Efficient haze detection and removal for large scale remote sensing images
- *Project Proposal* -

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1. Motivation and problem definition

The few last years have seen the availability of satellite images to explode, thanks to public initiatives such as the Copernicus program and the associated Sentinel satellites launched by the European Spatial Agency. This tremendous amount of data, consisting in high resolution images with relatively small revisit time, require new processing techniques to be valued, as they have the potential to provide a nearly real time monitoring of many human activities at the global scale.
On the other hand, due to major crisis such as climate change, risks over these activities are today unprecedented, as for instance floodings, wildfires or droughts are expected to become more and more frequent and intense in the close future. In this context, remote sensing may become a precious ally in monitoring almost day to day the evolution of such situations.

However, this nearly real time monitoring can be disrupted by a poor quality of the images captured. In the case of hyperspectral satellites such as Sentinel-2, whose bands of acquisition range from 494.4 nm to 1373.5 nm, the images can be severly obstructed by clouds or haze, for several passes in a row, having as a consequence a dramatic collapse in the time frequency of exploitable images (see Figure 1). In this scope, Visual Computing techniques have a big potential to help dealing with such issues, as they provide interesting methods to process or improve images, without the drawbacks that Deep Learning can have, e.g being time greedy computationally intensive, and not always robust to new data.

The problem tackled in this project will then be the following: evaluate the quality and time efficiency of recent Visual Computing methods from the literature ([2],[1], [3], [6]), in order to find a satisfactory tool for haze removal in remote sensing images, in order to preserve the time frequency of exploitable images.

Figure 1. Clean (upper) vs hazy (lower) Sentinel-2 images of agricultural fields close to Paris Saclay

1.1. Related work

The main related work for this task was studied in [3]. Indeed, in this paper, authors present the dark channel prior, which is a commonly used method for image "de-hazing". However, this methodology presents some limits, mainly for heterogeneous and dense haze. We will go further by implementing improvements to this method, similar to what have been done in [5].

2. Methodology

2.1. Background

2.1.1 The haze image model

Haze is traditionally an atmospheric phenomenon in which dust, smoke, and other dry particulates suspended in air, make light scatter. Thus, the observed image by satellite contains both the haze information and the ground features. In computer vision, the commonly used model to describe haze image [4] is the following, for a given pixel x :

$$\boldsymbol{I}(x) = \boldsymbol{J}(x)t(x) + \boldsymbol{A}(1 - t(x))$$

where $\boldsymbol{I}$ stands for the observed intensity, $\boldsymbol{J}$ is the scene radiance, $\boldsymbol{A}$ stands for the atmospheric light of the whole image, t is the medium transmission coefficient, representing the portion of the light that is not scattered and reaches the imaging instrument. Therefore, in order to remove haze and recover the original image, we need to get the $\boldsymbol{J}$ component. However, this is an ill-posed problem, because we don't really know $\boldsymbol{A}$ and t.

2.1.2 Dark Channel Prior

The dark channel prior is based on the following observation on outdoor haze-free images: In most of the nonsky patches, pixels in at least one color channel (r, g or b) have a low intensity value and close to zero. The low intensity in the dark channel is mainly due to the fact that natural images are colorful and full of shadows. As a result, we can use this specific criterion to first detect if an image is polluted by haze or not. Then, some assumptions can be made to estimate both $\boldsymbol{A}$ and t components in order to recover the original image.

2.2. Proposed method

First, we would like to confirm the observation of the dark channel prior, by investigating on pattern of intensity value for diverse satellite images (mountain, city, river..). This will allow us to build our haze detection algorithm. Once this hypothesis is confirmed, we will implement our dark channel prior dehazing algorithm. However, when the images have dense and heterogeneous haze, the results obtained by this method can have color distortion especially in the bright regions and loss of details ([3]). We can try to fine tune it by adding some post-processing steps, or improve the method, as suggested in [7].

3. Evaluation

In the last few years, it has become easy to export publicly available satellite images for given places and time periods. Thus, we will constitute a dataset of hazy Sentinel-2 hyperspectral images. The advantage of this source of data is that it is free and it covers a large part of the world's surface, so it can be used to generate very diverse datasets, for instance urban, forest, fields or mountain images. This will enable us to constitute a diversified set of images, to evaluate the chosen method's capacity to adapt to any context. Moreover, we will try to evaluate if the reconstructed image is physically relevant, that is to say the histograms of values for each band of wavelength in similar to the same image in a haze free situation at a close acquisition date. Indeed, a lot of post-processing is often necessary on satellite images, for instance to derive vegetation or moisture index from multiple bands, so we will have to control how the methods influence the values.

The experiments that will be carried out are :

- Comparing the different methods in the literature on diversified images
- Evaluating the quality of the reconstruction, in terms of histograms over all the bands available
- Evaluate the time efficiency of the methods, to see which is most suitable for large scale processing

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