Cloud Segmentation, Denoising, and Compression Techniques for use on Sentinel-3 Satellite Data

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Abstract

Satellite images of the Earth's surface have a multitude of uses. However, this data comes with some inherent issues:
1: cloud coverage -> image segmentation
2: size of the data -> image compression
3: varying quality -> image denoising

Problem 1: Cloud Identification

Method 1: K-Means clustering

K-Means clustering is an unsupervised learning algorithm that can be used to segment data into K clusters. It is particularly useful for identifying distinct differences in images based on pixel RGB values.

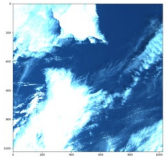
The K-Means clustering algorithm works by initializing K random centroids and assigning the data points to one of the centroids. The centroids are then adjusted based on the minimization of the distances of all associated data points. The function to be minimized is as follows: $\sum_{i=1}^{m}\sum_{k=1}^{K} w_{ik}||x^i - \mu_k||^2$

Method 2: Automatic Thresholding

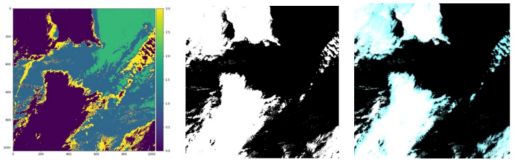
Thresholding is simply the selection of certain pixels based on a set threshold t. Images are typically converted to grayscale and normalized from 0 to 1. Each value in the image is compared to t and we create a binary mask based on it. The scikit-image module in python has a function that finds the threshold t using Otsu's method. This method essentially finds a value between peaks in a grayscale histogram.

Results

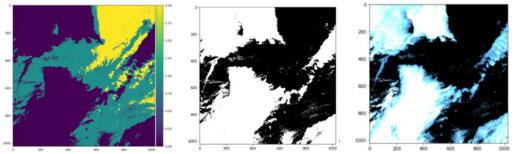
Original image



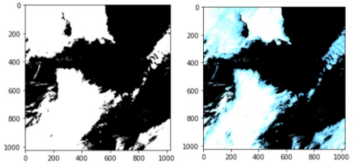
K-Means clustering for 4 clusters



K-Means clustering for 3 clusters



Automatic thresholding



Problem 2: Noise Removal

Method 1: Bicubic Resize

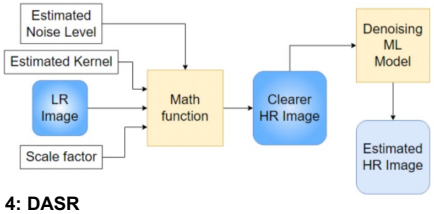
Bicubic resizing is a method that fits cubic functions to the two-dimensional image and uses those to estimate new pixel values during upscaling.

Method 2: Non-local Means Denoising

The non-local means denoising finds common patterns in images and averages them to remove noise.

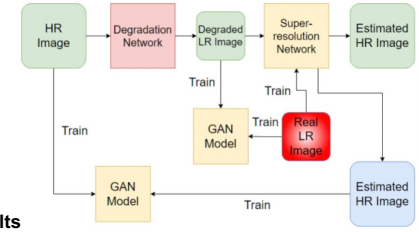
Method 3: USRNet

Unfolding super-resolution network (USRNet) is a neural network that takes four inputs: the low resolution (LR) image, estimated kernel, estimated noise level, and scale factor. Using these it creates a high-resolution image and then denoises that to create its predicted image.



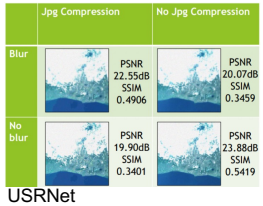
Method 4: DASR

Distance aware super-resolution (DASR) is a neural network that takes one input: the low-resolution image. It also contains a degradation network that creates its own degraded low-resolution image.

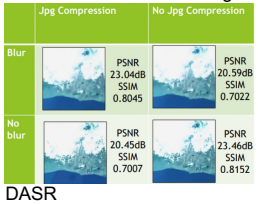


Results

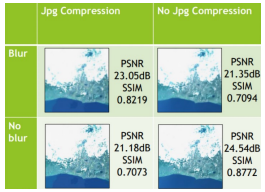
Bicubic Resize



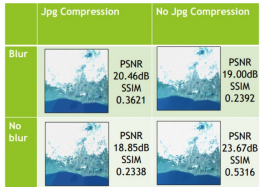
Non-local Means Denoising



USRNet



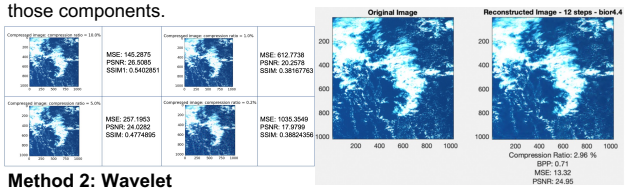
DASR



Problem 3: Compression

Method1: FFT

Fourier analysis is fundamentally a method for expressing a function as a sum of periodic components, and for recovering the function from those components.

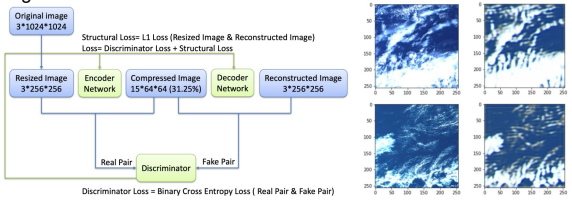


Method 2: Wavelet

Wavelet compression begins with a wavelet transform that produces a coefficient for each pixel. A few of these coefficients contain the majority of the data. These are used to encode the data.

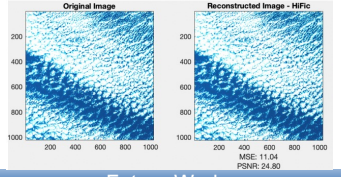
Method 3: GAN

Generative adversarial networks contain a generator and discriminator. This type of network can be used with an Encoder-Decoder model to create compressed images that are similar to the original.



Method 4: HiFiC

HiFiC is a GAN-based image compression tool, which has been trained to perform image compression about four times better than JPEG.



Future Work

1. Implement U-Net with MagmaDNN for performing cloud segmentation
2. Run denoising methods on an edge device, such as the Nvidia Jetson Nano
3. Custom train the HiFiC for our dataset

Acknowledgements

This project was sponsored by the National Science Foundation through Research Experience for Undergraduates (REU) award, with additional support from the Joint Institute of Computational Sciences at University of Tennessee Knoxville.

References

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Image Denoising: https://docs.opencv.org/3.4/d5/d69/tutorial_py_non_local_means.html
Zhang, K., Gool, L., Timofte, R.: Deep Unfolding Network for Image Super-Resolution. CVPR (2020) pp. 3214-3223. https://doi.org/10.48550/arXiv.2003.10428
Deep Unfolding Network for Image Super-Resolution: https://github.com/cszn/USRNet
Distance Aware Super-Resolution (DASR): https://github.com/ShuhangGu/DASR
Image Compression Using GAN: https://github.com/prbpedia/image_compression
Wavelet Analyzer App: https://www.mathworks.com/help/wavelet/ref/waveletanalyzer-app.html
HiFiC Colab: https://colab.research.google.com/github/tensorflow/compression/blob/master/models/hific/colab.ipynb