
Single Image Haze Removal Using Dark Channel Prior

Team4

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Outline

- Motivation
- Problem Definition
- Introduction
- Algorithm
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- Reference

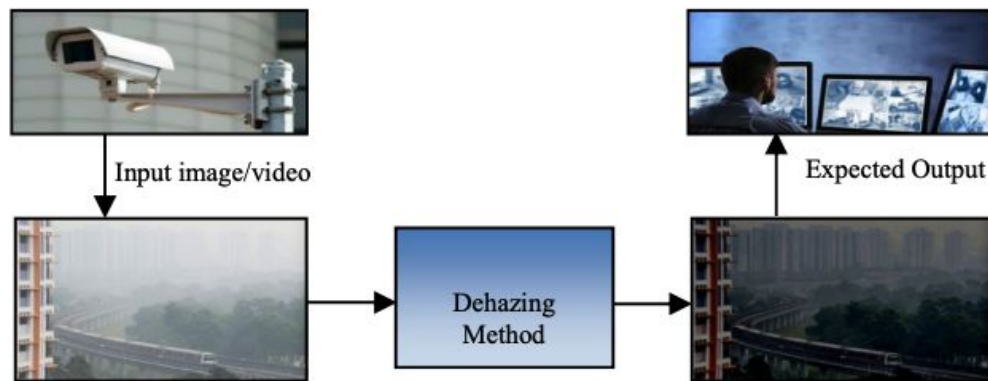
Motivation

When traveling in the mountains and forests, the photos often appear hazy and unclear. By using image dehazing, we can restore the pictures to their original clarity as much as possible.



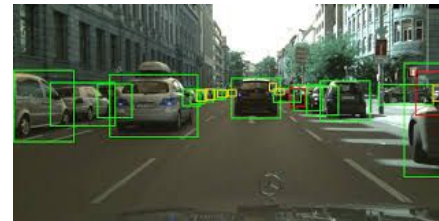
Problem Definition

Goal: Produce a visually pleasing and natural-looking haze-free image that enhances the details and colors of the scene while preserving its overall appearance.



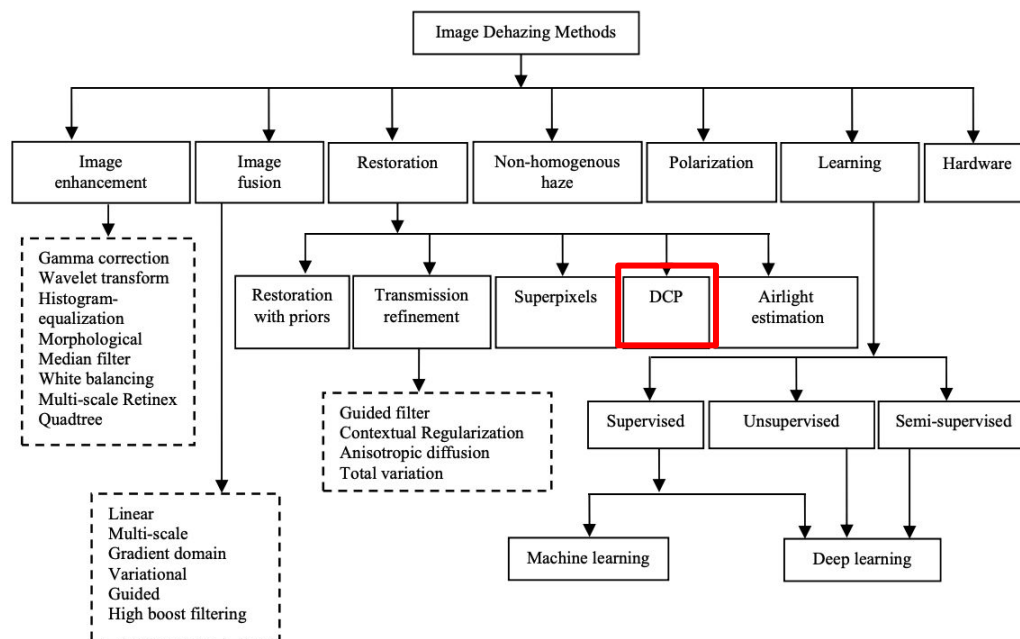
Application

- **surveillance**
 - object detection & recognition
 - identification of people or vehicles
- **aerial photography**
 - the clarity of the terrain
 - detect changes or anomalies in the landscape
- **computer vision**
 - image classification, segmentation, or tracking
 - improve the accuracy



Related Methods

Different categories of image dehazing methods [2]



Haze Imaging Equation

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

medium
transmission

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

observed intensity



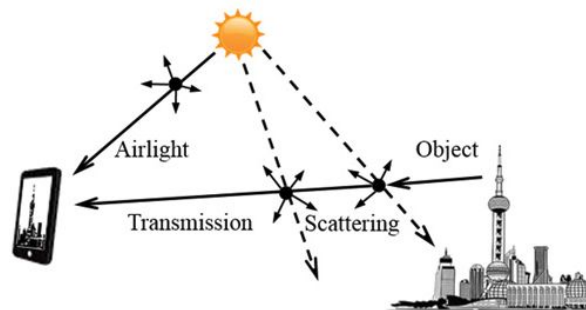
hazy

scene radiance



haze-free

atmospheric
light



Dark Channel Prior (DCP)^[1]

In outdoor haze-free images, pixels with low intensity in at least one RGB channel are commonly found in local regions not covering the sky.



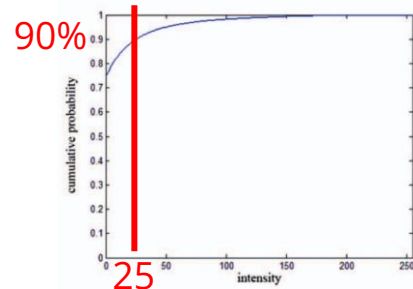
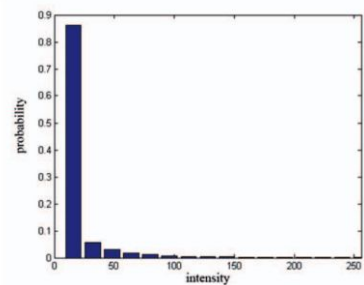
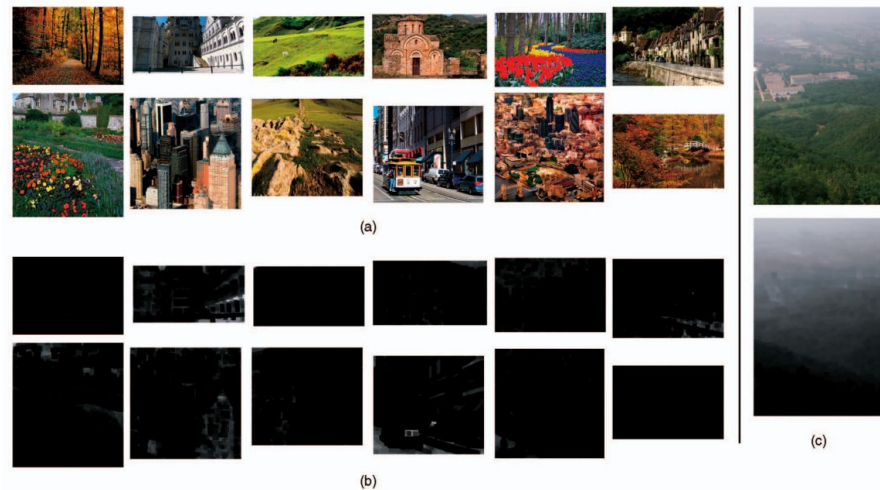
haze-free image

dark channel

Dark Channel Prior (DCP)_[1]

Mainly result from three factors:

- shadows
- colorful objects or surfaces
- dark objects or surfaces



Dark Channel Prior (DCP)_[1]

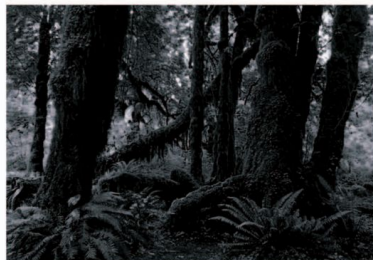
$$J^{\text{dark}}(\mathbf{x}) = \min_{\mathbf{y} \in \Omega(\mathbf{x})} \left(\min_{c \in \{r, g, b\}} J^c(\mathbf{y}) \right) \sim 0 \text{ if haze-free}$$



(a)

arbitrary image J

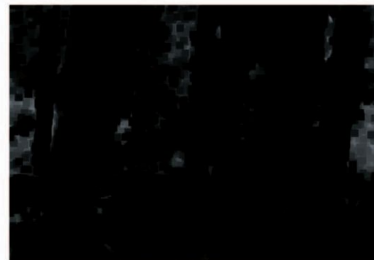
1



(b)

min of (r, g, b)

2

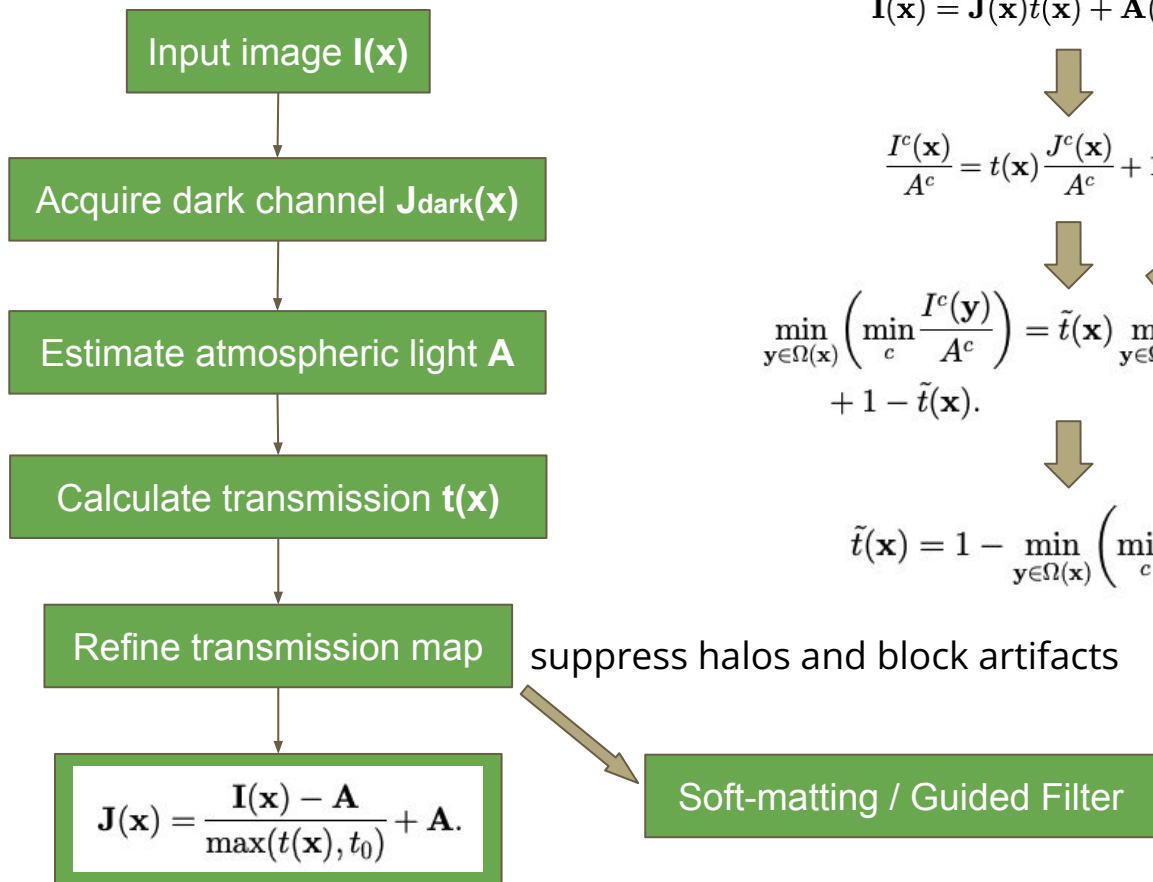


(c)

minimum filter (15x15)

3

Algorithm



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

$$\frac{I^c(\mathbf{x})}{A^c} = t(\mathbf{x}) \frac{J^c(\mathbf{x})}{A^c} + 1 - t(\mathbf{x}).$$

$$\min_{\mathbf{y} \in \Omega(\mathbf{x})} \left(\min_c \frac{I^c(\mathbf{y})}{A^c} \right) = \tilde{t}(\mathbf{x}) \min_{\mathbf{y} \in \Omega(\mathbf{x})} \left(\min_c \frac{J^c(\mathbf{y})}{A^c} \right) + 1 - \tilde{t}(\mathbf{x}).$$

0

$$\tilde{t}(\mathbf{x}) = 1 - \min_{\mathbf{y} \in \Omega(\mathbf{x})} \left(\min_c \frac{I^c(\mathbf{y})}{A^c} \right).$$

Refine Transmission Map

Soft-matting

- large sparse linear system
- time-consuming

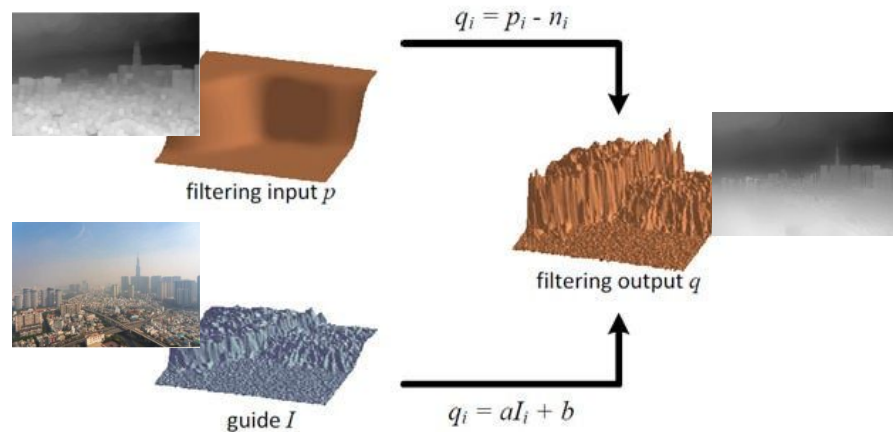
$$E(\mathbf{t}) = \mathbf{t}^T \mathbf{L} \mathbf{t} + \lambda (\mathbf{t} - \tilde{\mathbf{t}})^T (\mathbf{t} - \tilde{\mathbf{t}}).$$

$$\sum_{k|(i,j) \in w_k} \left(\delta_{ij} - \frac{1}{|w_k|} \left(1 + (\mathbf{I}_i - \mu_k)^T \left(\Sigma_k + \frac{\varepsilon}{|w_k|} \mathbf{U}_3 \right)^{-1} (\mathbf{I}_j - \mu_k) \right) \right),$$

(16)

Guided Filter

- spatial kernel (gaussian)
- guided range kernel
- much faster (box filter)



Expected Result - Qualitative

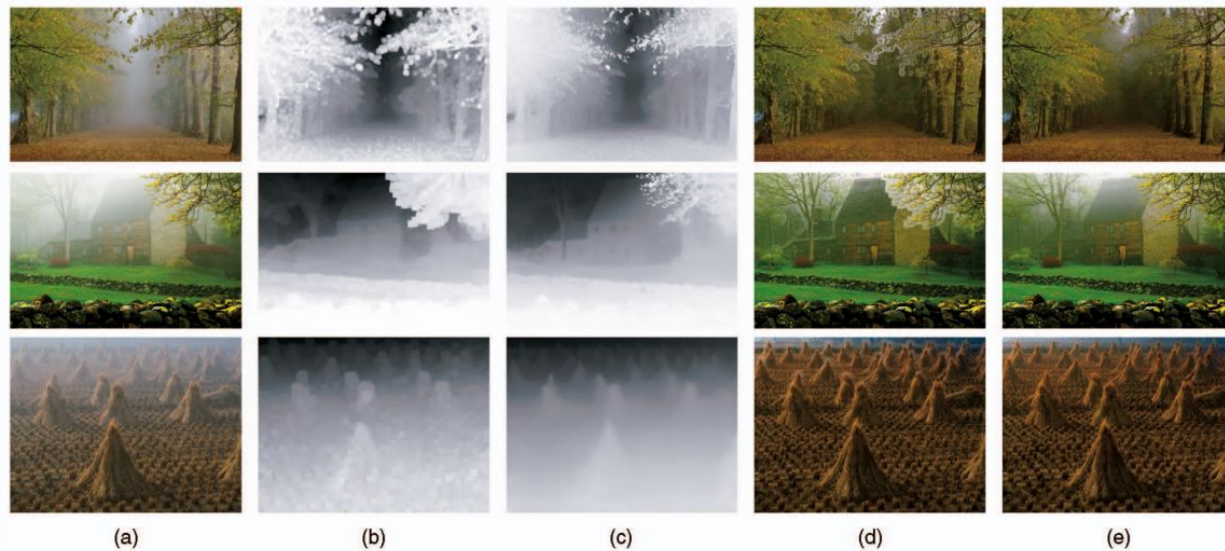


Fig. 6. Haze removal. (a) Input hazy images. (b) Estimated transmission maps before soft matting. (c) Refined transmission maps after soft matting. (d), (e) Recovered images using (b) and (c), respectively.

Expected Result - Quantitative

Peak Signal-to-Noise Ratio (PSNR)

$$PSNR = 10 \log_{10} \left(\frac{255^2}{MSE} \right)$$

Structural Similarity Index (SSIM)

$$SSIM(r, i) = \left(\frac{2\mu_r\mu_i + c_1}{\mu_r^2 + \mu_i^2 + c_1} \right) \left(\frac{2\sigma_r\sigma_i + c_2}{\sigma_r^2 + \sigma_i^2 + c_2} \right)$$



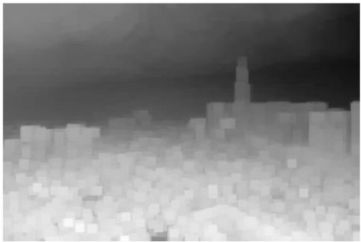



Table 17 PSNR and SSIM comparison of existing techniques on RESIDE dataset

Method	SOTS Outdoor		SOTS Indoor	
	PSNR	SSIM	PSNR	SSIM
DCP [63]	19.13	0.82	16.62	0.82



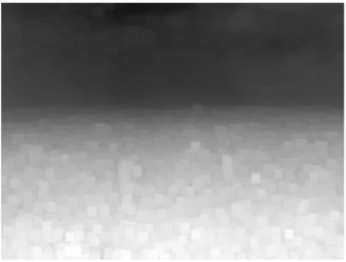



with ground-truth

Demo




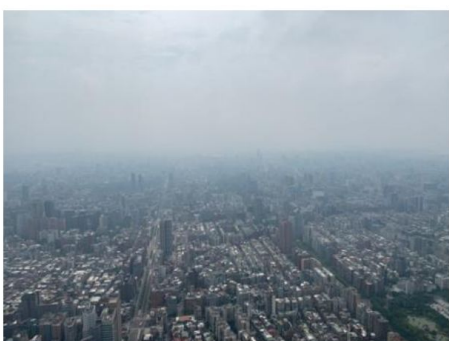
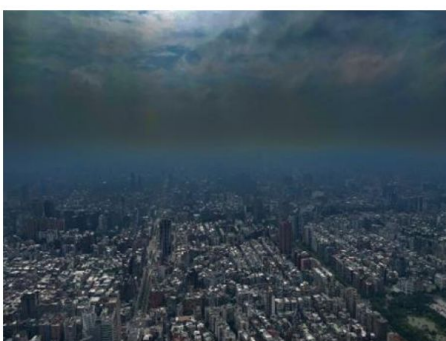
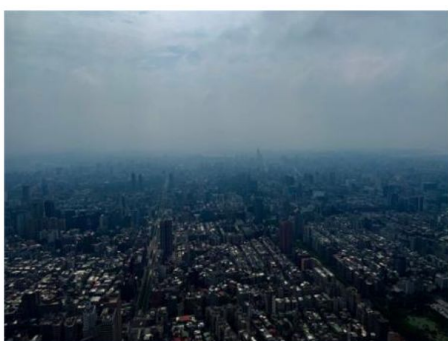
Result (DCP)

image	dark channel	transmission map	result
			
		refine 	result 



Result (DCP)

image	dark channel	transmission map	result
			
		refine	result
			


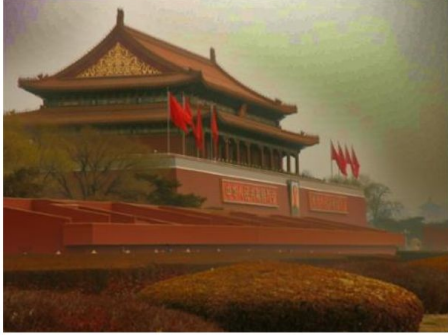




Scene - City

Original image	DCP	GIMP
 A wide-angle aerial photograph of a city skyline. The sky is a pale, hazy blue. In the center, a tall, slender skyscraper with a pointed top stands out among other high-rise buildings. A complex highway interchange with multiple overpasses is visible in the lower half of the frame. The city is densely packed with various types of buildings.	 The same cityscape as the original, but with a dramatic color grade. The sky is a deep, vibrant blue, transitioning to a bright yellow and orange glow near the horizon, suggesting a sunset or sunrise. The city lights and the skyscraper are more prominent against the darker sky.	 The same cityscape as the original, but with a more naturalistic color grade. The sky is a clear, bright blue. The city lights and the skyscraper are clearly visible, and the overall tone is more balanced and realistic compared to the original.
 The same cityscape as the original, but with a heavy, thick fog or smog overlay. The sky is a uniform, pale grey, and the city buildings are mostly obscured by the haze, with only the tops of the tallest structures visible.	 The same cityscape as the original, but with a heavy, dark, and dramatic fog overlay. The sky is a deep, dark blue-grey, and the city buildings are mostly obscured by the thick, dark haze, with only the tops of the tallest structures visible.	 The same cityscape as the original, but with a heavy, dark, and dramatic fog overlay. The sky is a deep, dark blue-grey, and the city buildings are mostly obscured by the thick, dark haze, with only the tops of the tallest structures visible.

Scene - Forests / Mountains

Original image	DCP	GIMP
		
		










Scene - Buildings

Original image	DCP	GIMP
		
		




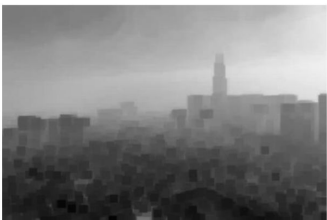





DCP Speed (s)

Image size	(408x612)	(800x1200)	(1500x2000)
1. preprocess	0.016	0.034	0.077
2. dcp	1.673	6.066	18.783
3. estimate A	0.011	0.042	0.157
4. estimate tmap	1.975	5.849	18.266
5. refine tmap (guided filter)	0.024	0.097	0.330
6. scene reconstruction	0.010	0.032	0.106
Total	3.709	12.121	37.719

DCP Window Size

w	dcp	refined tmap	dehazed image
5			
15			
25			

Guided Filter Window Size

w	dcp	refined tmap	dehazed image
5			
20			
60			

Future Work

- Apply DCP/GIMP on RESIDE dataset
 - image result
 - PSNR, SSIM
- Soft-matting vs. Guided filter (DONE)
 - speed & performance
- Pre/Post-processing for better result
 - contrast enhancement
 - color correction
 - noise reduction

Reference

- [1] He, Kaiming, Jian Sun, and Xiaoou Tang. "Single image haze removal using dark channel prior." *IEEE transactions on pattern analysis and machine intelligence* 33.12 (2010): 2341-2353.
- [2] Agrawal, Subhash Chand, and Anand Singh Jalal. "A comprehensive review on analysis and implementation of recent image dehazing methods." *Archives of Computational Methods in Engineering* 29.7 (2022): 4799-4850.

Todos

- DEMO 前
 - 傳統DCP
 - use guided filter (explain) DONE
 - 在不同階段的圖 (e.g. transmission map & refined map) DONE
 - 圖片結果
 - RESIDE dataset DONE , real image DONE
 - PSNR, SSIM
 - RESIDE dataset DONE
 - 不同場景比較 DONE
 - 速度分析 DONE
 - 不同參數速度、效果比較 DONE
 - NN-based
 - 用 pretrained model inference
 - 圖片結果
 - RESIDE dataset DONE, real image DONE
 - PSNR, SSIM
 - RESIDE dataset DONE
 - inference 速度 DONE
 - 不同場景比較 DONE
- DEMO 後 future work
 - RESIDE dataset DONE
 - 可能可以實作 soft-matting 看有多慢 DONE
 - 其他優化 (pre/post processing 讓圖片變更自然 Contrast Enhancement)