Detection of Clouds in Visible Band Nighttime Imagery

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Advisors

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Roles

Peiqi Liu: Developing cloud detection algorithm for Luojia-1 Satellite images.
Prabh Simran: Working on the challenges and forking and testing Tony's code.
Raymond Xiao: Developing cloud detection algorithm for Cities at Night dataset.

Abstract

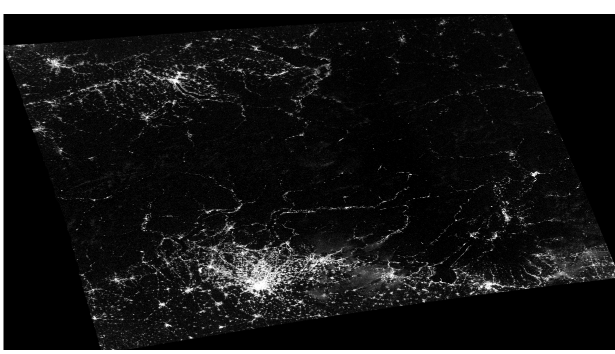
Accurate information on cloud occurrence is of great importance for a wide range of remote-sensing applications and analyses. Numerous studies have been conducted on infrared bands and other multiple sensors carried by the satellites to detect clouds. However, it will be valuable for existing and planned night satellites to identify cloudy areas in visible band nighttime imagery from space. This algorithm will further assist the astronomers in determining the amount of light pollution at various locations.

Problem Statement

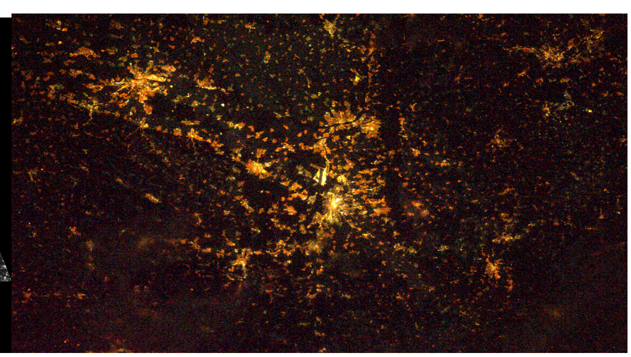
Define a cloud mask based on visible band nighttime imagery from space, to assist researchers in remote sensing applications, light pollution applications and analyses.

Datasets

1) Luojia-1 dataset: Grayscale dataset.
2) Cities at Night dataset: Coloured dataset.



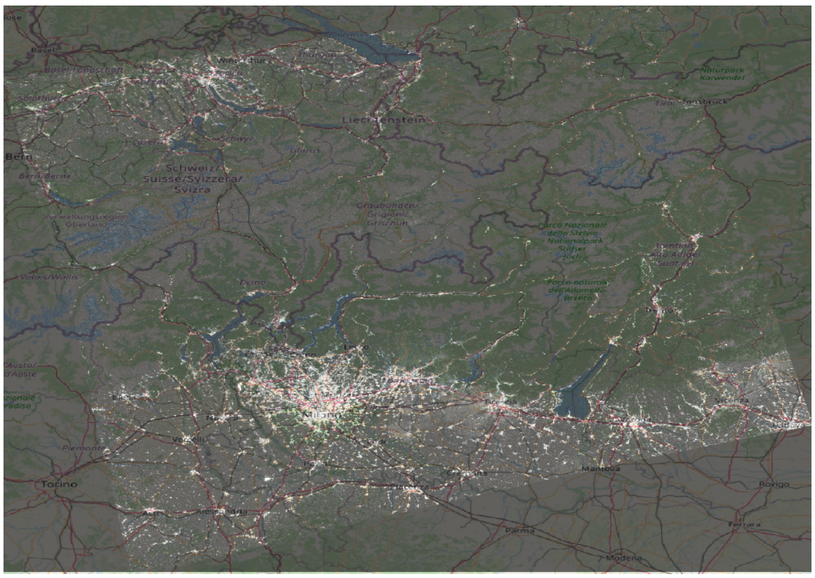
Luojia-1 dataset: Germany



Cities at Night Dataset: Luxembourg

Challenges

It is harder to identify cloudy areas in the night sky as compared to day time. Previously, researchers have developed algorithms to detect clouds in the night sky with the help of infrared satellites. In the visible band imagery, it is crucial to identify the city lights and the rural areas. This confirms the algorithm and a sanity check for the algorithm. Below is an example of a region in Germany overlaid over the OpenStreet maps to establish the cities and the other areas in the region.



Cloud Detection Algorithm for Luojia-1 Satellite Image

For Luojia-1 Image, we started out trying basic approaches like applying median on chunks of the image because cloudy areas will have a higher median. This, unfortunately, did not work as expected.

Later, Chris introduced some other techniques we can try, including Unsharp mask, a high-pass filter usually used to improve the clarity of an image. When applied to the nighttime satellite image from the Luojia-1 satellite, the scatter of streetlights in cloudy areas is significantly reduced while the cloud stays mostly intact. This makes it easier to separate streetlights from clouds. This has become the foundation of this algorithm.

The next step is to remove all pixels brighter than a threshold. Due to many images have very different local properties (e.g. urban vs rural, cloudy vs clear) and we get bad results from images with wide ranges of brightness.
We later introduced an improvement so that the threshold is computed and applied to individual chunks of the image. This step can eliminate the brighter part of streetlights. The image is now only left with clouds and dimmer parts of the streetlights.

The next step is average blurring, a low-pass filter, which removes streetlights with no nearby cloud because of their relatively bright and sparse pixels (very bright pixels are already removed in the last step).

Right now, the cloud mask is starting to take shape, but some noise reduction is still needed. The next step is to remove all pixels darker than a threshold. Similarly, the threshold is computed and applied to individual chunks of the image.

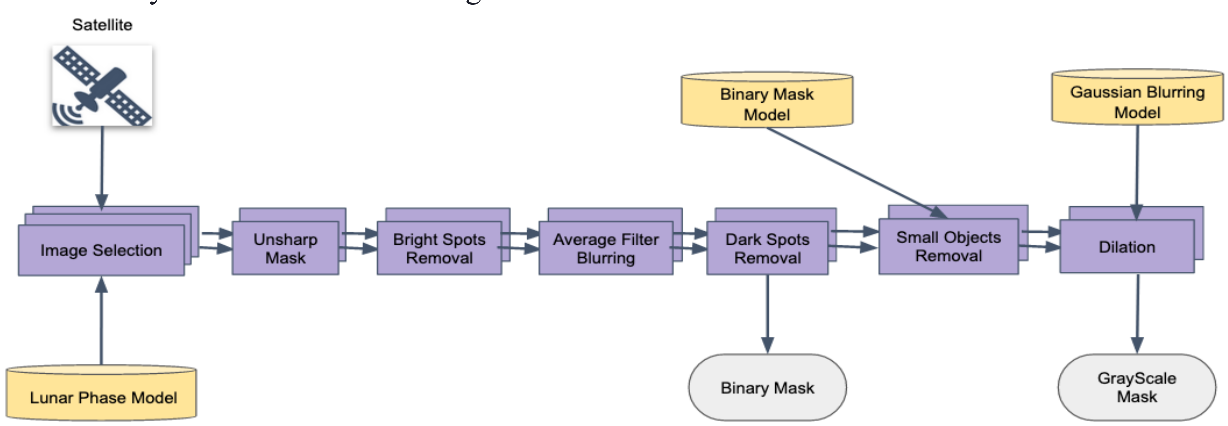
If the desired output is a binary mask instead of a gradient one, convert the image into binary.

The previous steps cannot remove some remaining spotty bright noises. The next step is to generate statistics of all connected components in the mask and remove the ones with an area smaller than a threshold (eg. the mean size of all connected components).

The mask now predicts where there are certainly clouds, but there are most likely clouds near the predicted areas. To be more conservative with the prediction, the next step is to run a grey dilation to extend the predicted area with the cloud. If gradient prediction is needed, another Gaussian blur can be applied to smooth out the dilated mask.

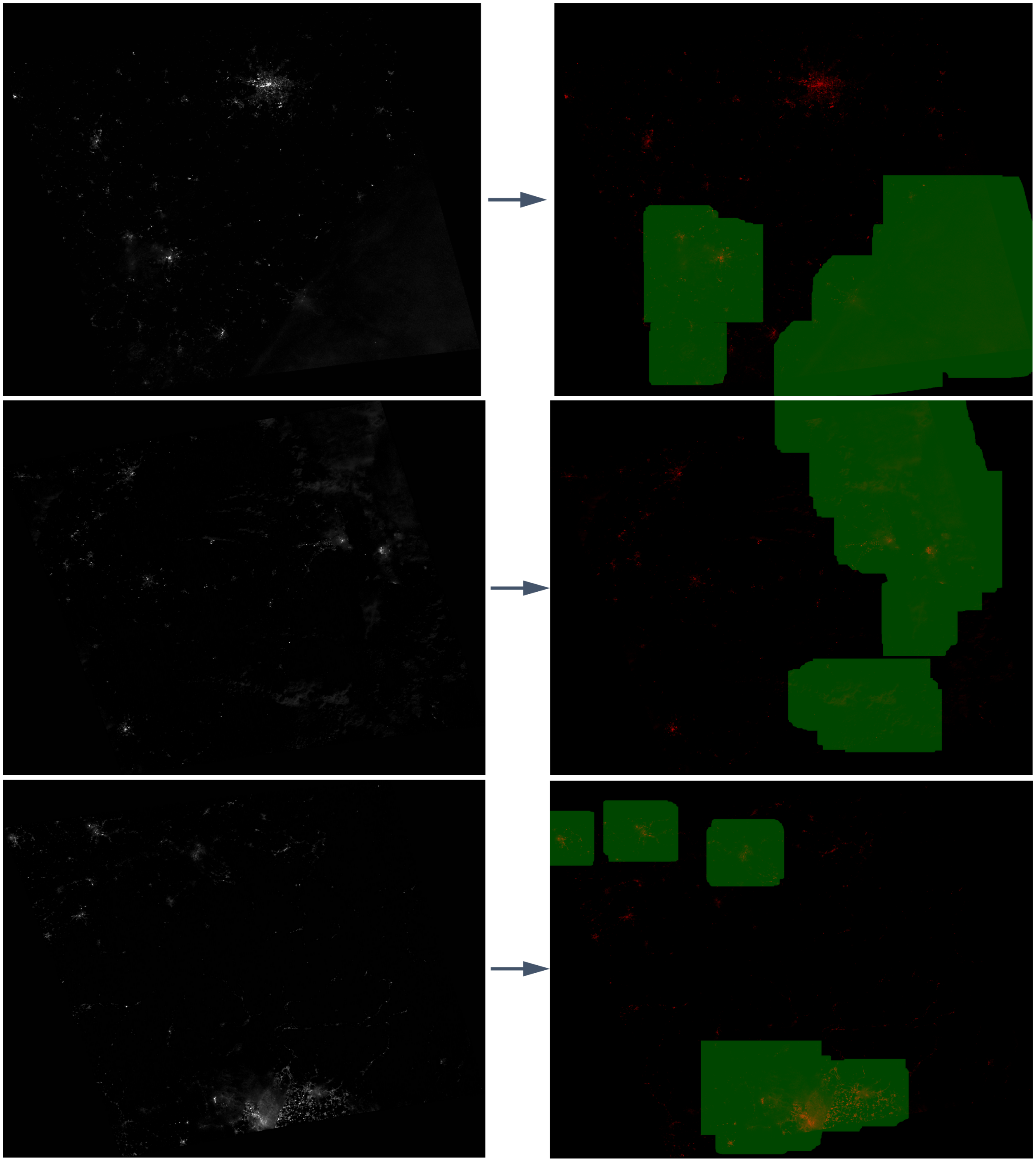
The process is not yet automated, given our limited time to work on the algorithm. It does not work well for images with a large amount of moonlight, so images with lunar phase close to a full moon need to be excluded manually. Also, the thresholds used for each step is manually set, with some variability according to the mean of the image.

Here is the system overview of the algorithm:

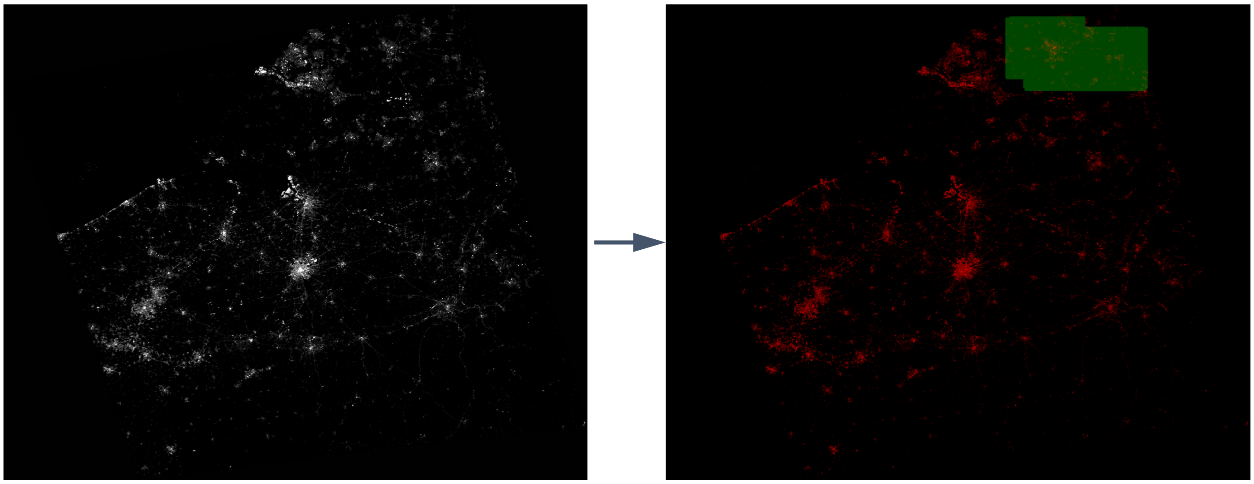


Results

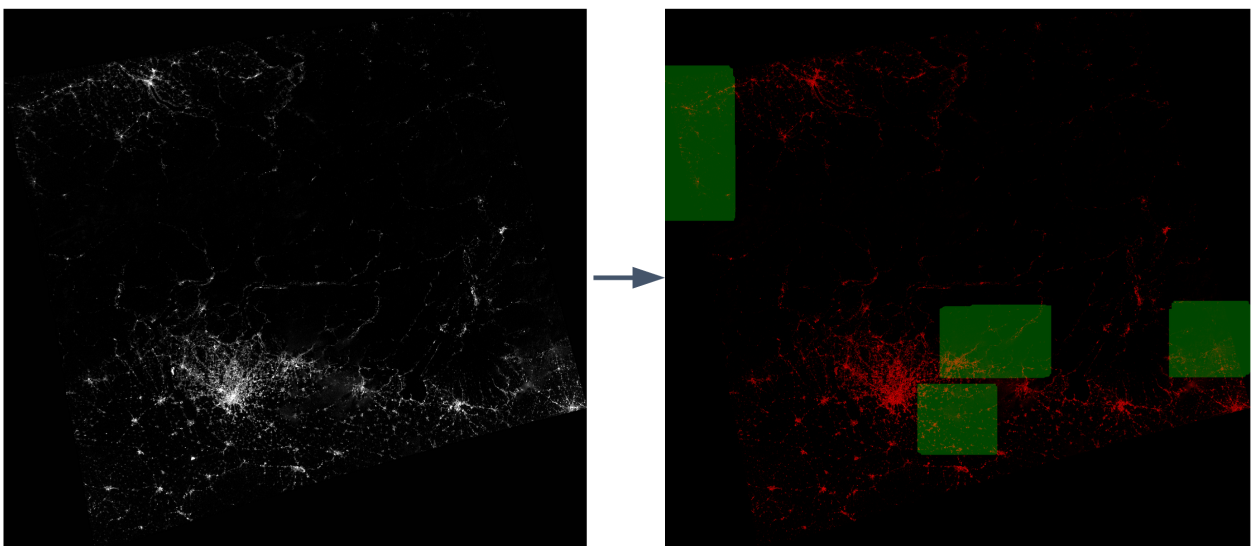
The algorithm generally can correctly predict most clouds, especially those that are lit by streetlights. The following three pairs of images are successful examples. The red is the original image and green is the predicted cloud mask.



The algorithm does produce some false positive predictions, such as the below image, where there are large areas with dim streetlight.



Here is another failure example. The cloud at the bottom centre which is not well-lit is not being correctly recognised, and there are some false positive cases as well.



Future Work

Develop a computer vision deep learning algorithm to automatically use the image processing filters and segment clouds from the night sky. This technique will be evaluated on a large dataset to see the accuracy of this deep learning algorithm. We might be collaborating to develop a robust algorithm for cloud detection and also try for a publication on the algorithm if we get satisfactory results.

Timeline

25th June - 8th July: Designing a basic cloud mask algorithm for Luojia-1 dataset.

8th July - 15th July: Overlaying images on top of OpenStreet Maps.

15th July - 8th August: Forked and ran Tony's code, and helped in smooth running of the code for easy transfer of the algorithm.

Experience Description

The experience of learning about light pollution and detecting clouds in the visible band night imagery has been interesting and challenging. This project has provided me with better clarity in the basic image processing processes and algorithms. It has also opened a whole new world of light pollution and the night sky for me, which is a fascinating topic. I will definitely keep looking into this topic and try to help astronomers and other researchers towards their goals.

Knowledge Gained

During this project, I learnt the basics of image processing and various transformations in computer vision. I also gained experience in Geographical Information System Mapping which is a unique skill to gain and it provides a different perspective of looking at the datasets. Overall, the project has provided me with insights about how to better tackle new areas of research. This project reminded me that things are usually easier when we are looking at them from a distance, but are definitely harder when you dig deeper into the research topic. I would like to thank Diane and Steven for providing me with this opportunity and opening my eyes towards a whole new world of research.