Stereo Vision of Dual View MSG Satellite Images

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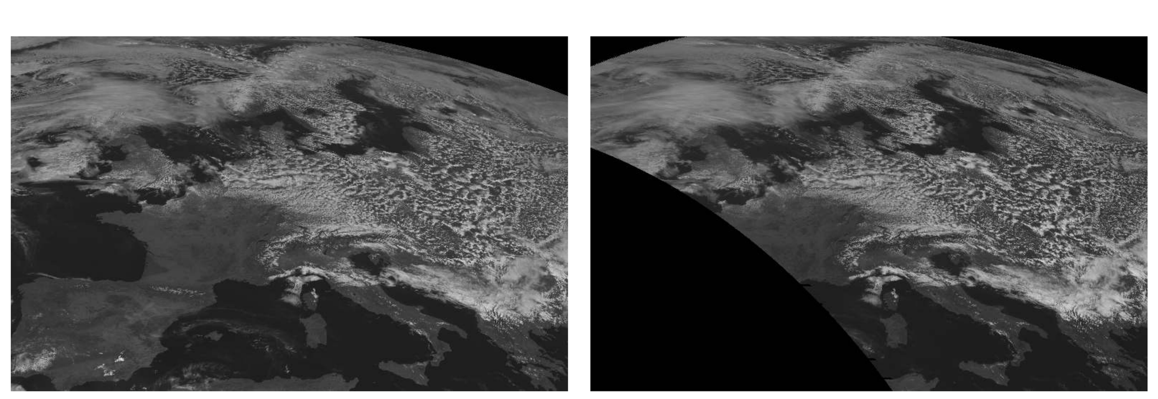
Objectives

In this thesis, we utilize the Meteosat Second Generation Satellites` capability to observe the same region over Europe from two different longitudes, i.e. 0° and 41.5° over the equator respectively for the two satellites. The ultimate objective of the thesis is to estimate the height of clouds over Belgium, by applying advanced stereo vision techniques.

Introduction

This thesis was implemented jointly by the University of Patras and the Vrije Universiteit Brussels in close collaboration with the Royal Meteorological Institute of Belgium (KMI). The central aim of the thesis is to develop a stereo vision computational pipeline that estimates the cloud top height of an area above Belgium using pairs of images obtained from the MSG3 and MSG1 satellites.

The MSG satellites are geostationary meteorological satellites, which means that they move with the same rotational speed as the Earth with a geosynchronous orbit exactly above the equator (latitude 0°) and thus maintaining their position with respect to a location on Earth. Both satellites orbit at an altitude of 36 000 km. and at the time when the images were taken, MSG-3 made observations at 0° over the west part of Africa and MSG-1 at 41.5°E over Indian Ocean.



(a) MSG-3 View at 0°   (b) Remapped MSG-1 View from 41.5°E to 0°

Figure: 1. Stereo Pair Images

Data

The Dataset was provided by the KMI. The images from MSG-1 have been remapped to 0° to match the perspective of the MSG-3 images and can be seen in Figure 1. In the framework of our study, LIDAR data is used to evaluate the accuracy of the computational pipeline to be implemented for the estimation of cloud-top height.

Typical Stereo Vision System

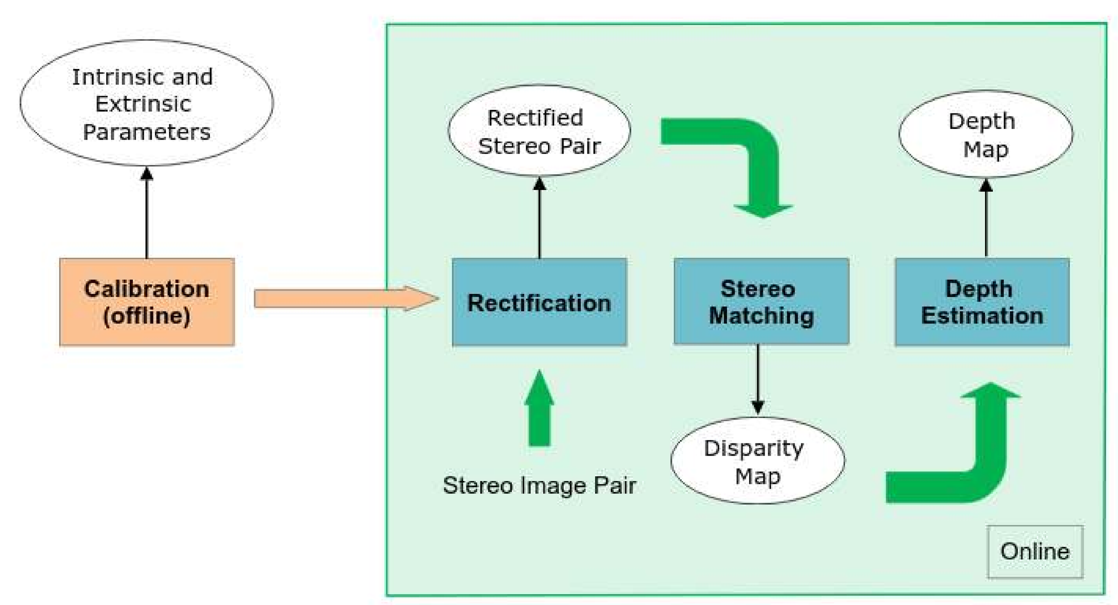


Image Registration

A relative displacement in number of pixels between the two views depending on the longitude and latitude of each location is osberved. In order to compensate for this error we crop the images around the area of interest (light blue rectangle in Figure 2) and apply image registration techniques on two clear-sky images and apply the computed transformation to each cropped image pair.

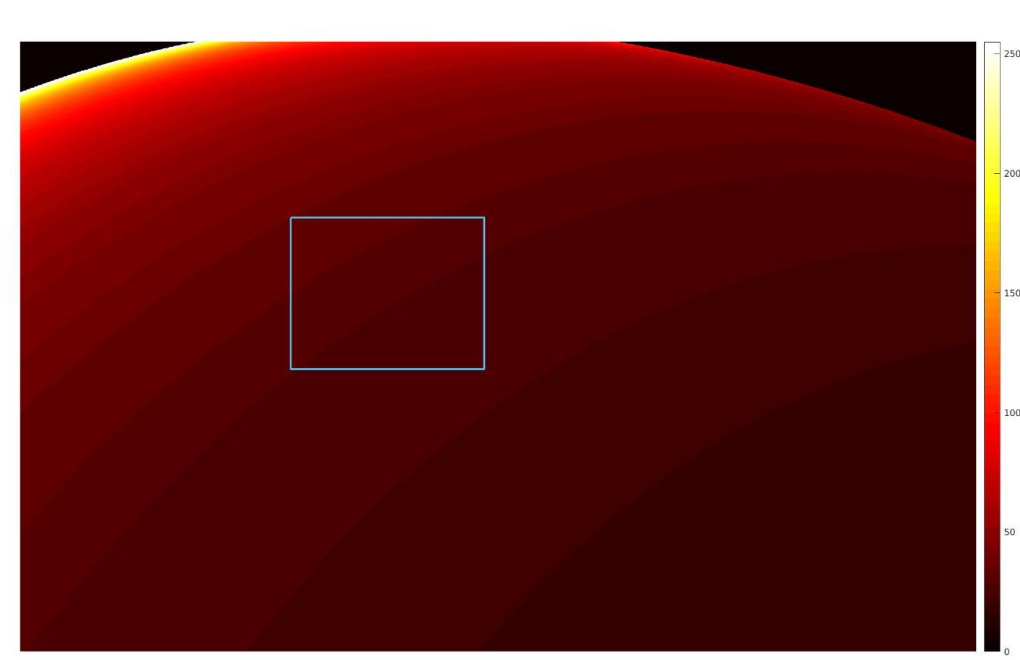


Figure: 2. Relative displacement in number of pixels

Image Registration (cont.)

We compare two registration methods, one based on maximizing the Mutual Information of the clear-sky image pair using either Gradient Descent or Powerll Optimizers. The second one is based on the low level features of the images, and in particular the SIFT/SURF algorithms are used to extract and describe the features and RANSAC algorithm to estimate the transformation. In order to evaluate the performance of those approaches we use the $SSIM$ and the $PSNR$ metrics.

At first, all four registration methods produce similar results. In order to conclude to one main algorithmic approach, these methods are tested using some artificially transformed MSG-1 clear sky images, given four different transformation cases. The superior performance of feature-based registration methods regarding the registration of the artificially produced images is clear.

Disparity Map

In order to compute the disparity map and estimate the clouds height two stereo matching methods based on Markov Random Fields are compared. In particular, we attempt to minimize an energy function using two graph-cut based algorithms, α-Expansion Move and $\alpha - \beta$ Swap Move.

Indicative Results

Although both the proposed method detects the high altitude cloud (upper left red cloud in ground truth) in Figure 4, it has difficulty detecting the low altitude cloud mass. Manual parameter tuning is a very difficult and slow task. Therefore, we developed a script in order to manually test a range of values for those parameters. However, the parameter tweaking was not successful as the results were poor compared to the respective LIDAR data.

Indicative Results (cont.)

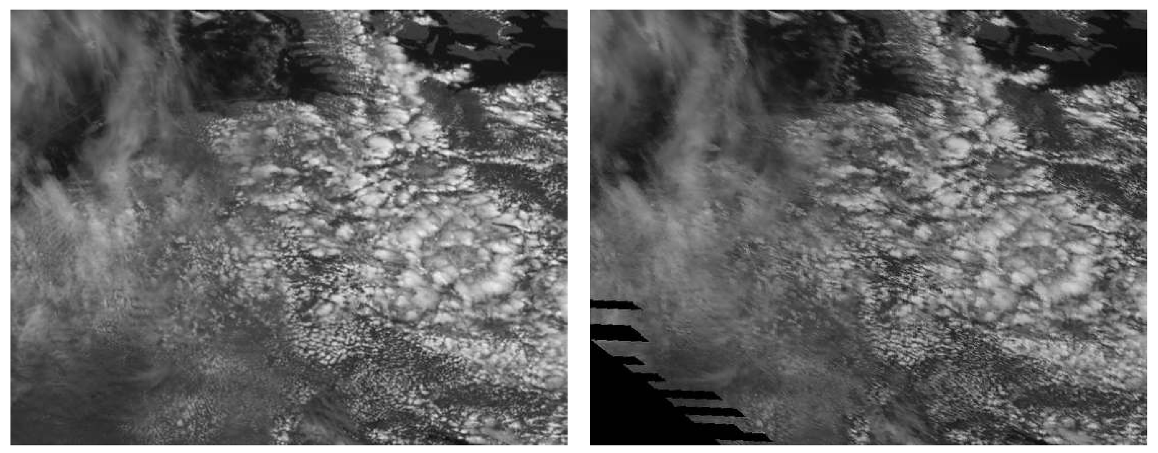


Figure: 3. Input Images

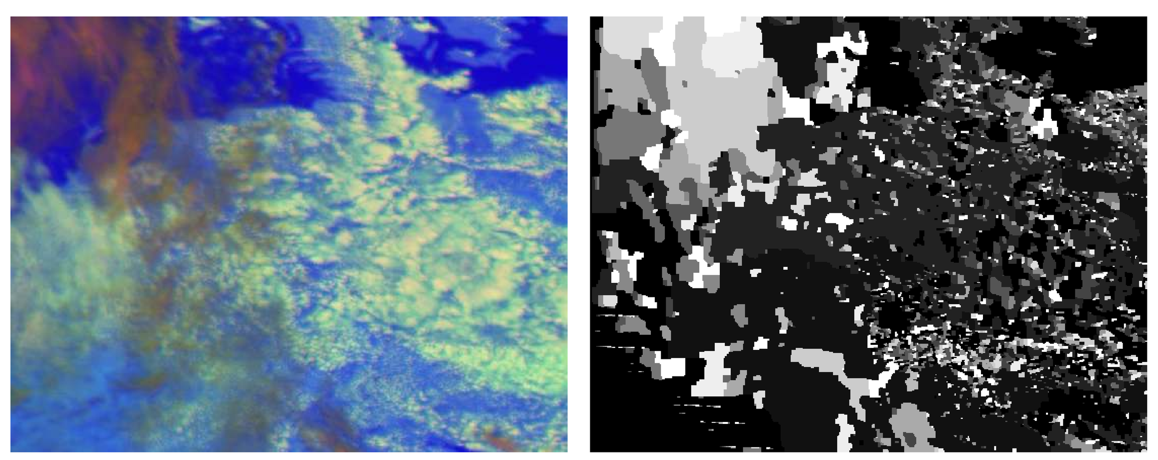


Figure: 4. Ground truth (left) and calculated disparity map (right)

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