Single Image Dehazing

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Abstract—Outdoor images are affected by atmospheric visibility reduction, particularly haze. The hazing effect is influenced by several factors including location, weather, pollution level and other geographic and environmental parameters. Visibility degradation depends on the distance between the camera and the scene points. Literature shares various algorithms to dehaze outdoor images. As part of the image processing project, our group will apply an algorithm performing a dehazing process requiring one single input developed by scientists from Hebrew University of Jerusalem [1] [2]. By delimiting and exploiting local patches from this single input, the global airlight vector - the atmospheric colour - and the transmission gradient - the hazing reduction coefficient - are extracted. Through this report, we will describe the three steps of the algorithm, validate the dehazing process by showing the after-process results and compare it with the original pictures.

I. Introduction

Haze, visibility reduction phenomenon, is coming from the presence in the atmosphere of particles scattering the ambient light, attenuating the contrast for outdoor images and corrupting the true radiance of the scenery by a ambient colour. Most dehazing algorithms are performed based on the RGB representation of the images. The haze effect is commonly modelled by the following equation [1]:

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

where $\mathbf{x}$ is the pixel position, $\mathbf{I}$ is the pixel colour under hazing condition or in other words, the image input, $\mathbf{A}$ is the ambient light colour, $\mathbf{J}$ the true pixel radiance, t is the transmission coefficient ranging from 0 (airlight colour) to 1 (true colour), which is distance-dependent. It is defined by [2] as:

$$t(\mathbf{x}) = e^{-\beta d(\mathbf{x})} \qquad (2)$$

where β is the wave phase number and $d(\mathbf{x})$ the scene pixel distance from the camera. From equation (2), one can observe $t(\mathbf{x})$ is dependent on the wavelength and is thus different for each colour component. Nevertheless, the used algorithm assume a constant matting gradient $t(\mathbf{x})$ for each colour channel. The contrast attenuation and the ambient colour corruption can be highlighted by breaking the equation (1) in two distinct parts:

- $t(\mathbf{x})\mathbf{J}(\mathbf{x})$, the true radiance component,
- $(1 - t(\mathbf{x}))\mathbf{A}$, the ambient light effect.

$\mathbf{I}(\mathbf{x})$ being the input image, the dehazing process is reduced to find the transmission and the global airlight parameters to recompose the true radiance scenery. This process can be decomposed in three steps : determining the airlight vector direction, finding its magnitude and finally computing the transmission coefficient.

II. Airlight vector determination

Even if the algorithm is indeed based on the equation (1), it uses a reformulation of it [1]:

$$\mathbf{I}(\mathbf{x}) = l(\mathbf{x})\mathbf{R}_i + c_i\mathbf{A} \qquad (3)$$

Where $l(\mathbf{x})$ expresses the shading coefficient related to the angle between the normal direction of the scene surface and the 3D line from the camera to this specific surface, R_i is the true radiance and c_i, the ambient light coefficient $(1 - t(\mathbf{x}))$. The airlight determination method described in [1] is a local patch-based algorithm meaning the image is decomposed on patches on which information is gleaned after image treatment. The patches should obey to specific conditions : it should be composed of pixels with same true radiance and with constant transmission coefficient. The motivation behind this decomposition lies in the retrieval of the airlight vector. By finding patches composed of pixels fulfilling the previous constraints, we can construct the line $\mathbf{I}(\mathbf{x}) = l(\mathbf{x})\mathbf{R}_i + \mathbf{C}$ with $\mathbf{C}$ a constant equals to $c_i\mathbf{A}$. The funding idea is that the constructed line will intersect the airlight vector in the RGB frame. Reconstructing lines from multiples patches will lead to the determination of the airlight vector which ultimately will result to the dehazing of the image.

The importance of the airlight determination has been introduced in the introduction and we will now move to its computation. the first part will be focused on the determination of the orientation of the airlight vector. It can be split in 6 steps:

  i *Patch decomposition* As mentioned previously, the airlight vector can be calculated through local patches processing. Thus the initial step is to generate these local patches from the image. The size of those patches is set to 10×10 pixels, which leads to optimal results for most cases [1]. Only patches with smooth variations should be kept avoiding rough colour distortion within a patch which affect the colour line based on the shading coefficient. Therefore, Canny algorithm is run upstream detecting patches with edges and getting rid of them for next steps.

  ii *Eigenvalue comparison* Once patches are validated, the colour line slope are calculated through the determination of the eigenvalues. Ensuring the slope is reflecting

the shading coefficient $l(x)$, first the main eigenvalue should be passing a threshold ensuring being high enough - $\lambda_1 > \tau_1$. Secondly, the ratio between the main eigenvalue and the sub ones should be higher than a threshold τ_1 - $\frac{\lambda_1}{\lambda_2} > \tau_2$.

iii *Distance to origin* Another criteria is the distance from the main eigenvector and the origin of RGB space. If the eignevector passes by the origin or close to the origin, it would mean that the pixels within the patches would be not affected by the global airlight and thus would contain no valuable information to reconstruct the airligth vector. The distance from the origin should therefore be higher than a threshold τ_3. The distance from the eingenvector to the origin can be computed through the cross product usage.

$$dist_{0,0} = \frac{||\vec{v_{eig}} \times \vec{\mu}||}{||\vec{v_{eig}}||} \tag{4}$$

where v_{eig} is the eigenvector and μ the centroid of the pixels withtin the local patch. Additional filtering should be done to ensure that all the valid pacthes eigenvector contains only non negative components being not representative of outdoor reflective light $l(x)R_i$.

iv *Eigenvector angles threshold* Ultimately, the crossing eigenvector of two filtered patches will lead to the airlight vector definition. To ensure no false crossing or error generation, the angle between two patch lines should be above $15 \deg$ [1].

v *Eigenvector intersection after projection* Intersection computation is done by first computing the plane defined from the patch line and the centroid to origin vector. Once the planes are defined for each patches, each pair of planes intersection are calculated and defines airlight vector candidates :

$$\vec{n_i} = \vec{v_{eig_i}} \times \vec{\mu_i} \tag{5}$$

$$\vec{\hat{A}}_{cand} = \frac{\vec{n_i} \times \vec{n_j}}{||\vec{n_i} \times \vec{n_j}||} \tag{6}$$

where n_i, n_j are normal vector from the centroid x patch line plane and $\hat{A}_{cand}$ the airlight vector.

vi *Minimal distance for $\hat{A}$ determination* Finally, the each potential airlight candidates are compared by computing the Eculidian distance between the candidate and the patch lines. The lowest median distance candidate is selected as the best fit vector. Mathematically, it gives the equation (7).

$$\vec{\hat{A}}_{vector} = argmin_j(median_i(d_{ij})) \tag{7}$$

where d_{ij} is the Euclidian distance between the j-th airlight candidate $\hat{A}_{cand}$ and the i-th patch line.

The threshold τ_1, τ_2, τ_3 are initiated to keep more than 10 patches and are afterwards refined by increasing step by step the thresholds until 10 patches remain. These patches will be used for the airlight candidates determination.

III. AIRLIGHT MAGNITUDE DETERMINATION

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V. VALIDATION

VI. CONCLUSION

REFERENCES

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