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Texas A&M University

Electrical and Computer Engineering Department

Dr. Raffaella Righetti

Final Project Report

Name: Flavia Ratto

UIN: 130004853

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Aggie Code of Honor

An Aggie does not lie, cheat or steal or tolerate those who do.

ECEN 642 Project: Morning View Mode

Problem Statement –

Images taken outdoor, especially in the mornings can sometimes be messed up due to unpredictable atmospheric and weather conditions like haze, fog and smoke. This causes a beautiful morning image to be hazy, which makes it less pleasing. So, I have created a "Morning View Mode" using which I remove haze from the pictures and restore the original scene behind the haze.

There are a lot of methods available currently to remove haze. I have done haze removal by implementing the method of "Single Image Haze Removal using Dark Channel Prior" [1]. Later, I have tried to refine the results of the previous method by using "Guided Image Filtering" [2].

Approach –

In the first paper, a method is proposed for haze removal of a single image using its dark channel prior. It is seen that in most of the regions in the image, except the sky area, some pixels very often have very low intensity in atleast one of the RGB channel. In images that have been distorted by haze, these low intensity pixels called the dark pixels are contributed by airlight. Hence these dark pixels can give an estimation of haze in the image.

Using the haze imaging model mentioned below, a haze free image is recovered using this technique –

$I(x) = J(x)t(x) + A(1 - t(x))$

Where,

$I(x) \rightarrow Input\ hazy\ image$

$J(x) \rightarrow Haze\ free\ image$

$t(x) \rightarrow Transmission\ of\ the\ medium$

$A \rightarrow Atmospheric\ Light$

The approach here is that, given a hazy image I, first find its dark channel J_{Dark}. This is given by the formula below –

$J_{Dark} = \underset{y\epsilon\Omega(x)}{min}(\underset{c\epsilon\{R,G,B\}}{min} J^c(y))$

Here, $\Omega(x)$ is the local patch centered at x. I have fixed the patch size as 15x15 here for all the images.

The dark channel here is the result of two min operators. One min operator operates on each R, G and B channel and gives us the minimum pixel intensity in the local patch for each channel. The second min operator gives the minimum pixel intensity among the minimum values of each channel. These min operators are commutative. Using this dark channel prior J_{Dark}, we calculate the values of A and t

Atmospheric light A is estimated by picking the top 0.1% brightest pixels in the dark channel. Among these pixels, the pixels with the highest intensity in the input hazy image is selected as the atmospheric light.

The transmission of the medium is estimated using the formula below –

$$t(x) = 1 - \omega_{y\epsilon\Omega(x)}^{min}(min_c \frac{I^c(y)}{A^c})$$

As in the paper, I have fixed the value of ω as 0.95.

Using these computed values in the below equation, we can recover the haze free image.

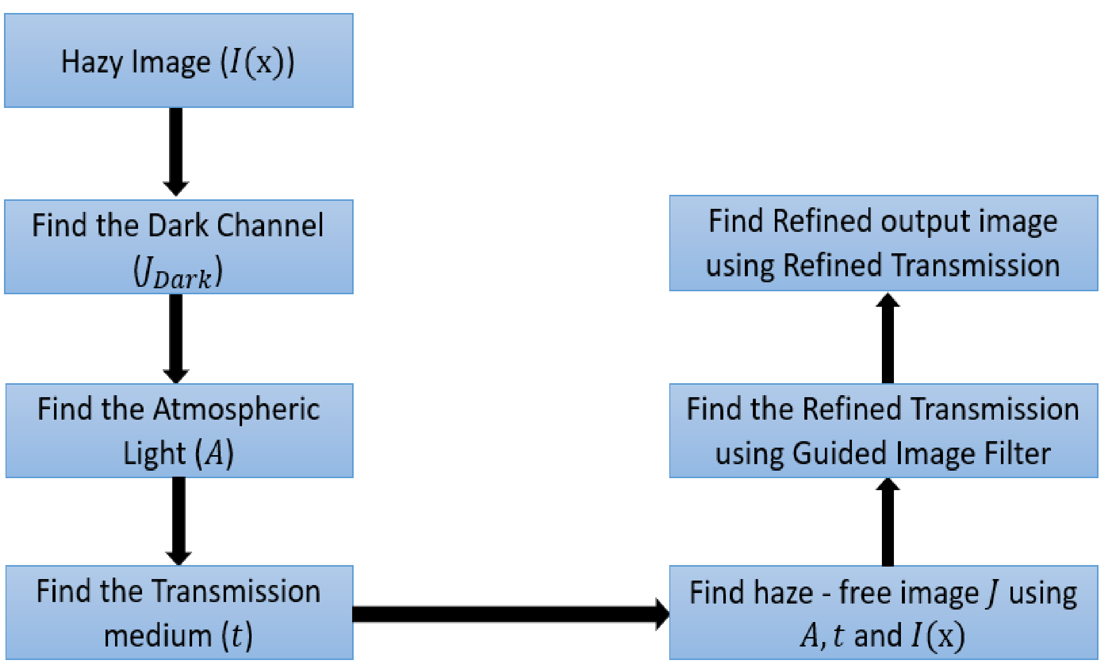
$$J(x) = \frac{I(x) - A}{\max(t(x) - t_0)} + A$$

As in the paper, I have fixed the value of t_0 as 0.1.

The results obtained by the above approach removes haze successfully. However, the result shows presence of halo artifacts which I have refined using the "Guided Image Filter". I have implemented this filter by using the algorithm stated in the paper.

Block Diagram –

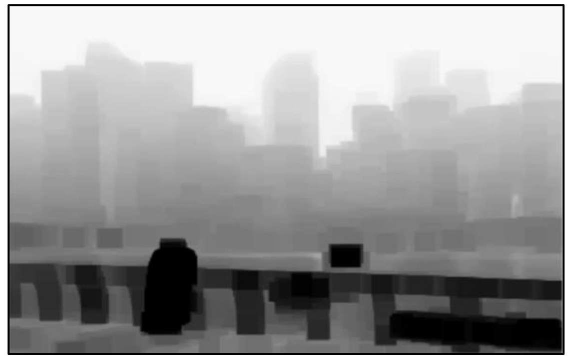
Below is the algorithm for the approach mentioned above that I am going to follow to implement the haze removal technique along with refinement:



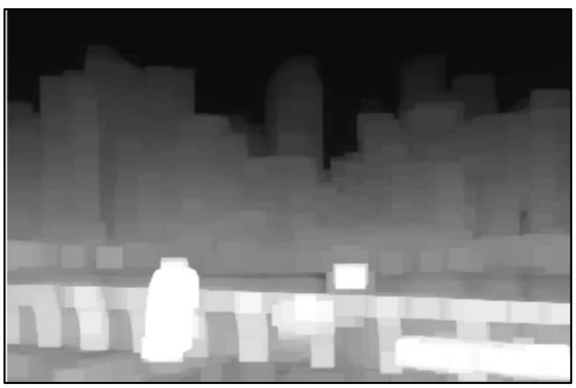
Experimental Results and Discussion–

I have made use of 16 images (RGB + Grayscale) of varying sizes. Most of these images I have collected from Flickr.com so that I get a gamut of images.

We first see the haze free image we have recovered without doing any refinement below:



(a) (b)



(c) (d)

Fig. 1. Haze removal without refining. (a) Input hazy image. (b) Dark Channel of the image. (c) Estimated Transmission before refinement. (d) Recovered image using (c).

In the results above, we see that the recovered images are haze free. But, the image has halo and block artifacts. This happens because of the transmission estimated by this method. Here, while estimating the transmission, we assume that the transmission within a particular patch is constant. Therefore, we need to refine the transmission to get rid of the artifacts.

There are two methods that can be utilized for refining the transmission –

- Soft Matting [1]
- Guided Image Filtering [2]

I have tried to refine the transmission in this project using the Guided Image Filtering technique. Here, I have set Epsilon = 10^(-3) and the window size = 5*patch_size.

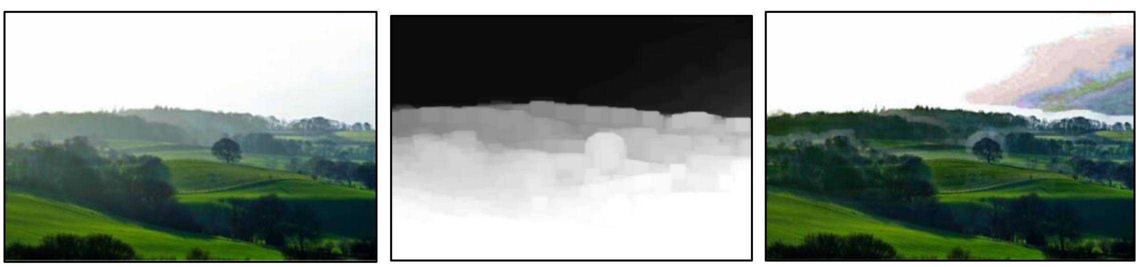
The Refined Transmission Estimate and Refined Haze free image for the same are as below –

(a) (b)

Fig. 2. Haze removal after refining. (a) Refined Transmission Estimate after Guided Image Filtering. (d) Refined image using (b).

In the results above, we see that the haze has been effectively removed with no presence of artifacts. We also see that the Refined Transmission Estimate in Fig. 2(a) is smoother than the Transmission Estimate in Fig. 1(c). There are no blobs in Fig 2(a).

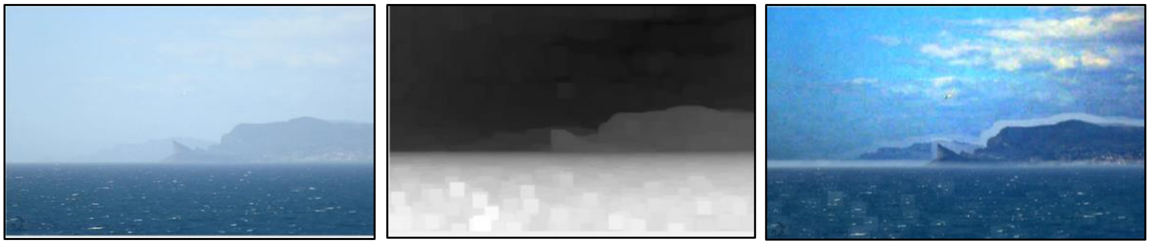
We now see the results of haze removal on a few more images before and after refining.



(a) (b) (c)

(d) (e)

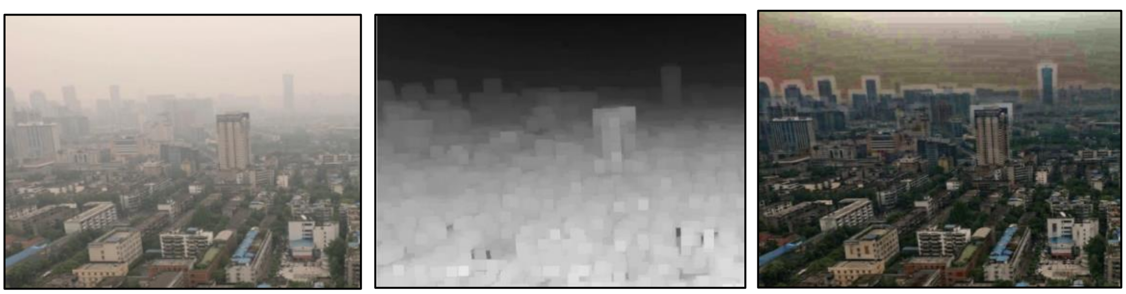
Fig. 3. Haze removal. (a) Input hazy image. (b) Estimated Transmission before refinement. (c) Recovered images using (b). (d) Refined Transmission Estimate after Guided Image Filtering. (e)Refined image using (d).



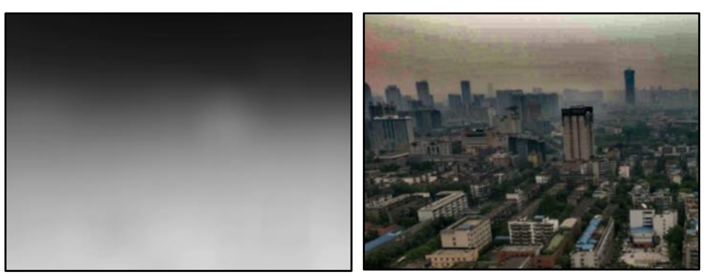
(a) (b) (c)

(d) (e)

Fig. 4. Haze removal. (a) Input hazy image. (b) Estimated Transmission before refinement. (c) Recovered images using (b). (d) Refined Transmission Estimate after Guided Image Filtering. (e)Refined image using (d).



(a) (b) (c)



(d) (e)

Fig. 5. Haze removal. (a) Input hazy image. (b) Estimated Transmission before refinement. (c) Recovered images using (b). (d) Refined Transmission Estimate after Guided Image Filtering. (e)Refined image using (d).

Also, this technique can be implemented on grayscale image. Below are the results I have received on two grayscale images.


(a) (b)

(c)

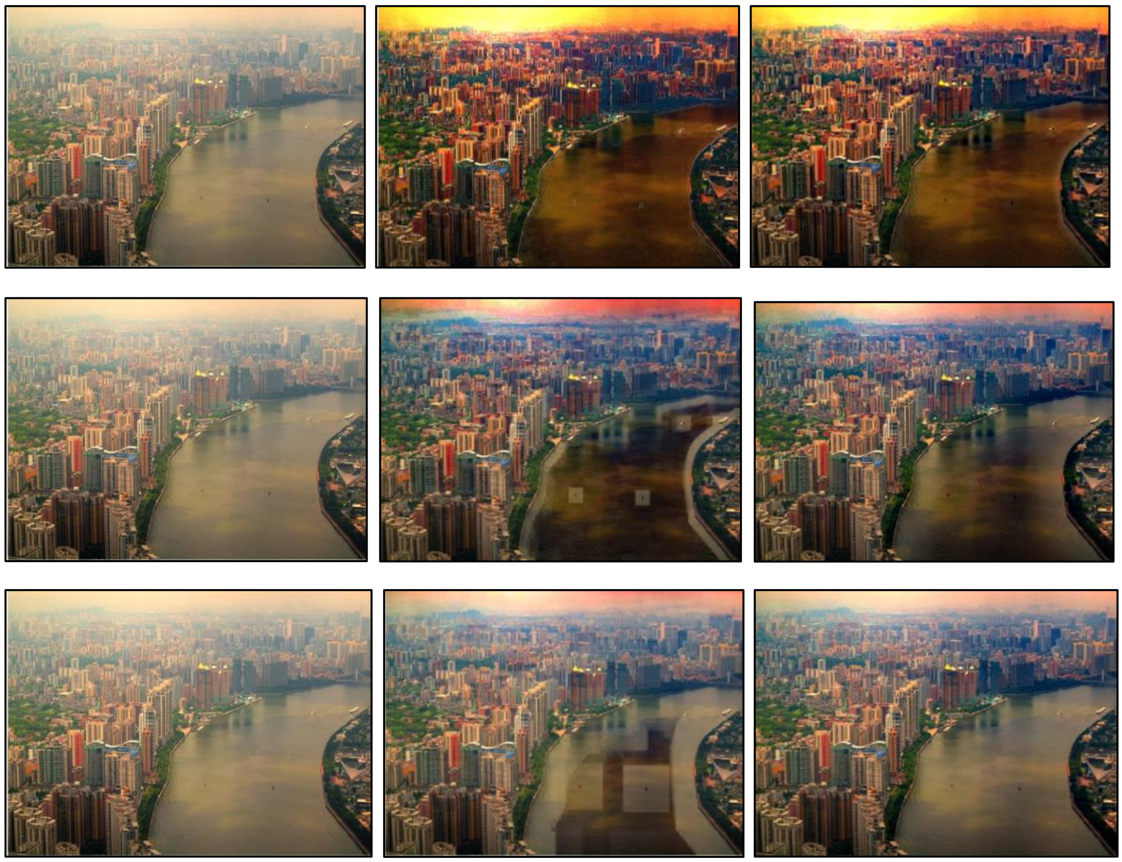
Fig. 6. Haze removal in Grayscale image. (a) Input hazy image. (b) Recovered images without refining. (c)Refined image using Guided Image Filtering.


(a) (b)

(c)

Fig. 7. Haze removal in Grayscale image. (a) Input hazy image. (b) Recovered images without refining. (c)Refined image using Guided Image Filtering

We now see the difference in result with respect to variation in patch sizes. We examine the results with patch sizes of 3x3, 15x15 and 51x51.



(a) (b) (c)

Fig. 8. Recovering images using different patch sizes. (a) Input hazy images. (b) Before Refining. (c) After Refining.

We can see using patch size of 3x3 gave us results which are highly oversaturated. As the patch size increase, the saturation of colors reduces. But we can see blobs and halo artifacts beginning to appear in the unrefined images (Refer to the second and third row of column b in Fig. 7). This happens because the transmission estimate now becomes constant over a larger patch. However, the results of the haze free images after refining with large patch sizes is considerably better. There are no artifacts and the saturation get lesser as the patch size increases.

Scope for improvement –

- There could be more work done to decrease the computation time required for haze removal of large size images or when we need to use a larger patch size for dark channel or a larger window size for the guided image filter.
- Also, this technique could be improved further to give better results when the image includes white objects like snow as in the below case.

(a) (b)

Fig. 9. Recovering images having white objects. (a) Input hazy images. (b) Refined Haze Removal.

References –

[1] HE ET AL.: SINGLE IMAGE HAZE REMOVAL USING DARK CHANNEL PRIOR, IEEE TRANSACTIONS ON PATTERN ANALYSIS AND MACHINE INTELLIGENCE, VOL. 33, NO. 12, DECEMBER 2011

[2] HE ET AL.: GUIDED IMAGE FILTERING, IEEE TRANSACTIONS ON PATTERN ANALYSIS AND MACHINE INTELLIGENCE, VOL. 35, NO. X, XXXXXXX 2013