MAIA - MedicAl Imaging and Applications

Advanced Image Analysis

Lectures on Advanced Color Image Processing

B6 – Image Dehazing

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The Problem of Image Dehazing

HAZE ~ MIST, FOG, SMOG =
DEGRADATION DUE TO BAD WEATHER

The Problem of Image Dehazing

Particularity of haze degradation: it is **depth-dependent**.

A good dehazing method will increase more contrast in regions far-away from the observer, while increasing less contrast on nearby regions.

Hazy image

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Histogram Equalization

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Dehazed image

Key Ingredient

A physical model of the degradation: $$\mathrm{I}(x) = \mathrm{J}(x)\mathrm{t}(x) + \mathrm{A}(1 - \mathrm{t}(x))$$

H. Kochsmieder, Theorie der horizontalen Sichtweite: Kontrast und Sichtweite, 1925

- I(x) is the acquired pixel intensities – Input Image
- J(x) is the degraded intensities – Haze-Free Image
- t(x) is transmission – Inverse of 3D depth $$\mathrm{t}(x) = e^{-\beta d(x)}$$
- A is the airlight – Color of Fog

Physical Model - Intuition

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

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

J(x), the haze-free image, is what we want to retrieve. According to the model, it undergoes a **multiplicative** degradation depending on depth, and an **additive** degradation depending on depth and haze color.

As distance goes to 0, t(x) $\longrightarrow$ 1. Near the observer, haze has no effect and we have:

$$\lim_{t(x)\to 1} \mathrm{I(x)} = \mathrm{J(x)}$$

As distance increases, haze takes over the scene, and we have:

$$\lim_{t(x)\to 0} \mathrm{I(x)} = \mathrm{A}$$

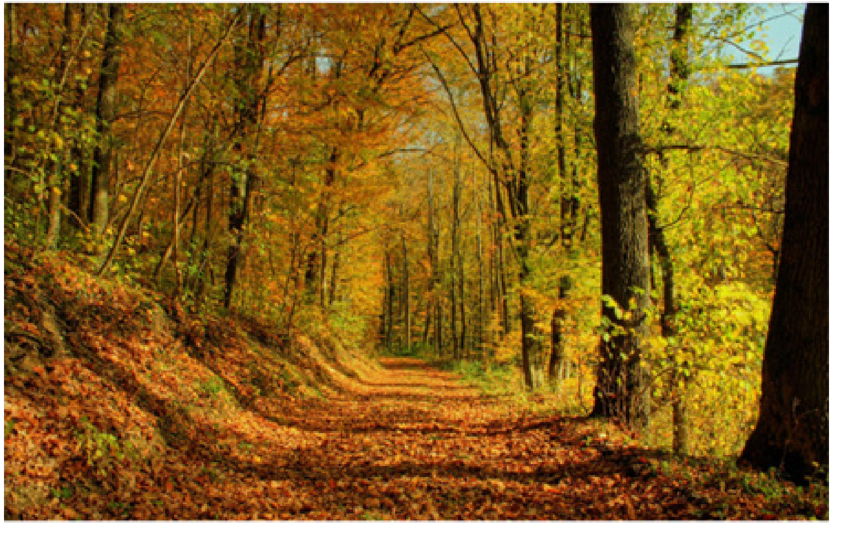
The Dark Channel Method

- Outdoor haze-free images contain shadows and colorful texture everywhere.
- Thus, locally at least some color channel will have low values.
- This is encoded in the so-called Dark Channel Prior:

$$\boxed{\mathrm{J}^{\text{dark}}(x) = \min_{y \in \Omega(x)} \left(\min_{c \in \{R,G,B\}} \mathrm{J}^{c}(y) \right)}$$

- For haze-free images,

$$\mathrm{J}^{\text{dark}}(x) \rightarrow 0$$



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$$\boxed{\mathrm{I}(x) = \mathrm{J}(x)\mathrm{t}(x) + \mathrm{A}\,(1 - \mathrm{t}(x))}$$

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

$$\boxed{\mathrm{J}^{\mathrm{dark}}(x) = \min_{y\in\Omega(x)}\left(\min_{c\in\{R,G,B\}} \mathrm{J}^c(y)\right) \sim 0}$$

Dark-Channel Prior

Taking minima on the model, the first term on the rhs vanishes, and we can estimate t(x) from the hazy input.

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

This assumes locally constant depth in the scene.
It results in block artifacts in the depth map.

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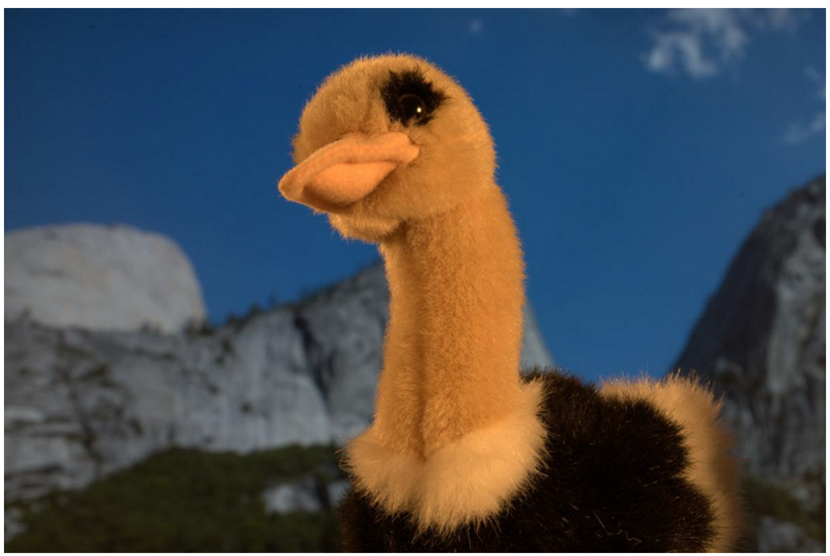
Depth Map Refinement



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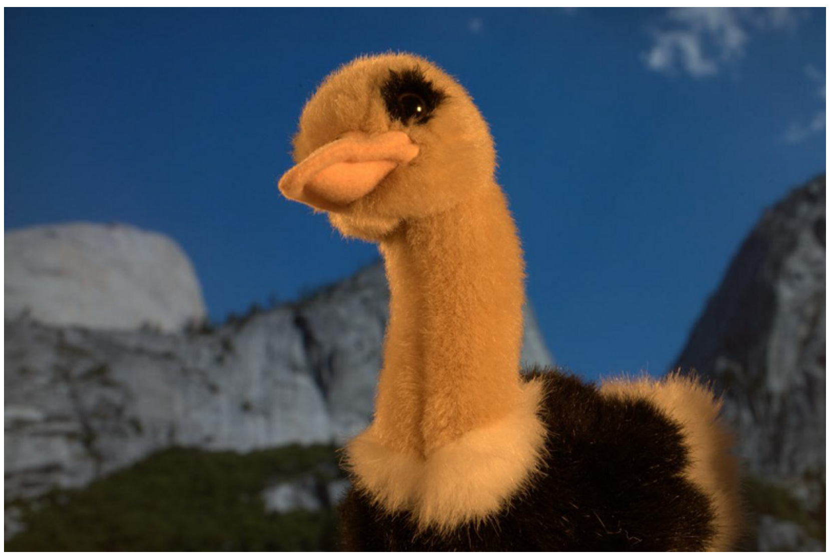

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Depth Map Refinement

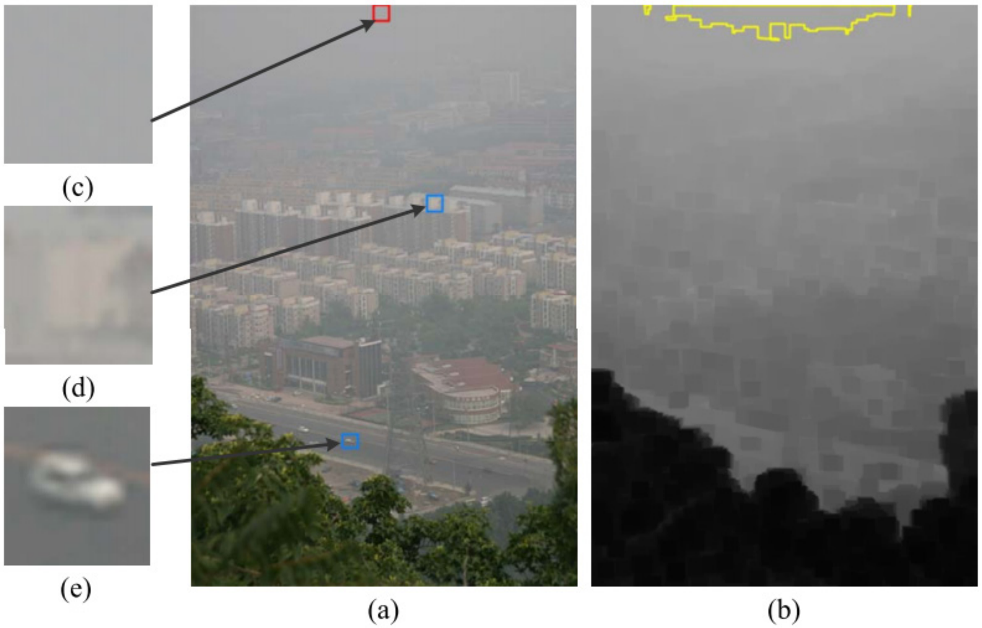
The Dark Channel Method - Model Inversion

$$\boxed{\mathrm{I}(x) = \mathrm{J}(x)\mathrm{t}(x) + \mathrm{A}\left(1 - \mathrm{t}(x)\right)} \longrightarrow \boxed{\mathrm{J}(\mathrm{x}) = \frac{(\mathrm{I}(\mathrm{x}) - \mathrm{A})\mathrm{t}(\mathrm{x}) + \mathrm{A}}{\max(\mathrm{t}(\mathrm{x}), 0.1)} + \mathrm{A}}$$

- After depth has been estimated, we simply invert the degradation model.
- But we have assumed all the time we knew A!

Airlight Estimation

- Once the dark channel image has been built, select from it the brightest pixels (1%).
- Those should correspond to the furthest pixels in the RGB image. Select the corresponding brightest RGB pixel as A.



The Dark Channel Method – Pseudo-code

1.- Compute: $\mathrm{J}^{\mathrm{dark}}(x) = \min\limits_{y\in\Omega(x)}\left(\min\limits_{c\in\{R,G,B\}} \mathrm{J}^c(y)\right)$

2.- Estimate A from I as the brightest pixel in the Dark Channel

3.- Compute transmission map: $\tilde{\mathrm{t}}(x) = 1 - \boxed{\min\limits_{y\in\Omega(x)}\left(\min\limits_{c}\left(\frac{\mathrm{I}^c(x)}{\mathrm{A}^c}\right)\right)}$

4.- Refine the transmission map (guided filtering).

5.- Invert the model: $\mathrm{J}(\mathrm{x}) = \frac{(\mathrm{I}(\mathrm{x}) - \mathrm{A})\mathrm{t}(\mathrm{x}) + \mathrm{A}}{\max(\mathrm{t}(\mathrm{x}), 0.1)} + \mathrm{A}$

The Dark Channel Method - Results

Hazy image

The Dark Channel Method - Results

Dehazed image

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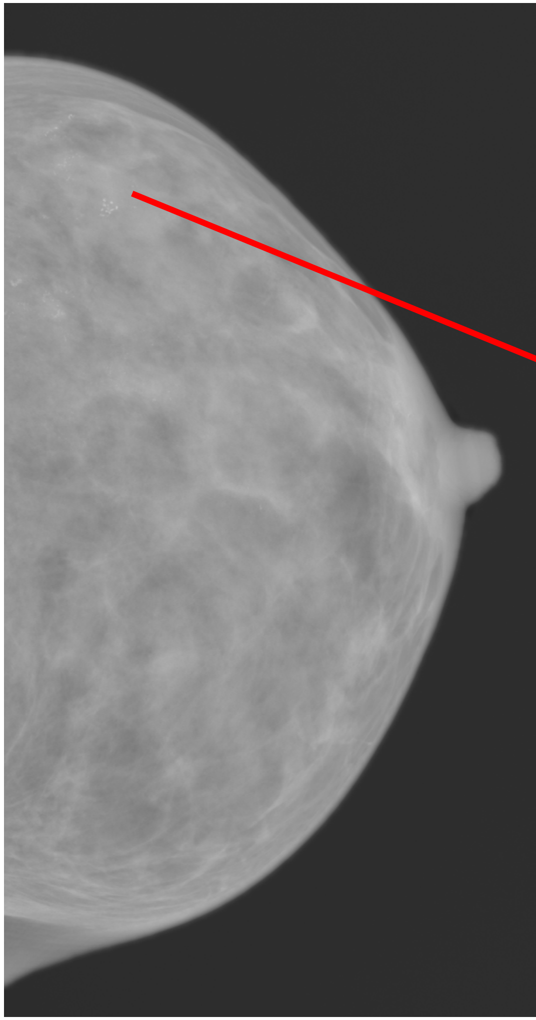
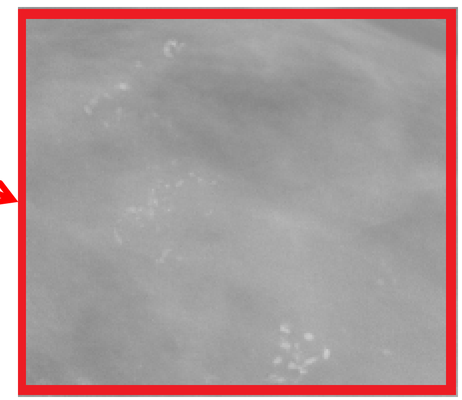
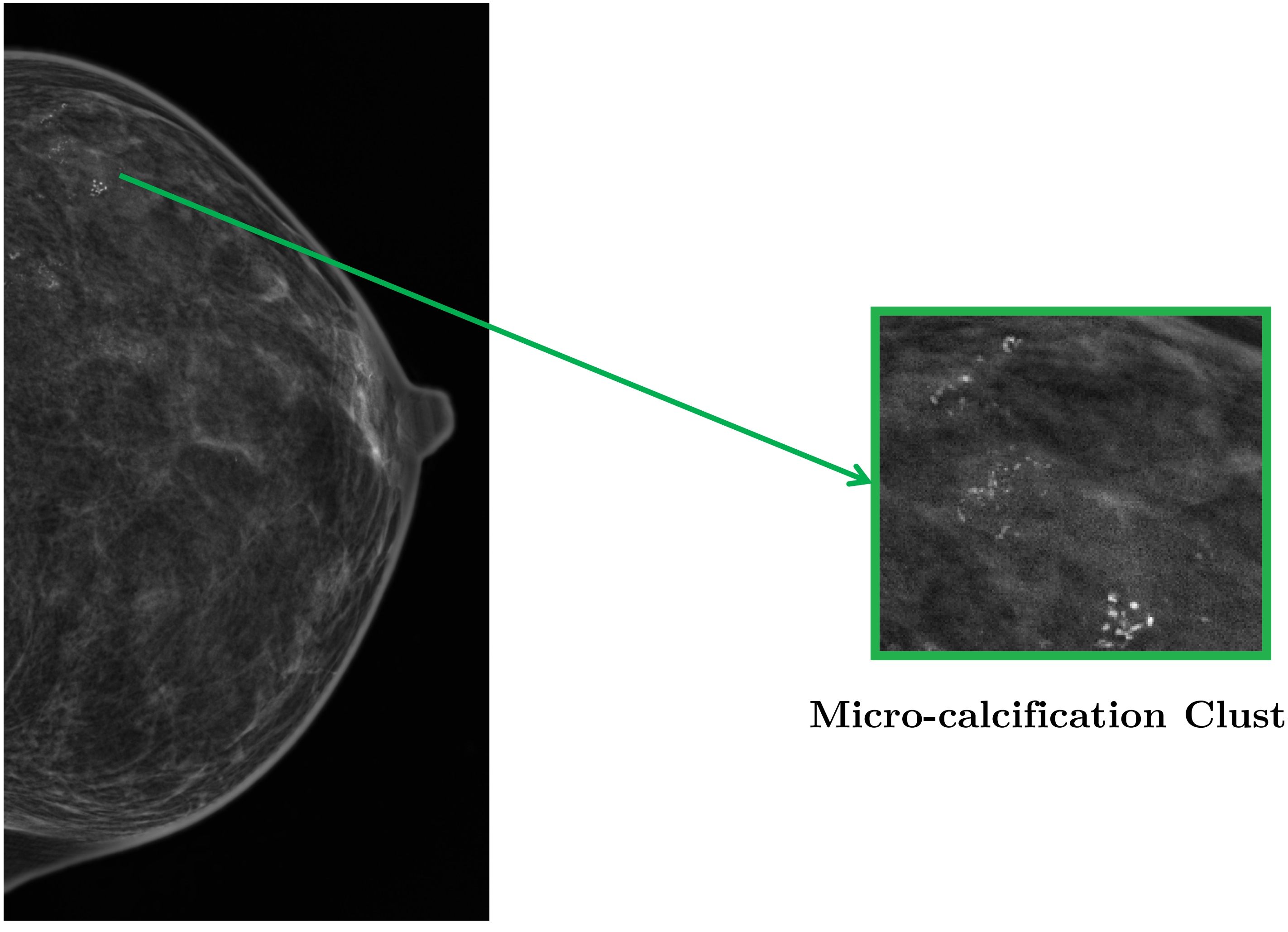


Digital Mammogram



Micro-calcification Cluster

The Dark Channel Method - Results



Micro-calcification Cluster

Digital Mammogram

Inverted Dark Channel

- Think of shadows as the inverse of fog.
- They drive intensities towards white instead of towads dark.

$$\text{Shadow Removal}(I(x,y)) \rightsquigarrow \mathbb{1} - \text{Dehazing}(\mathbb{1} - I(x,y))$$

Fog Map Estimate

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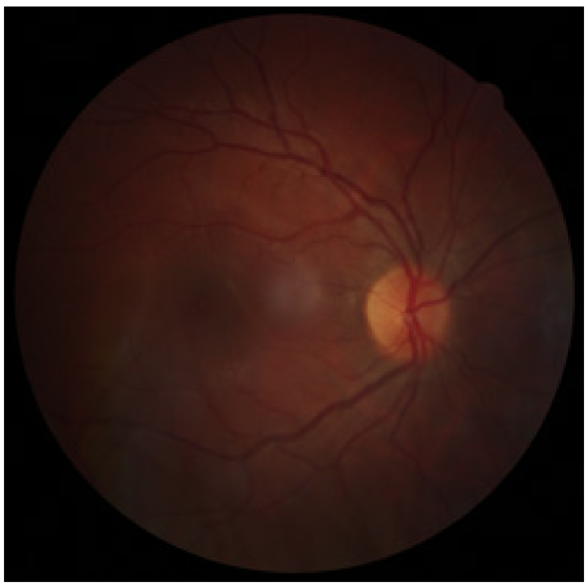
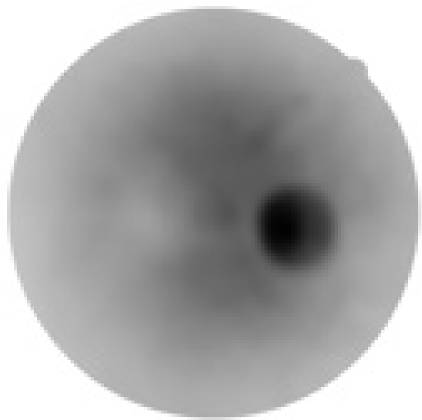
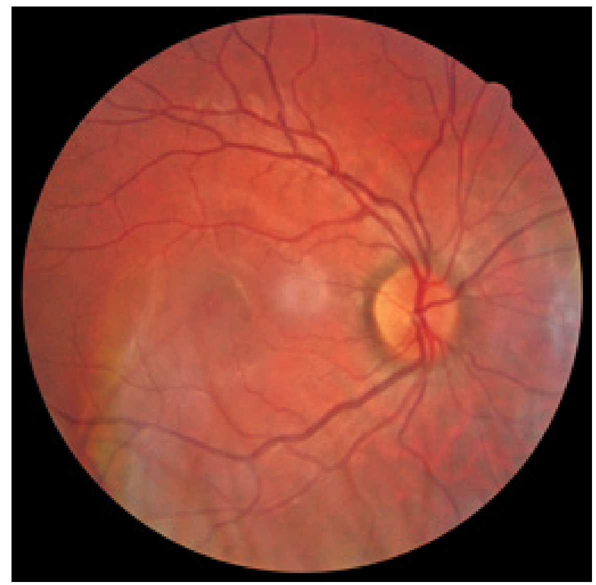




Shadow Map Estimate



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