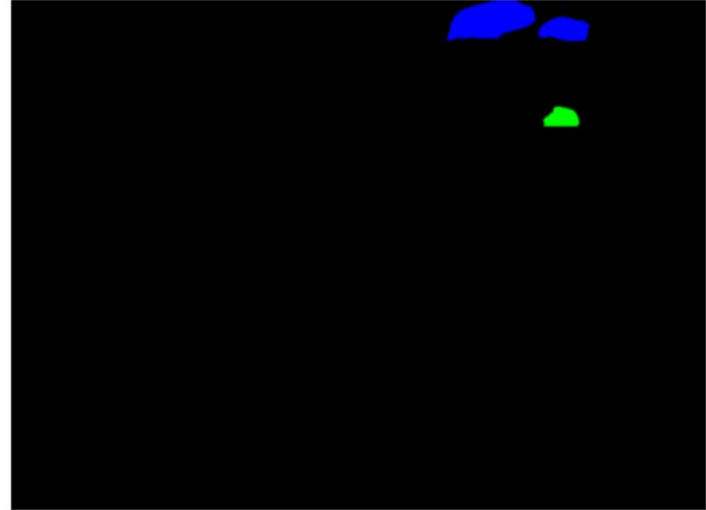


Figure 12: Real lunar image and ground truth mask example³



Real Image Example III

— — —

Original:
TCAM3.png



Ground Truth Mask:
g_TCAM3.png

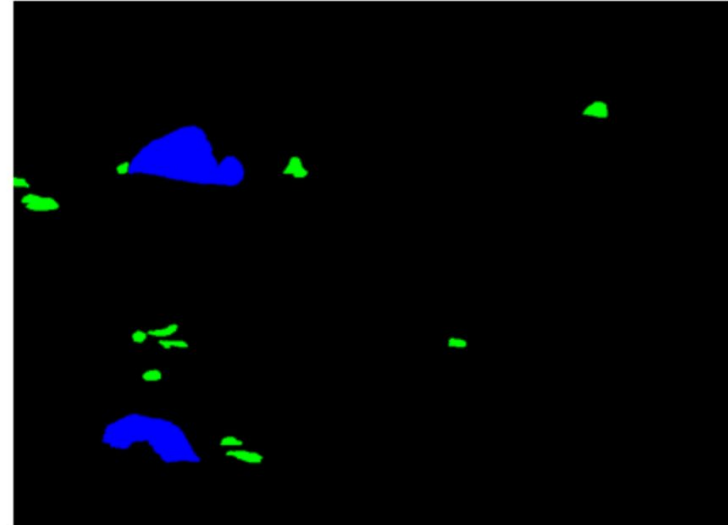
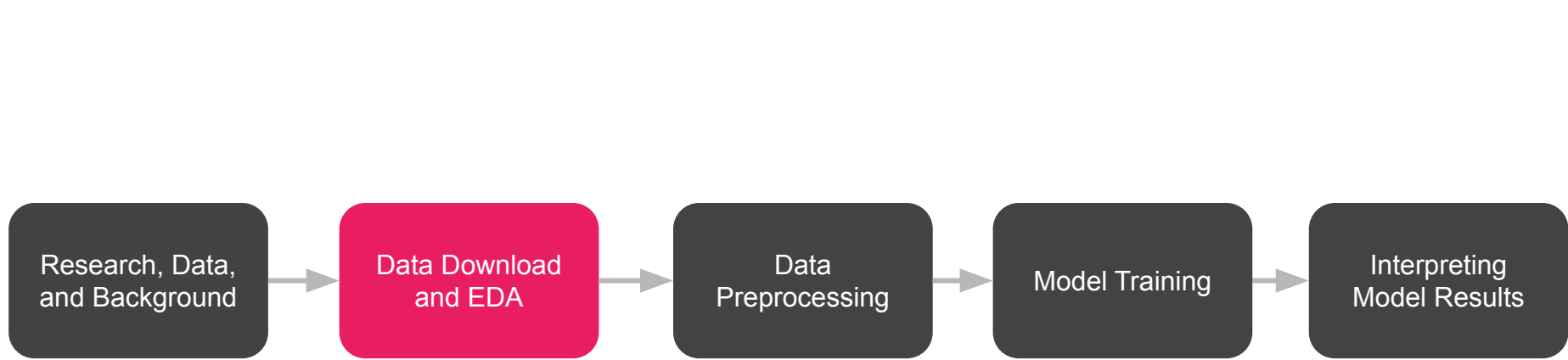


Figure 13: Real lunar image and ground truth mask example³



Overview of Project Lifecycle

— — —



EDA

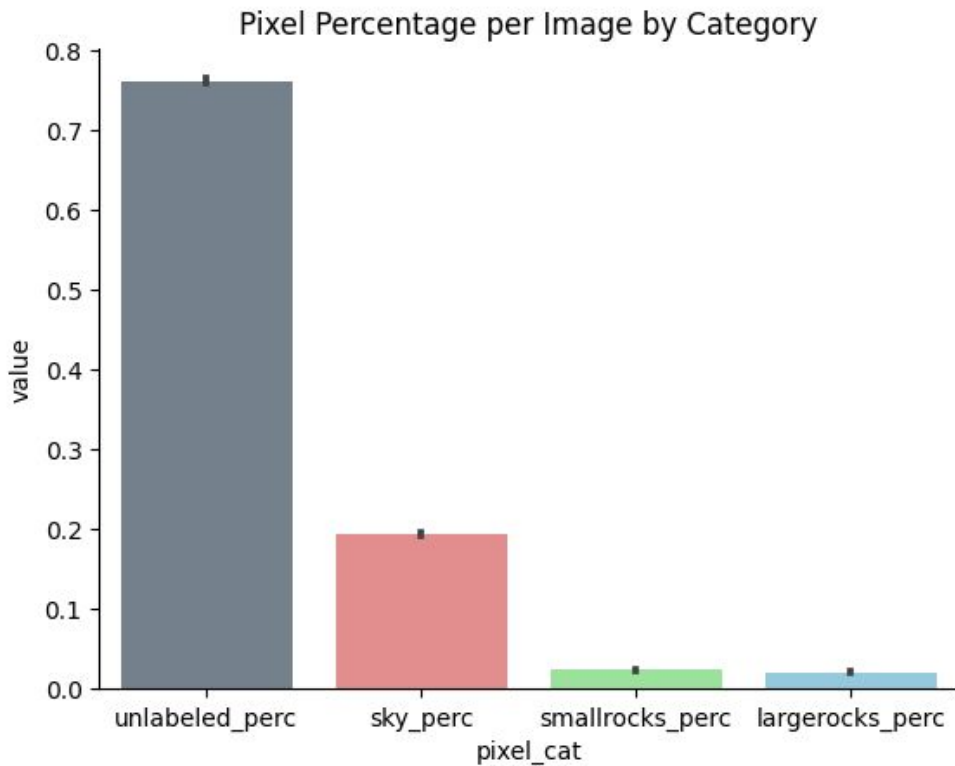


Figure 14: Class Imbalance

EDA

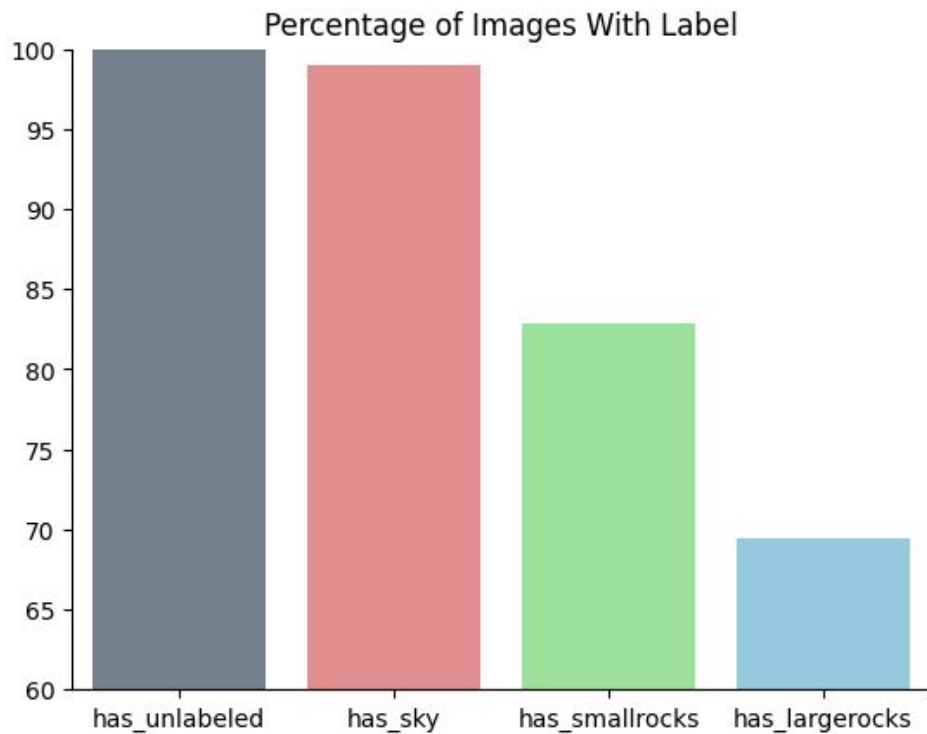


Figure 15: How Many Images Have Which Class Labels

EDA

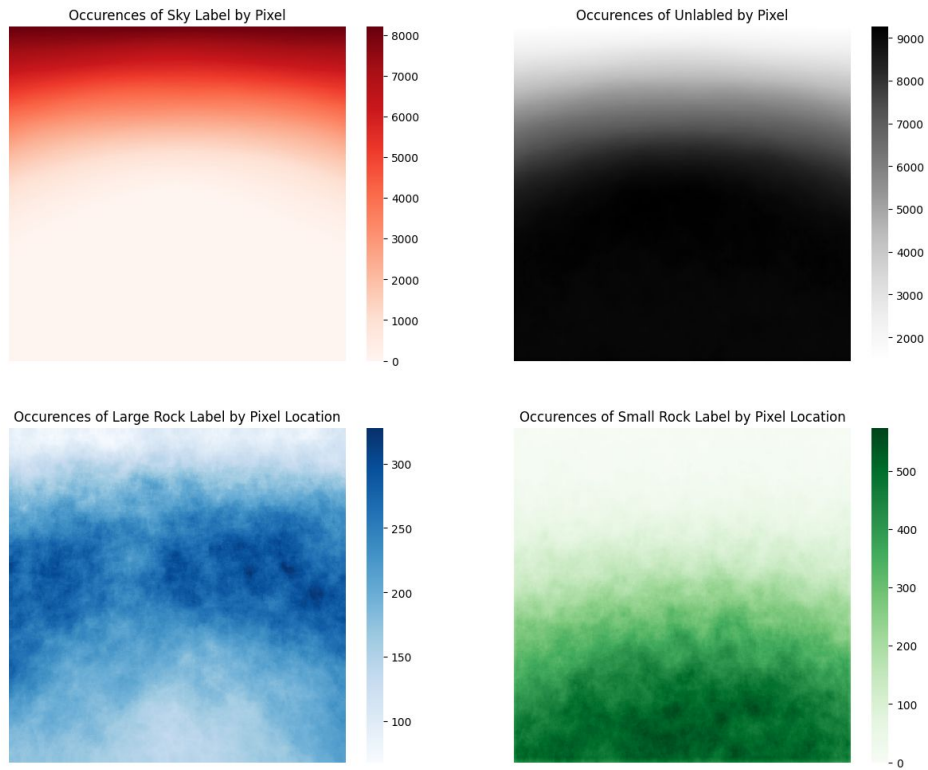
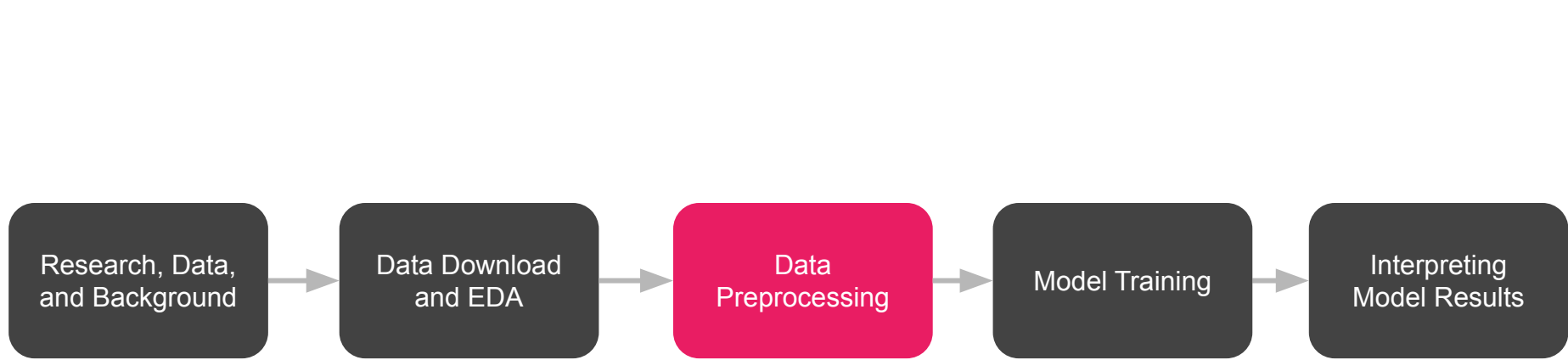


Figure 16: Overall Class Occurrence Intensity by Image Location



Overview of Project Lifecycle

— — —





Data Preprocessing

- **Custom DataLoader**
 - Loads image and mask
 - Resize to 256x256
 - Applies data augmentation
 - Rescale pixels to between 0-1
 - One Hot Encode masks
 - Change ordering of channels - image dim last
 - Convert to torch tensor
- **Torch DataLoader**
 - Batch data



One Hot Encoding the Ground Truth Mask

— — —

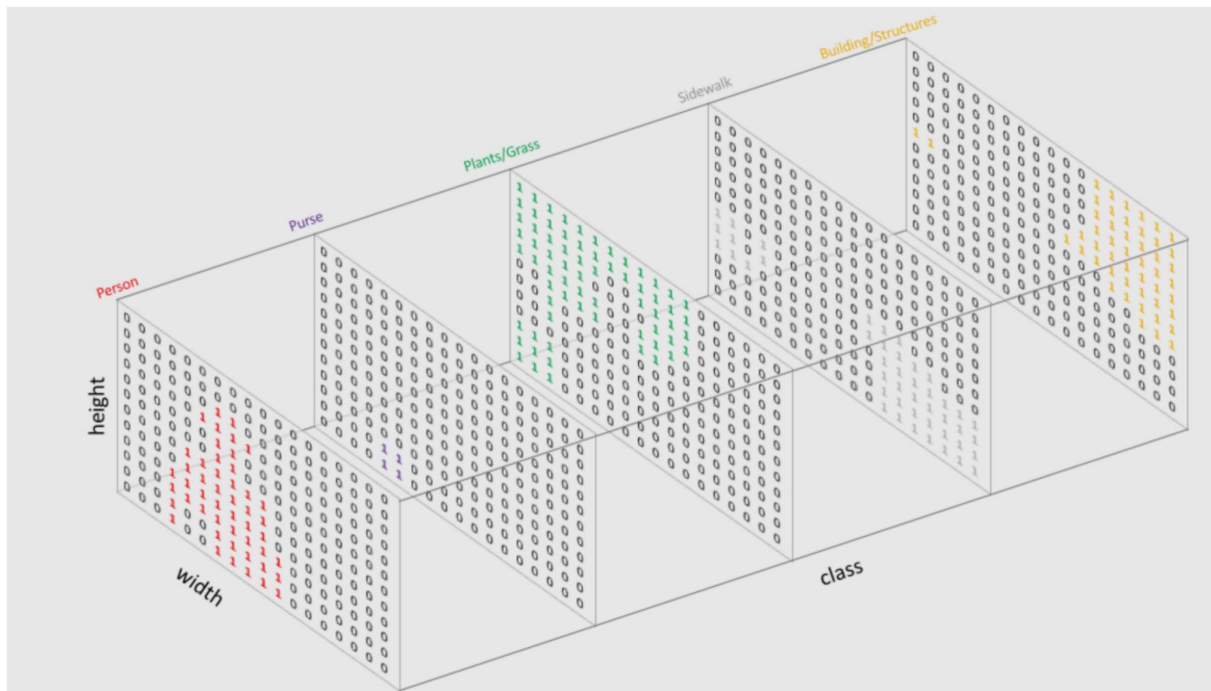


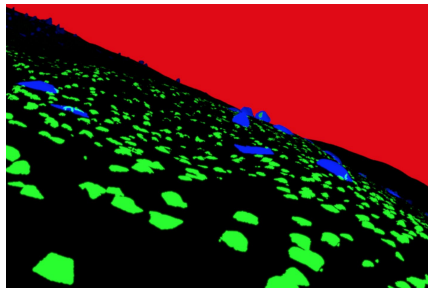
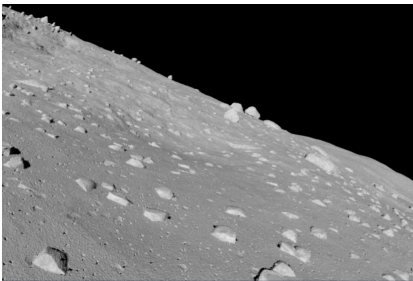
Figure 17: One Hot Encoding the Ground Truth Masks⁵



Data Augmentation

- Images & Masks
 - Random **Vertical Flip**
 - Random **Horizontal Flip**
- Images Only
 - Random **Color Jitters**
 - Brightness
 - Contrast
 - Saturation
 - Hue

Before



After

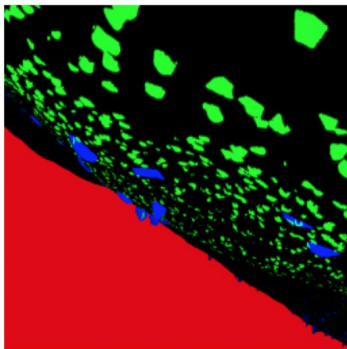
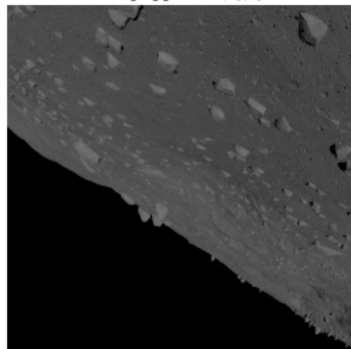
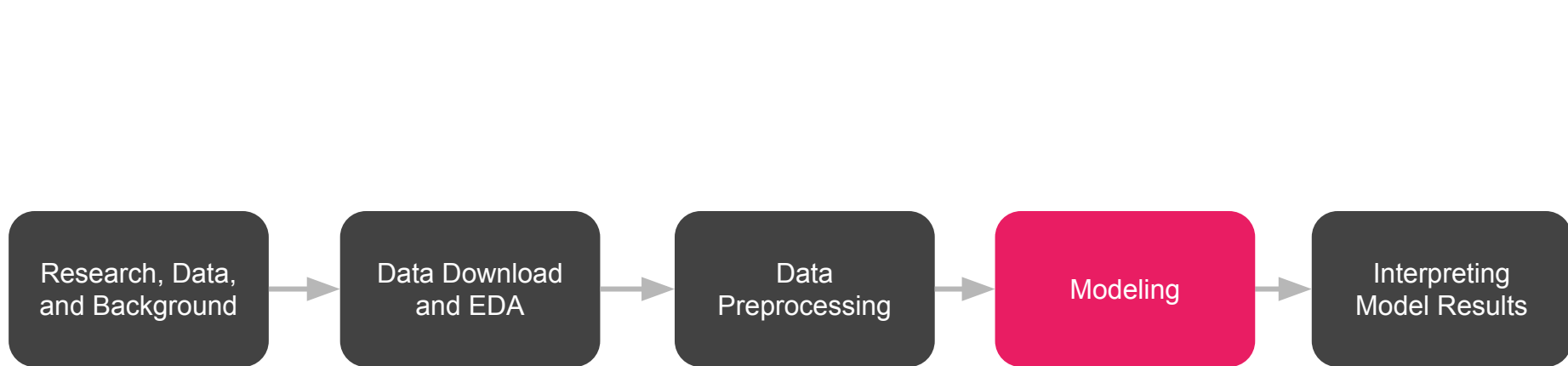


Figure 18: Before and after data augmentation



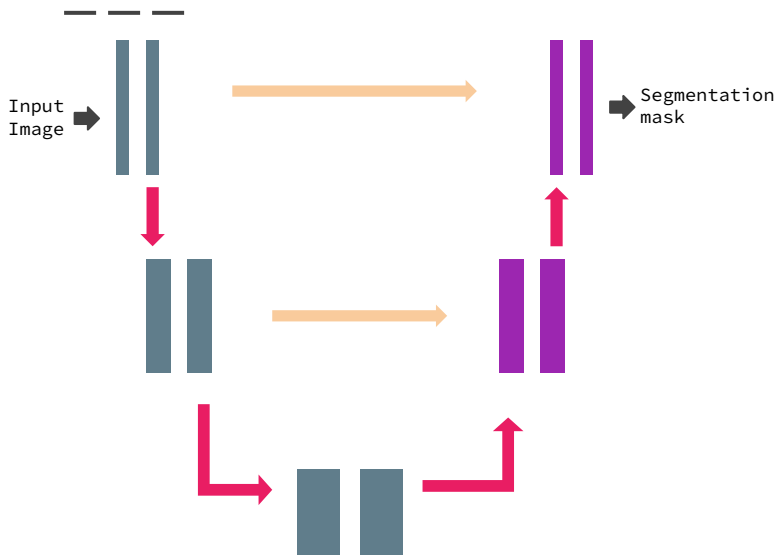
Overview of Project Lifecycle

— — —





Model Selection: U-Net



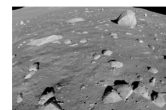
Encoder - Decoder model

- **Encoder:**
 - Down samples the image with convolutional layers and max pooling
- **Decoder:**
 - Up samples the image with transposed convolutional layers

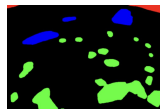
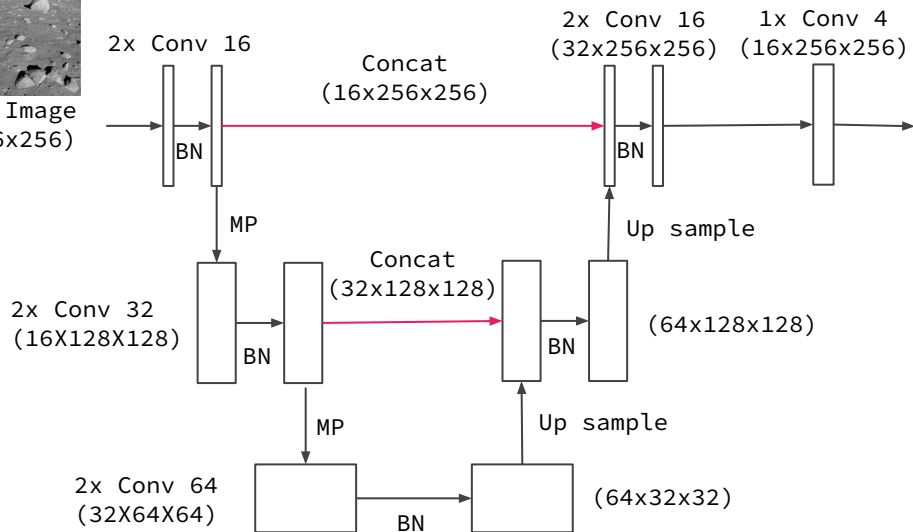
Feature maps from the encoder of the same level are concatenated and passed through the decoder



Our Model



Input Image
(3x256x256)



Segmentation Mask
(4x256x256)

Other Notes:

Block Activation: ReLU

Padding: Same

Conv2d Filters: 3x3

Dropouts between all blocks

*MP = Max Pooling

*BN = Batch Norm



Metrics

— — —

Jaccard's Index (IOU):

- Measures how much overlap exists between the predicted mask and the true mask

$$J(A, B) = \frac{|A \cap B|}{|A \cup B|} = \frac{|A \cap B|}{|A| + |B| - |A \cap B|}$$

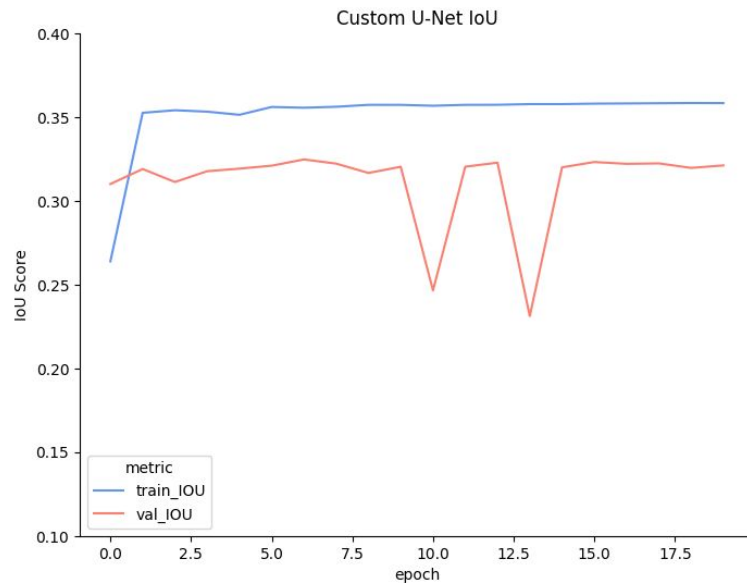
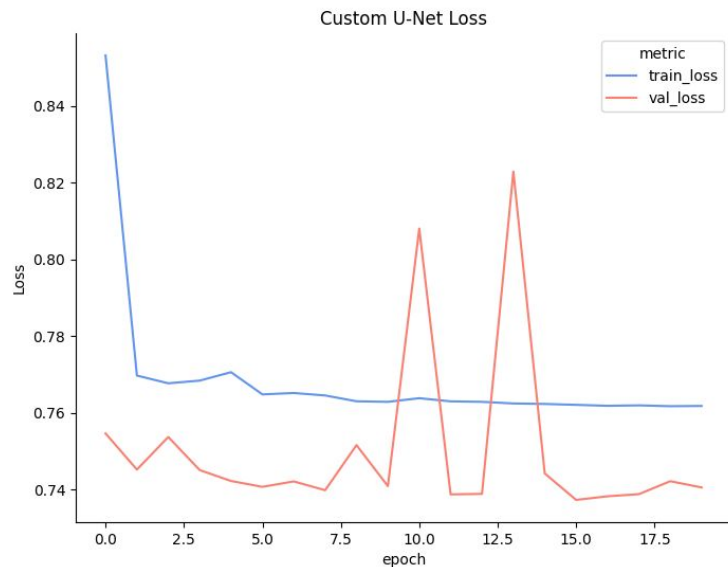
$$\text{IoU} = \frac{\text{Area of Overlap}}{\text{Area of Union}}$$





Model Training: Custom U-Net

— — —



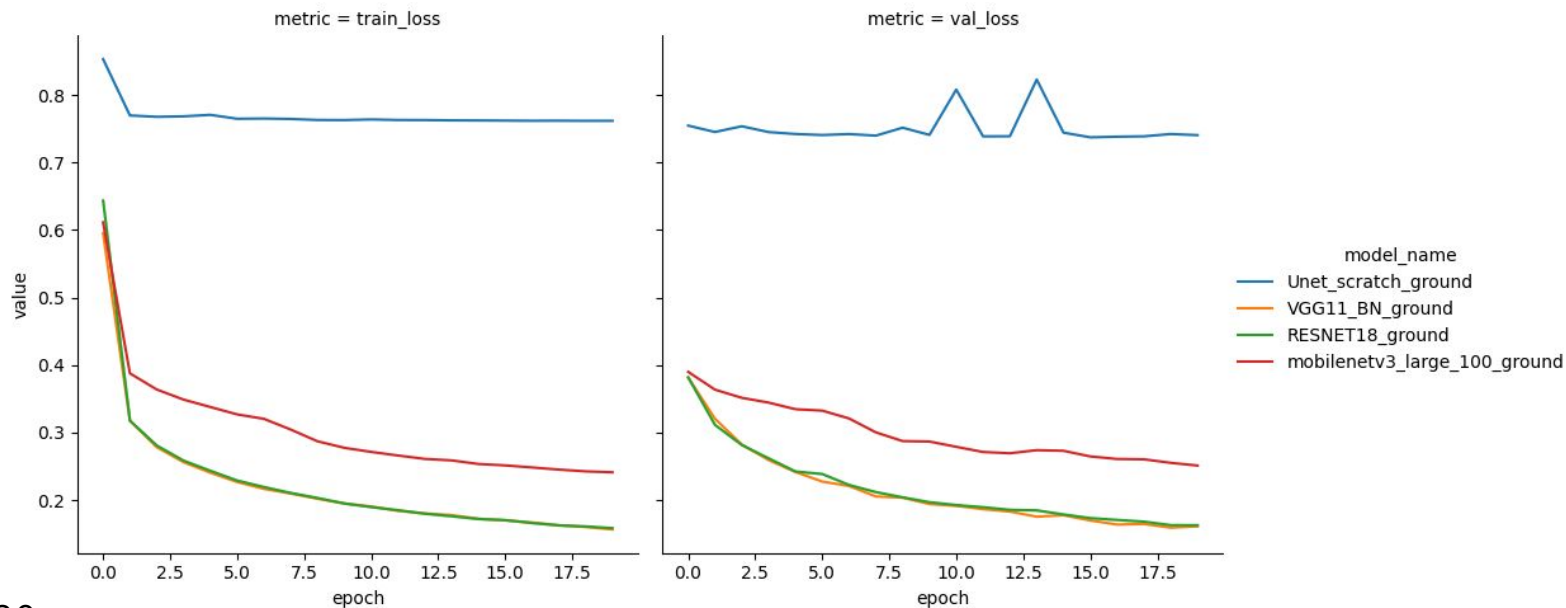
Epochs - 20

Optimizer - Adam

Loss - Cross Entropy Loss



Model Training: Pre-trained U-Nets



Epochs - 20

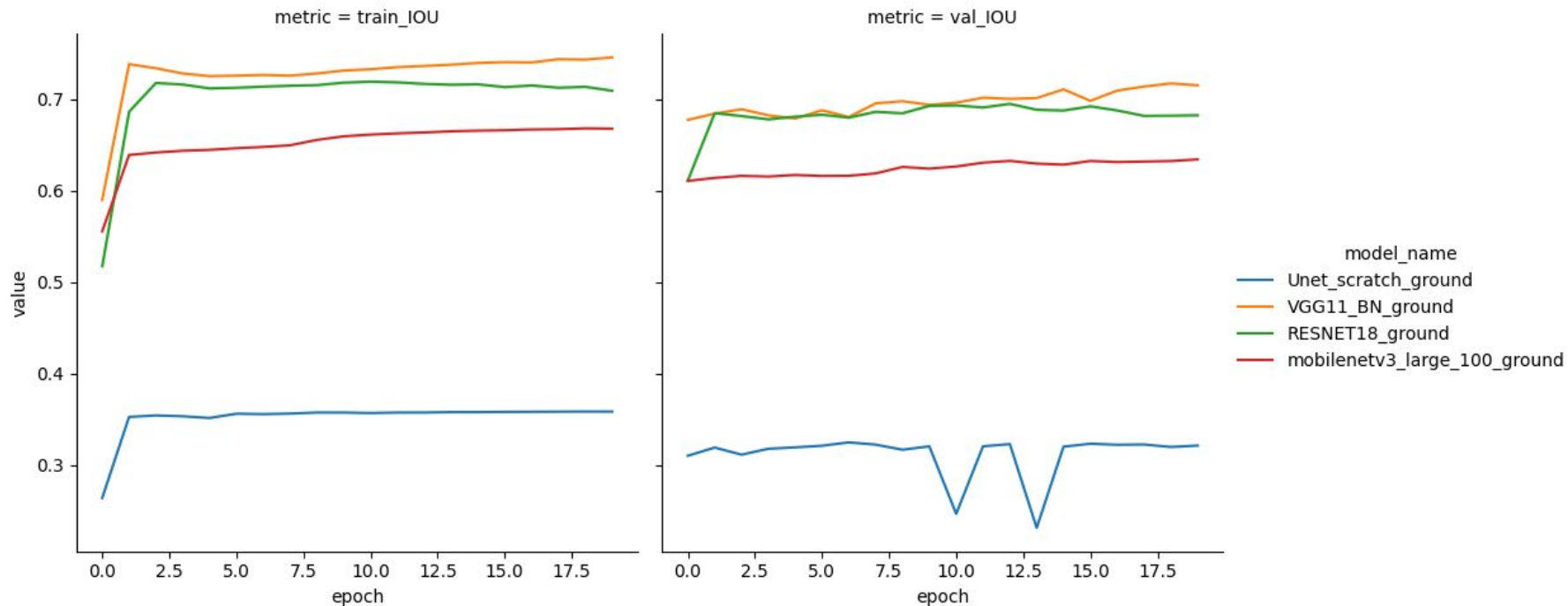
Optimizer - SGD

Loss - Cross Entropy Loss



Model Training: Pre-trained U-Nets

-- -- --

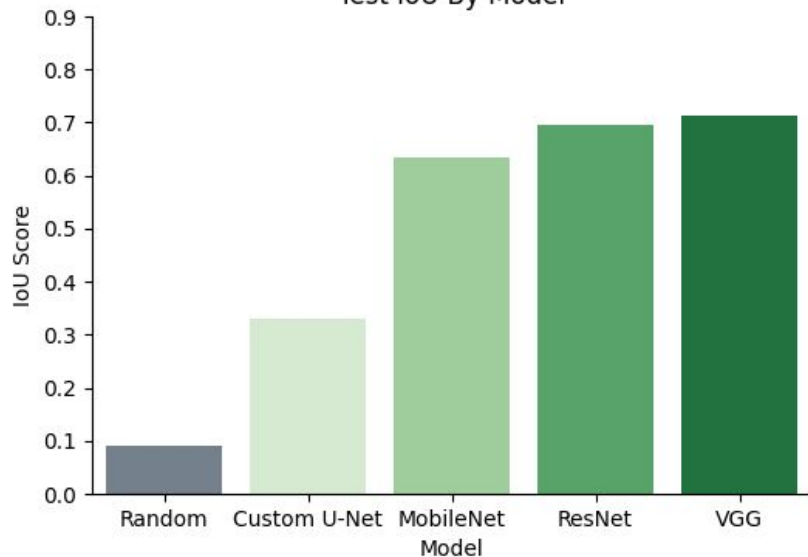




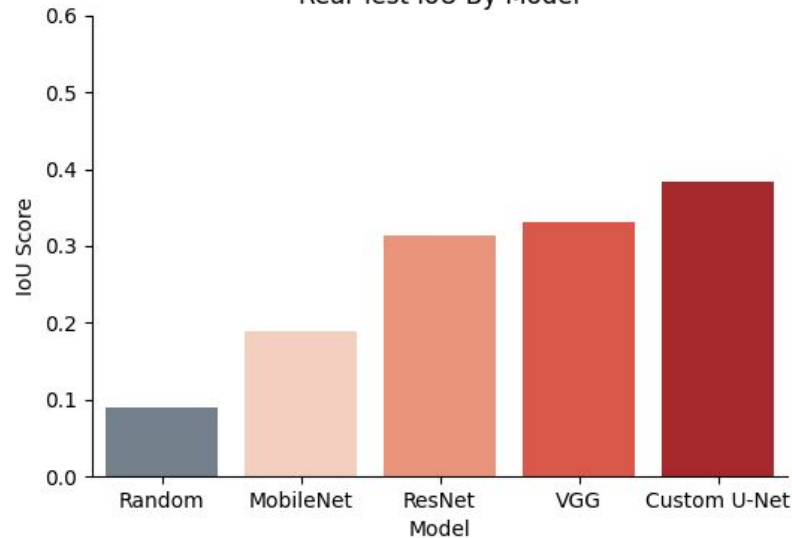
Model Results: Model Testing

— — —

Test IoU By Model



Real Test IoU By Model



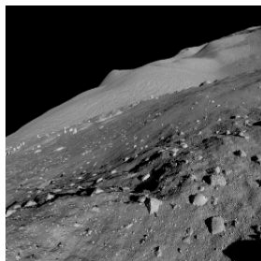


Model Results: Example Rendered Segmentations

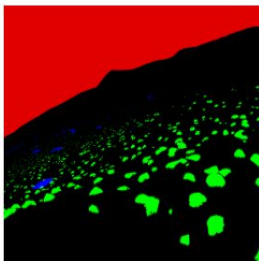
— — —

VGG11

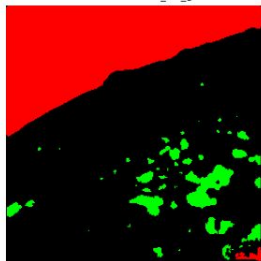
Original:
render7083.png



Ground Truth Mask:
ground7083.png

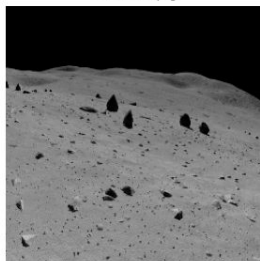


Predicted Mask VGG11_BN_ground:

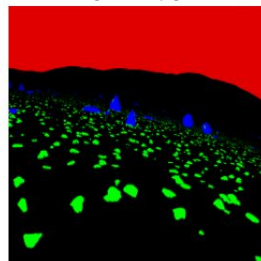


Custom Model

Original:
render2600.png



Ground Truth Mask:
ground2600.png



Predicted Mask Unet_scratch_ground:

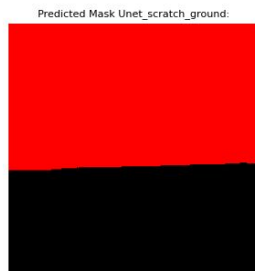
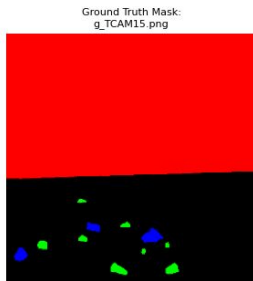




Model Results: Example Real Image Segmentation

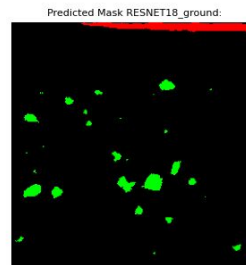
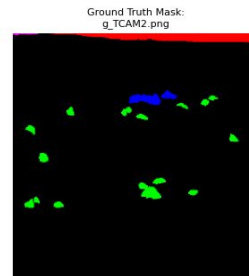
— — —

Custom Model



IOU: 0.48

ResNet



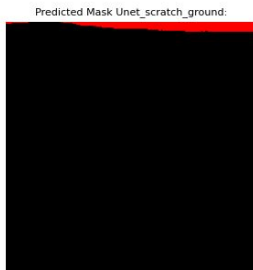
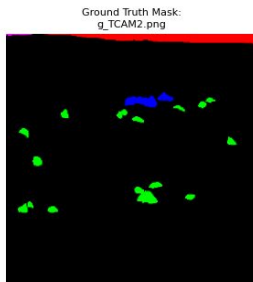
IOU: 0.46



Model Results: Example Real Image Segmentation

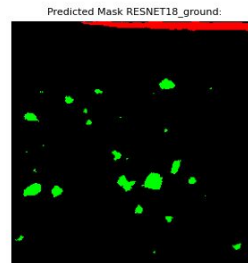
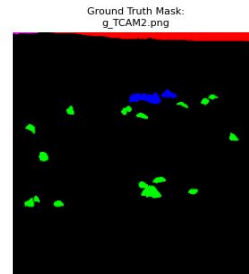
— — —

Custom Model



IOU: 0.44

ResNet

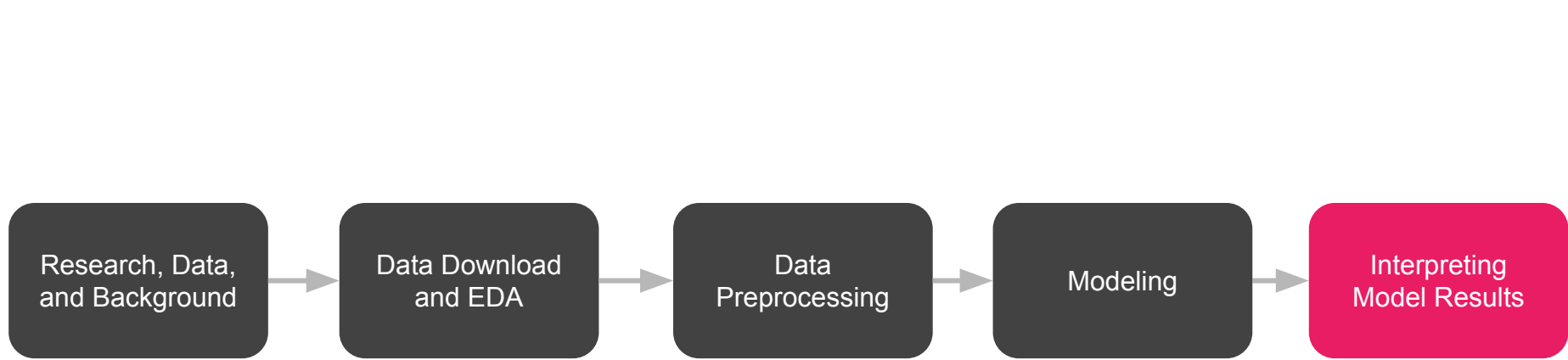


IOU: 0.46



Overview of Project Lifecycle

— — —





Interpreting Results

— — —

- The **VGG11 Model** was the strongest model we trained
 - This is likely due to being the largest model
- Our custom model underfit the dataset
- None of the models performed well on the real lunar images



Final Words and Areas of Improvement

— — —

- We succeeded in **comparing multiple different pre-trained U-Nets**
 - Although the conclusion we came to was consistent with previous attempts to solve this problem
- In the future:
 - Run full hyperparameter grid-search
 - Attempt adding attention to the models
 - Increase the complexity of the scratch model to attempt and compete with the pre-trained models

References

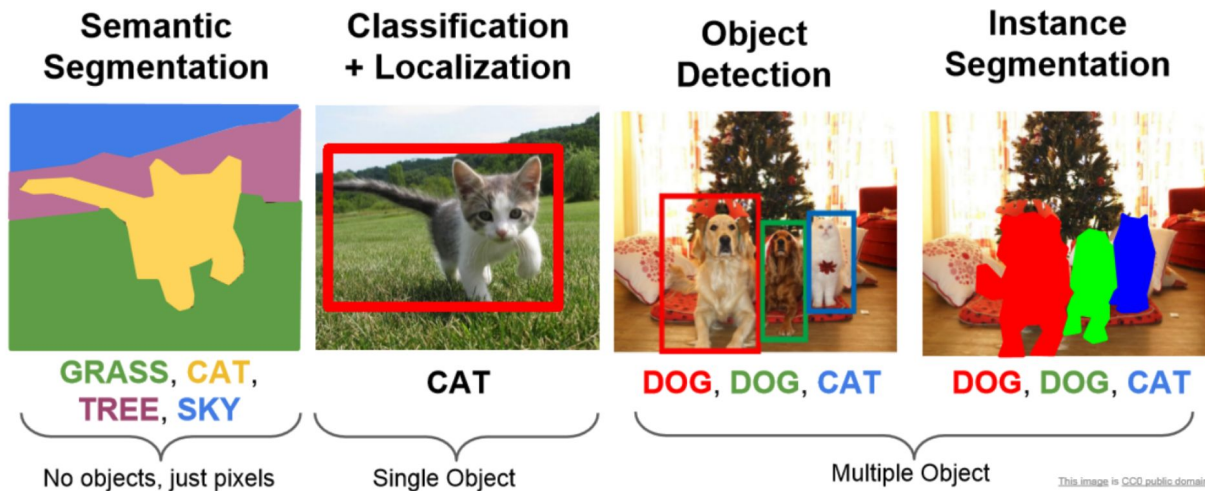
1. [Jonathan Long et. al \(2014\) - Fully Convolutional Networks for Semantic Segmentation](#)
2. [Ronneberger et. al \(2015\) - UNet: Convolutional Networks for Biomedical Image Segmentation](#)
3. [Artificial Lunar Landscape Dataset on Kaggle](#)
4. [Lunar Surface Image - thespaceacademy.org](#)
5. [An Overview of Semantic Segmentation](#)
6. [Stanford CS231: Detection and Segmentation](#)
7. [Kaggle - Artificial Lunar Landscape Dataset](#)
8. [Kaggle - Artificial Lunar Landscape Dataset - Silver Notebook](#)
9. [Jaccard Index](#)
10. [Understanding and Visualizing ResNets](#)
11. [Architecture and Implementation of VGG16](#)
12. [MobileNet v3](#)
13. [Metrics to Evaluate Semantic Segmentation](#)
14. [Cross Entropy Loss](#)



Background

— — —

Other Computer Vision Tasks



Fei-Fei Li & Justin Johnson & Serena Yeung

Lecture 11 - 17 May 10, 2017

Source http://cs231n.stanford.edu/slides/2017/cs231n_2017_lecture11.pdf

Figure X: Overview of CV Tasks⁶



Environment Setup/Data Download

— — —

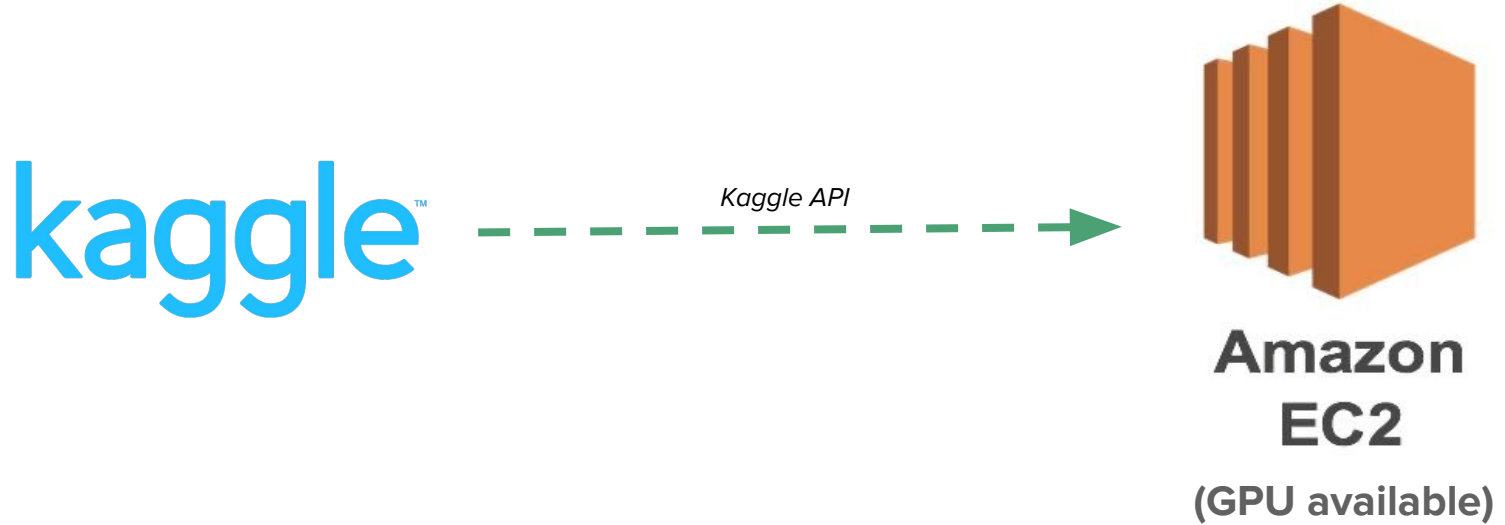


Figure X: Data Acquisition Diagram

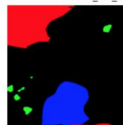
Model Results: ...

— — —

- Not sure if we wanna show class breakdowns for a couple like this with the predictions, might be better for the report.
- → depending on what plots i make for the results I might put on of these in there, they're pretty so they'll for sure be in the report lol

Something like this->

Predicted Mask VGG11_BN_Ground:



Big Rocks, Blue:11.02905% Pixels Activated



Unlabeled, Grey:74.53919% Pixels Activated



Sky, Red:13.27972% Pixels Activated



Small Rocks, Green:1.15204% Pixels Activated

