Machine Learning for Community-Driven Coastal Erosion Monitoring and Management

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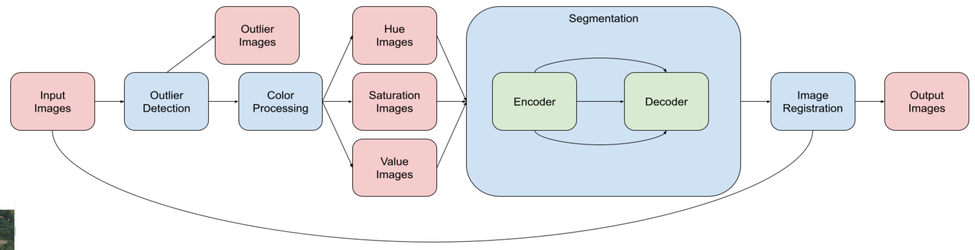
Motivation

- Coastal erosion is an issue that affects and endangers communities worldwide
- North Cove, a coastal town 2.5 hours southwest of Seattle, Washington, faces one of the fastest rates of coastal erosion on the West Coast of the United States
- Below, images of the coastline from 1997, 2002, and 2006 show how significantly the coastline receded in a ten years
- Dozens of homes, businesses, and a schoolhouse have been lost to the sea over the past few decades

Whole Pipeline Processing



Outlier Detection

$$(Image_1, Image_2, \ldots Image_m) \rightarrow \text{transformer} \rightarrow \begin{matrix} x_{11} & \ldots & x_{m1} \\ x_{12} & & x_{m2} \\ \ldots & & \ldots \\ x_{1n} & \ldots & x_{mn} \end{matrix} = X_1 \ldots X_M$$

$$\sum_{k=1}^{m} X_k = \hat{X}$$

$$Image_t \rightarrow \text{transformer} \rightarrow \begin{matrix} y_1 \\ y_2 \\ \ldots \\ y_n \end{matrix} = Y \qquad \frac{Y \cdot \hat{X}}{\|Y\| \|\hat{X}\|} \geq 0.75$$

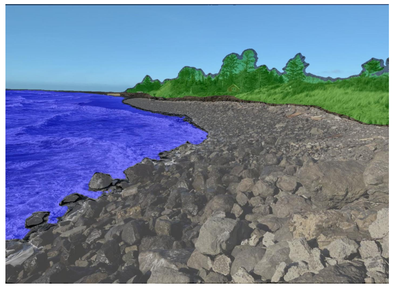
- The outlier detection stage uses image feature extraction & cosine similarity to compare image feature vectors and outlier images
- Reference images and test images are passed through the Google ViT Image Transformer, giving feature and reference vectors.
- Similarity score is computed using cosine similarity of these feature vectors, where a score of 1 implies perfect alignment, and a score of 0 implies vicer versa.
- An image with a score above 0.75 is kept in the dataset

Image Segmentation

- Our model classifies each pixel into one of 6 classes: Wet sand, dry sand, cobble, sky, vegetation & water.
- We tested 5 segmentation models and compared performance metrics such as Intersection over Union, Dice, FLOPs, Inference time and Throughput
- We then selected the DeepLab v3+ with Efficient Net-B4 (T3) model, which exceeded all performance benchmarks.

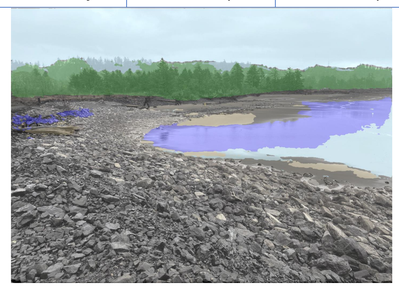
Why was T3 the best option?

- Pre-trained on ImageNet
- Uses Atrous Spatial Pyramid Pooling technique for multi-scale segmentation and compound scaling to extract finer features of the images
- At 2.82 GFLOPs, our model is a light model.



Test Metric	T3	T4	T5
Dice (F1) Score	0.945	0.935	0.940
Intersection Over Union (IoU) Score	0.907	0.879	0.888
Loss	0.256	0.244	0.224

Metric	Standard We Aimed For	T3 Results
Inference Time (in ms)	< 50	33.975
Throughput (in imgs/s)	> 20	29.43
FLOPs (in GFLOPs)	< 5 (light model)	2.82 (light model)



Data Retrieval

- MyCoast.org is a platform that allows users to report and document coastal issues such as flooding, storm damage, and marine debris through photos and data submissions
- Image data were primarily sourced from the Metal Marcy and Silhouette Jaenette sites

Silhouette Jaenette

Metal Marcy

Image Pre-Processing

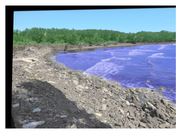
- We noticed that differences in lighting, due to variations in weather and time of day, could affect the segmentation results
- To minimize the impact of lighting differences, we converted the RGB images to HSV.
- Issues were best addressed by setting V to 200, scaling S by 200, and making no changes to H channel

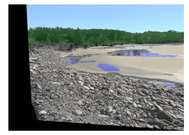
Original RGB Images

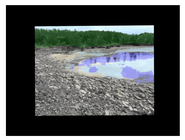
Converted HSV Images

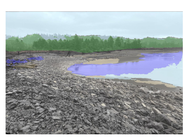
Image Registration

- Aim is to align images to a standard view of the coast using stable features of the image to help compare the changes on the coast over time
- Original images are registered using the LightGlue model to find matching features to compute a holography matrix.
- Segmentation images are similarly registered using the same holography matrix.









QR code for animation on Small Dataset

Future Work

- Since our model has been pre-trained on ImageNet and our own set of data, there are future opportunities for segmentation at other composite beach sites with minimal re-training required by the model.
- For beach sites with more object classes, the model can produce similar results after minor edits to add more classes and retraining with a small set of data.
- Our final model can also be tweaked to measure the area of each object class for different images – aiding in research related to tidal patterns, beach conservation, and coastal erosion.

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