Single Image Haze Removal Using Dark Channel Prior

Kaiming He, Jian Sun, Xiaoou Tang, *CVPR 2009*.
Microsoft Research Asia, The Chinese University of Hong Kong.

Reported by 陆济川
2011.12.08

Outline

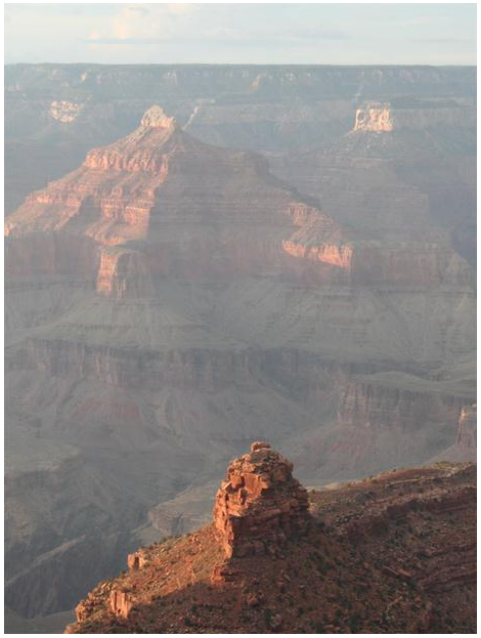
- Introduction
- Background
- Dark Channel Prior
- Haze Removal
- Results and conclusion
- Code and analyses

Introduction

- Purpose of dehazing
  - *Remove haze from a single input image*
- Function of dehazing
  - Increase the visibility of the scene and correct the color shift caused by the atmospheric light
  - Benefit computer vision algorithms
  - Produce depth information(De-focus)

Background

- Form of hazed image
  - $I(x) = J(x)t(x) + A(1 - t(x))$
  - observed intensity(I)=scene radiance(J)*t + global atmospheric light(A)*(1-t)



Background

- Related work
  - Tan's method [Visibility in bad weather from a single image CVPR 08]
    - able to greatly unveil details and structures from the haze image, but usually tend to have larger saturation values
    - contain halo effects near the depth discontinuities
  - Independent Component Analysis [Single image dehazing. Siggraph 08]
    - Any lack of variation or low SNR will make the statistics unreliable
    - invalid for gray scale images

Background

- Tan's
  - Before

After

Background

- Tan's
  - Before

After

Background

- Independent Component Analysis
  - Before
  - After

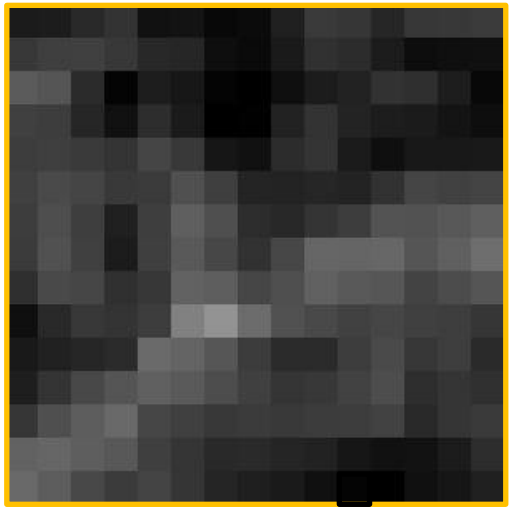
Background

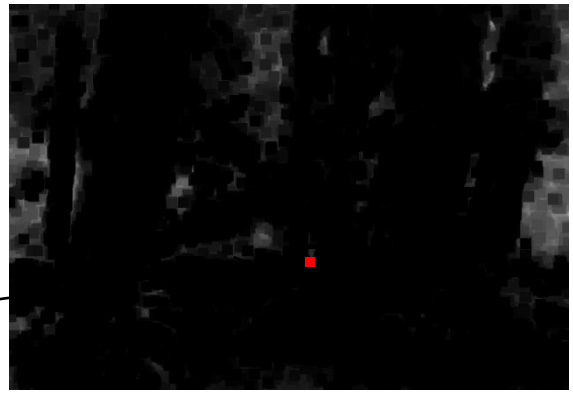
- Independent Component Analysis
  - Before

After

Dark Channel Prior

- $J^{dark}(x) = \min(\min(J^c(y)))$
- $c \in \{r, g, b\}$
- $y \in \Omega(x)$



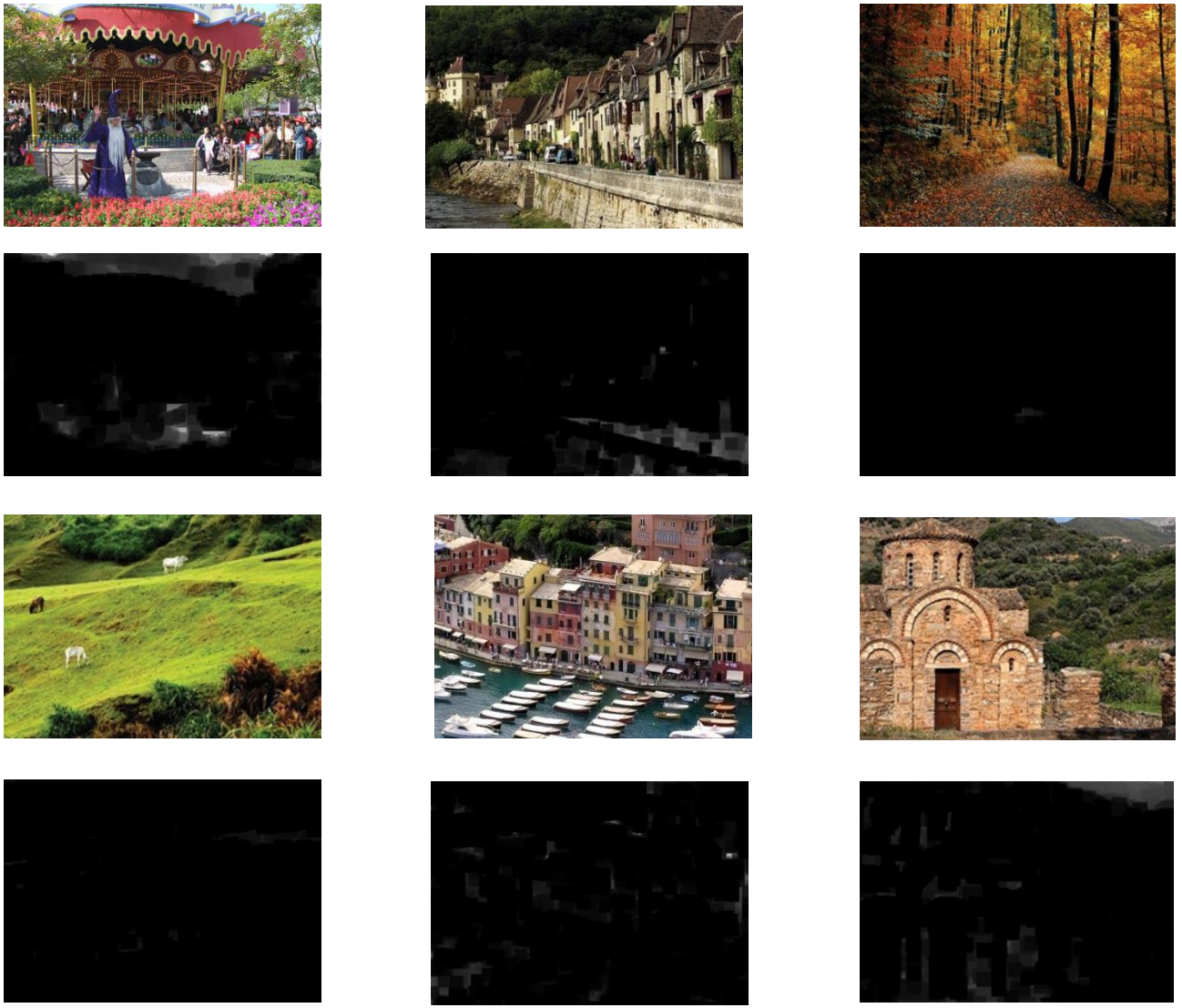


Dark Channel Prior

- Reasons for low intensities in the dark channel
  - Shadows
  - colorful objects or surfaces
  - dark objects or surfaces

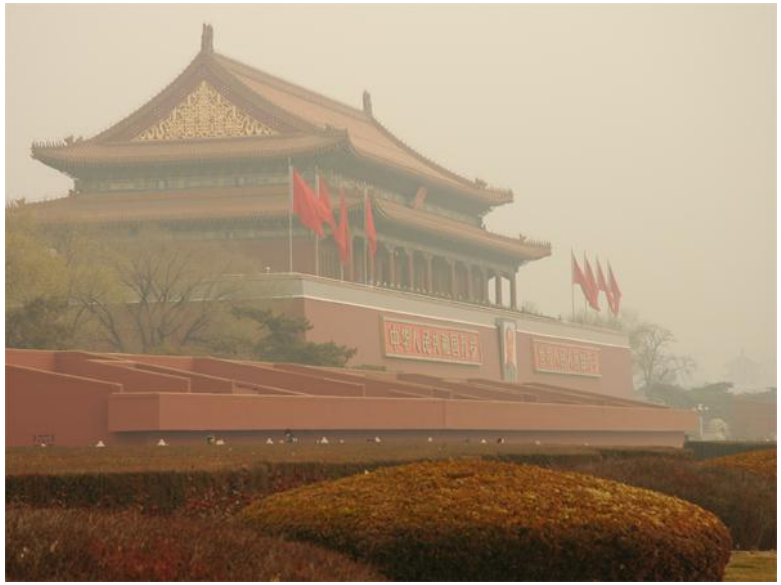
Dark Channel Prior

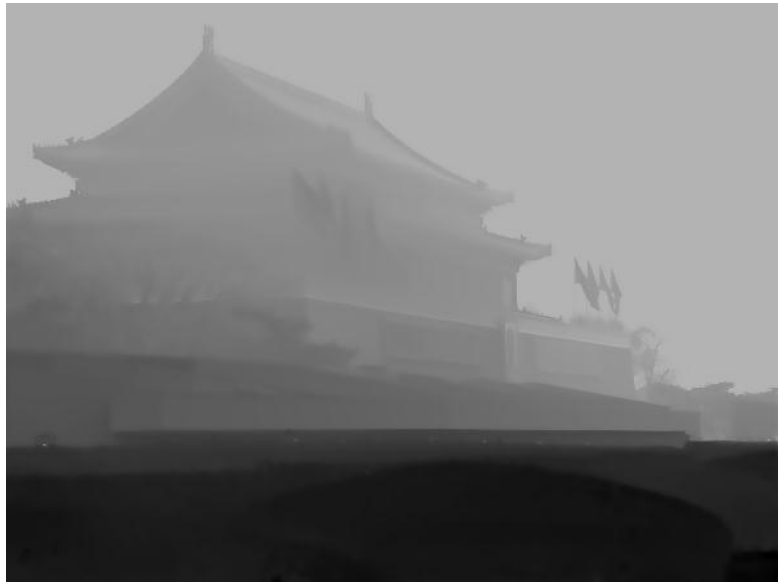
- haze-free images



Dark Channel Prior

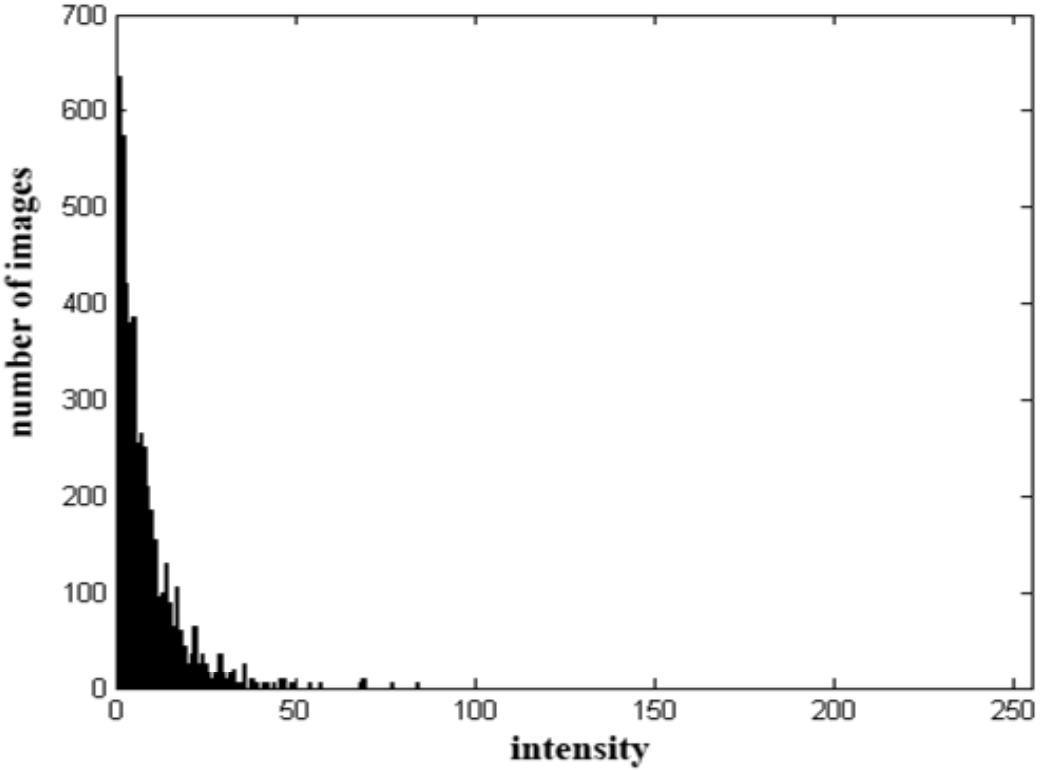
- haze image





Dark Channel Prior

- the average intensity of each dark channel (5000 samples)



Haze Removal

- Haze imaging model
  - $I = Jt + A(1 - t)$
- Normalize
  - $\frac{I}{A} = \frac{J}{A}t + (1 - t)$
- Calculate the dark channel
  - $\min(\min\left(\frac{I}{A}\right)) = \min\left(\min\left(\frac{J}{A}\right)\right)t + (1 - t)$

$\longrightarrow$ 0

Haze Removal

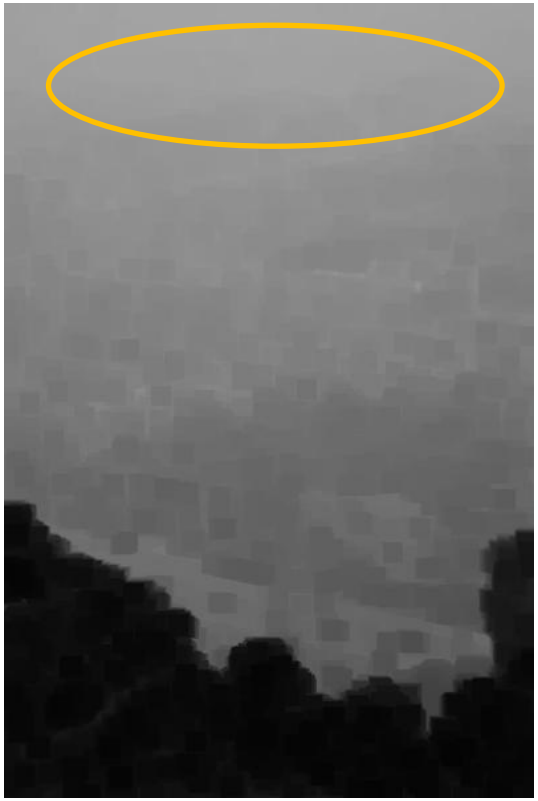
- Transmission
  - $\mathbf{t} = \mathbf{1} - \boldsymbol{min}(\boldsymbol{min}\left(\frac{\boldsymbol{I}}{\boldsymbol{A}}\right))$

Haze Removal

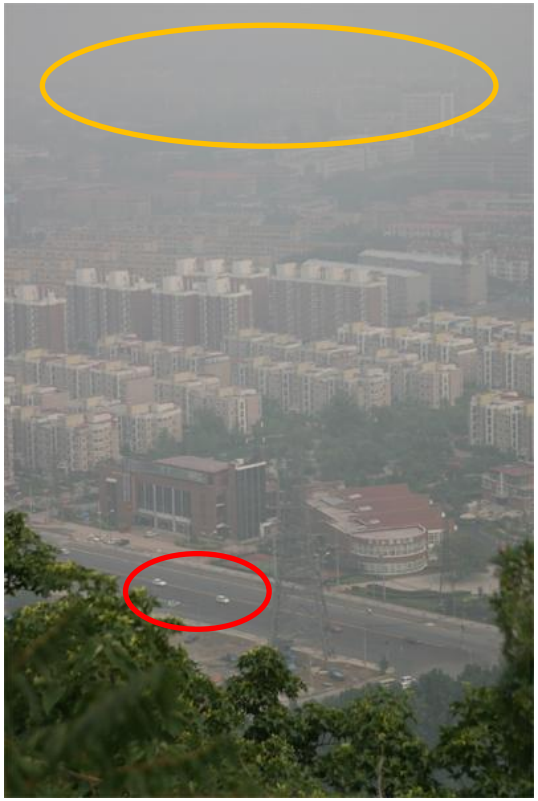
- Transmission Optimization
  - $E(t) = \lambda \parallel t - t' \parallel 2 + t^T L t$
  - $(L + \lambda U)t = \lambda t'$
  - [L - matting Laplacian]

Haze Removal

- Estimating the Atmospheric Light



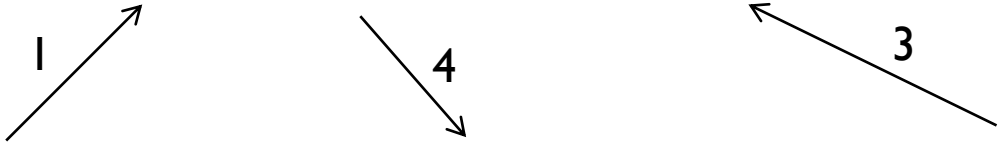
most haze-opaque pixel



Haze Removal

- Recovering the Scene Radiance

$$I = Jt + A(1 - t)$$



Results

- Original

Results

- CVPR 09

- My

Results

- Depth

Results

- Original

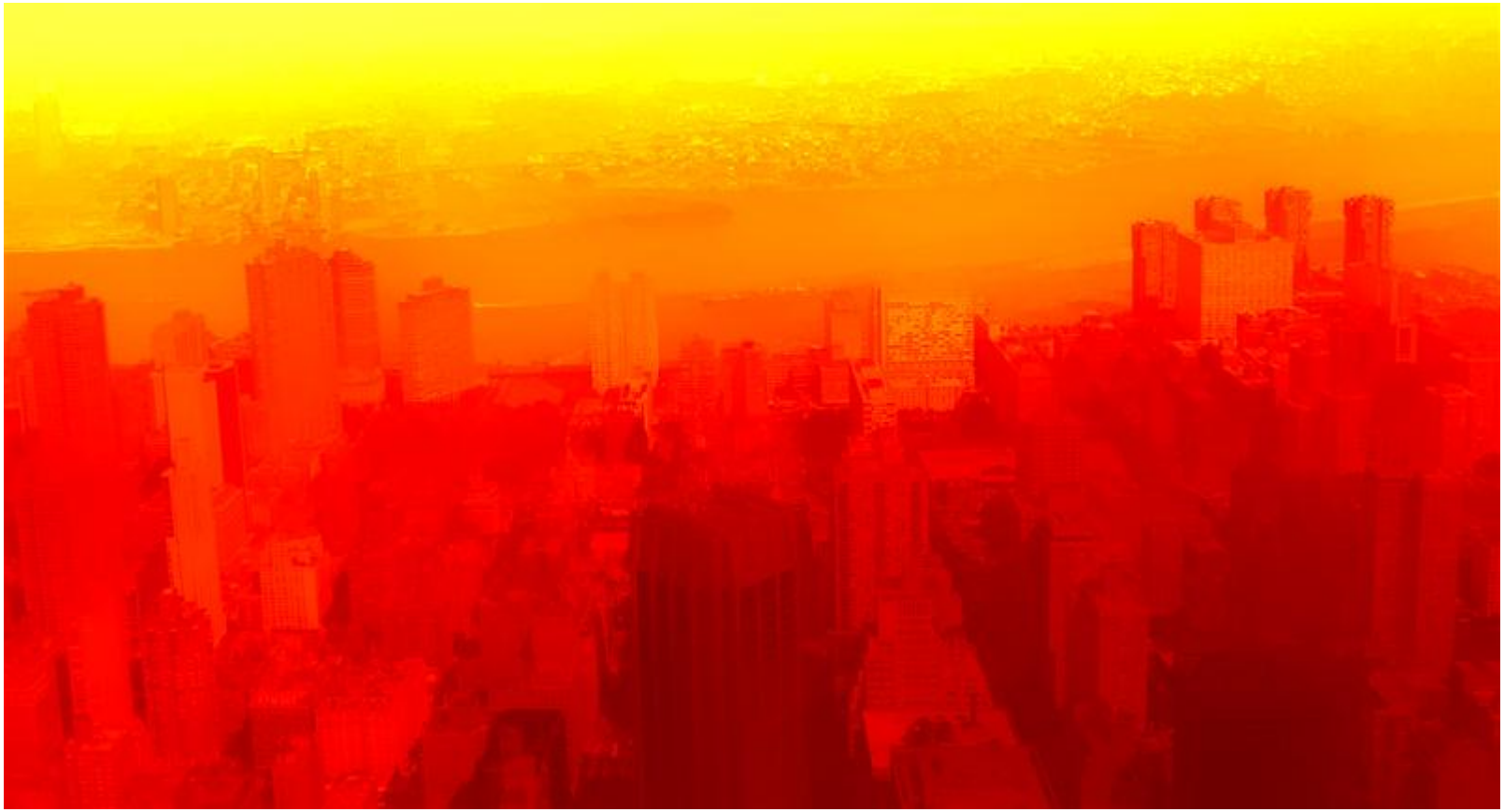
Results

- CVPR 09

- My

Results

- Depth



Results

- Original

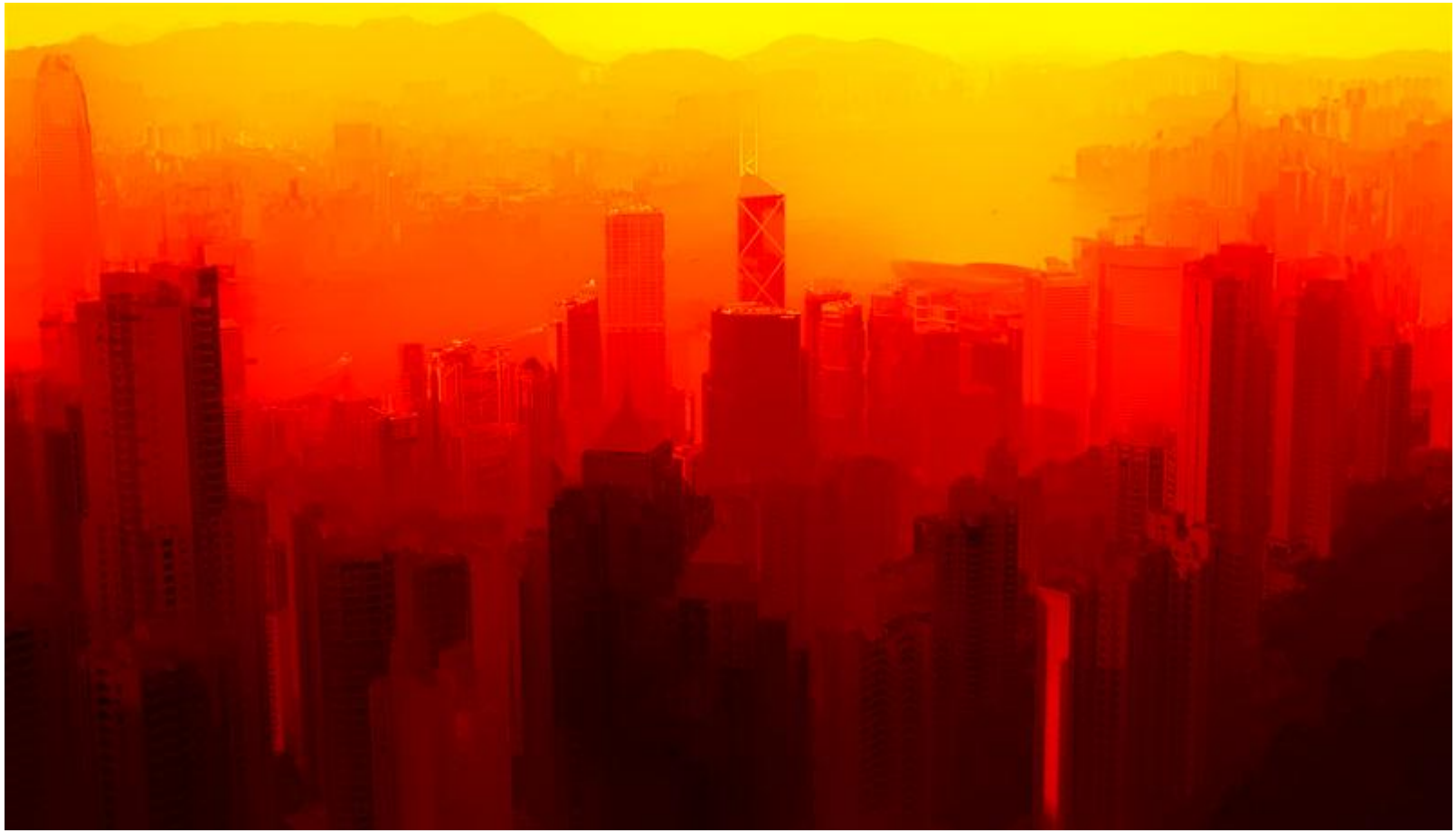
Results

- CVPR 09

- My

Results

- Depth



Results

- Original

Results

- CVPR 09

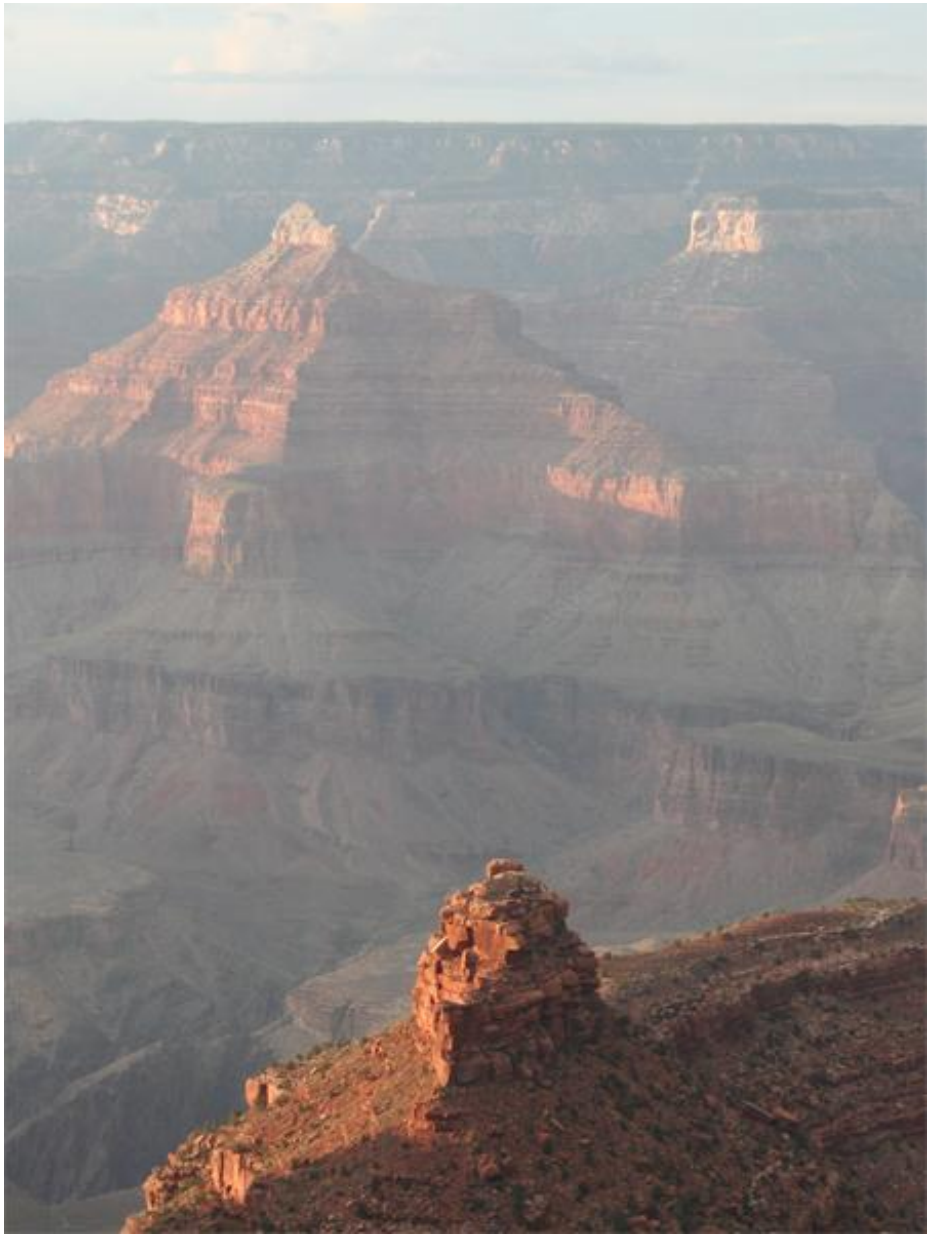
- My

Results

- Depth

Results

- Original



Results

- CVPR 09

My

Results

- Depth

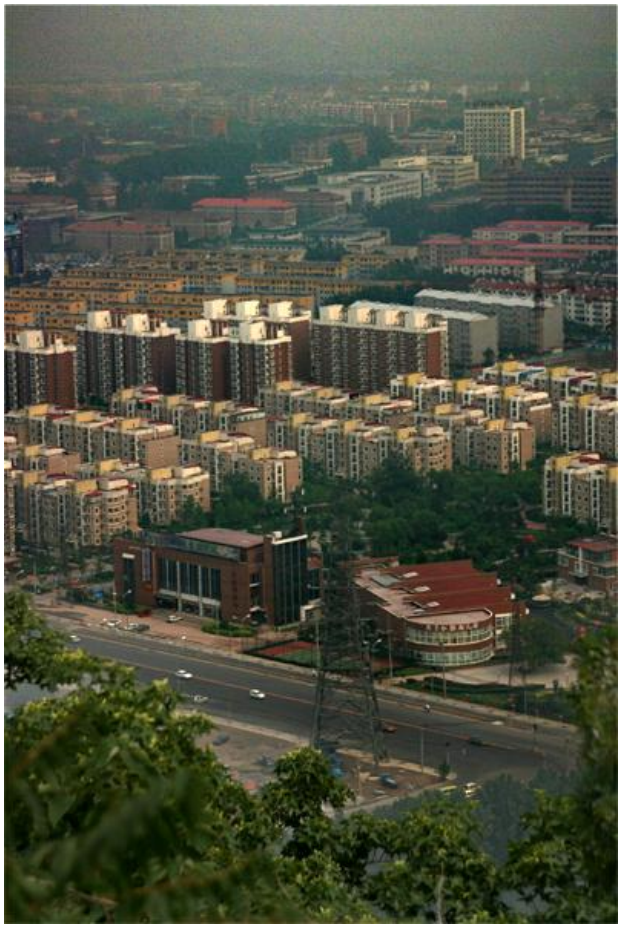
Results

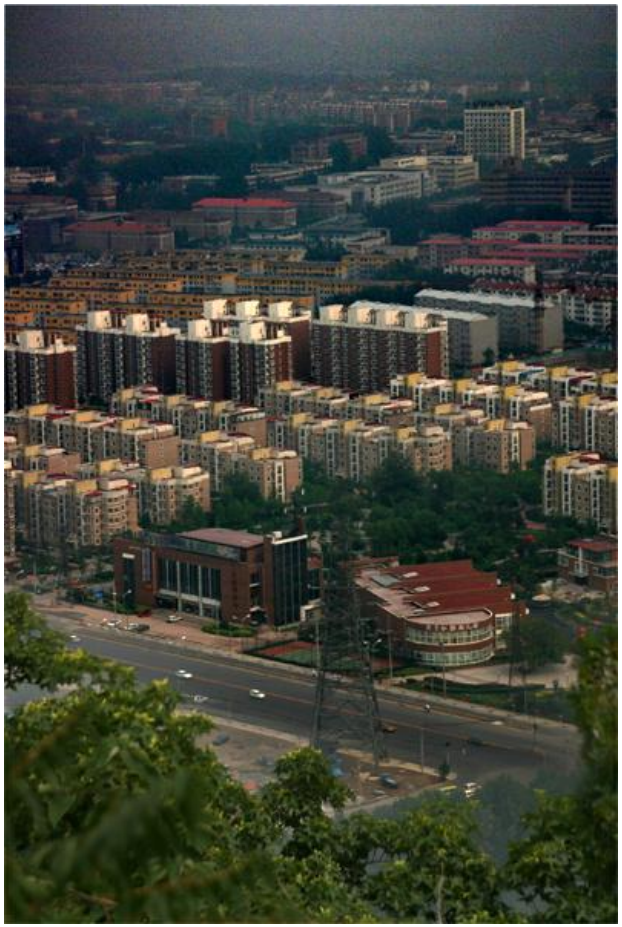
- Original

Results

- CVPR 09

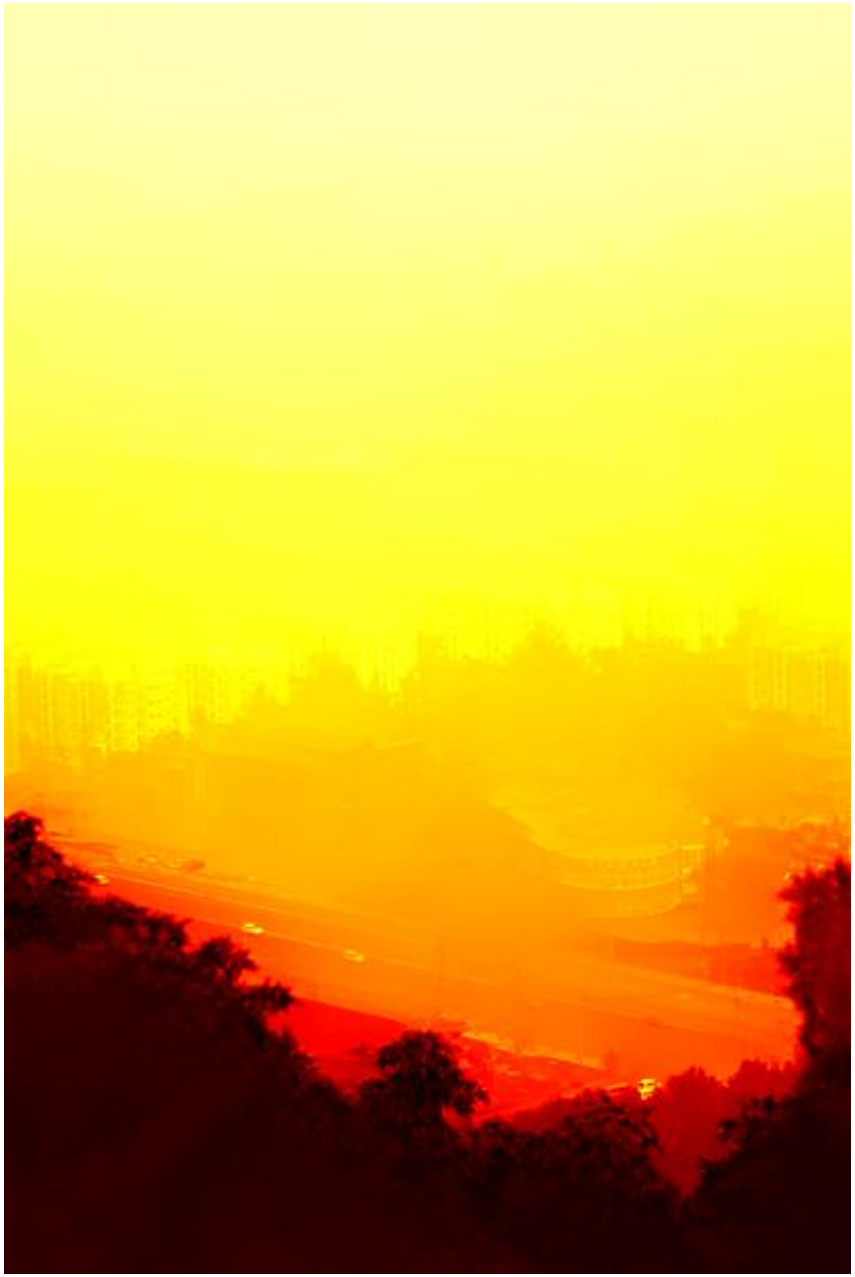
My





Results

- Depth



Results

- Original

Results

- CVPR 09

My

Results

- Depth

Results

- De-focus

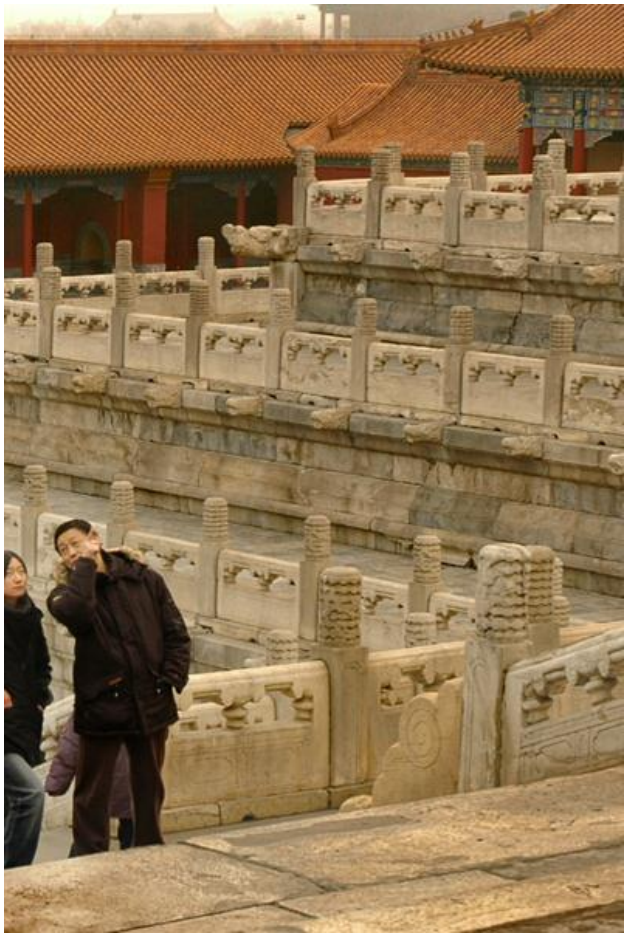
Results(failure)

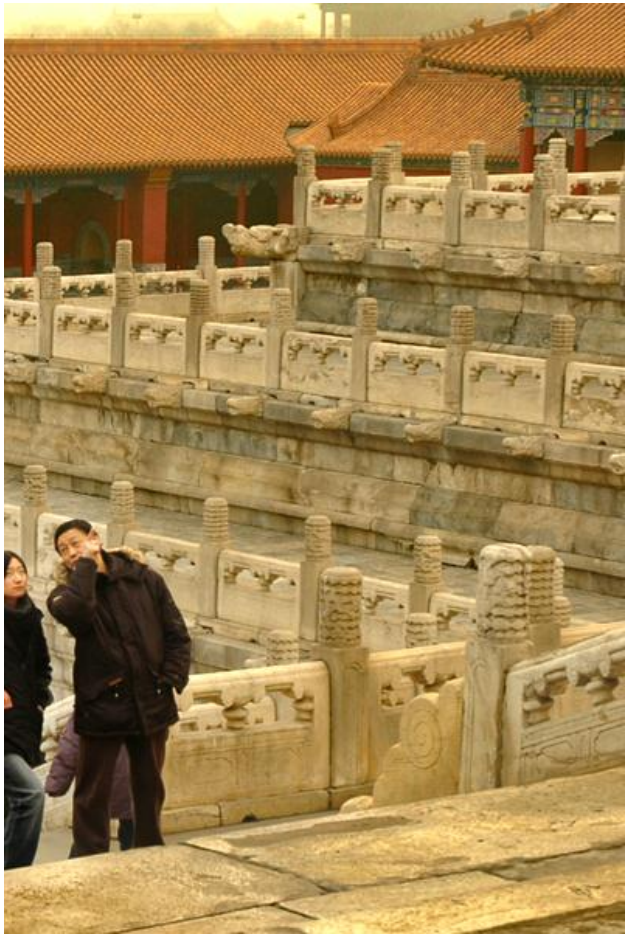
- Original

Results(failure)

- CVPR 09

My





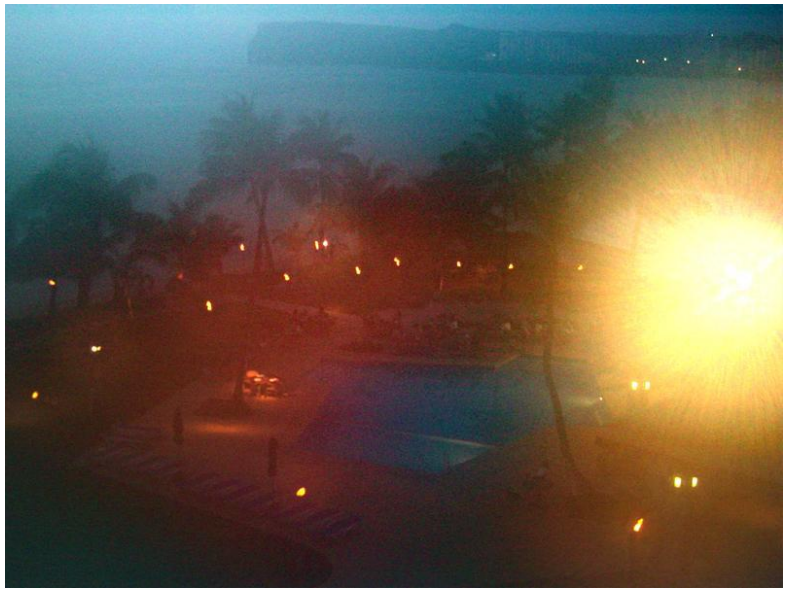
Results(failure)

- Depth

Results(failure)

- Original

CVPR 09



Conclusions

- Advantages:
  - simple but powerful
  - bad haze image can be put to good use
- Disadvantages:
  - Invalid when the scene objects are inherently similar to the atmospheric light and no shadow is cast on them
  - Invalid when non-constant A

Code

- Algorithm：
  - 1、initiate and read the image
  - 2、calculate the gray scale
  - 3、calculate the atmospheric light A
  - 4、calculate the dark channel using the gray scale and atmospheric light A
  - 5、get rough transmission using the dark channel
  - 6、Soft matting to get real transmission
    - Calculate the L matrix
    - Solve the linear equation using PCG
  - 7、get the dehazed image
  - 8、produce the depth image

Analyses

- Difficulty
  - Choosing atmospheric light A
  - Calculating the L matrix
  - Preconditioned Conjugate Gradient
- Difference between my results and He's
  - He's better in the sky part
  - My results are in low intensity
  - My program costs more time (70 seconds / image)

Thanks ~