Single Image Haze Removal Using Dark Channel Prior

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VITAL-VIVA Meeting
Haze Imaging Model

\[ I = J \cdot t + A \cdot (1 - t) \]
Haze Imaging Model

\[ I = J \cdot t + A \cdot (1 - t) \]

\[ d = -\beta \ln t \]
Previous Works

• Polarization filter [Shwartz et.al., CVPR’06]
• Multiple images [Narasimhan & Nayar, CVPR’00]
• Known 3D model [Kopf et al., Siggraph Asia’08]
• User-assistance [Narasimhan &Nayar, CPMCV’03]
Haze?
Common characteristics of Natural Scene without Haze?
COLORFUL?

Then what does the darkest channel looks like?

\[ J_{dark}(x) = \min_{c \in \{r,g,b\}} \left( \min_{y \in \Omega(x)} J_c(y) \right) \]
Dark Channel

- \( \text{min}(\text{rgb, local patch}) \)

\[
J_{\text{dark}}(x) = \min_{c \in \{r,g,b\}} \left( \min_{y \in \Omega(x)} J^c(y) \right)
\]
A Surprising Observation

Prob.

86% pixels in [0, 16]

5,000 haze-free images

Pixel intensity of dark channels
Dark Channel Prior

• For outdoor haze-free images

\[
\min_{\Omega} \left( \min_c J^c \right) \to 0
\]

Minimum value over RGB channels(c) and among neighbor(Ω)
Back to Haze Imaging Model

\[ I = J \cdot t + A \cdot (1 - t) \]
Try to solve Haze Imaging Model

- Patch-based derivation

\[
\min_{y \in \Omega(x)} (I^c(y)) = \tilde{t}(x) \min_{y \in \Omega(x)} (J^c(y)) + (1 - \tilde{t}(x)) A^c
\]

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

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

\[
J^{dark}(x) = \min_c \left( \min_{y \in \Omega(x)} (J^c(y)) \right) = 0
\]

\[
\tilde{t}(x) = 1 - \min_c \left( \min_{y \in \Omega(x)} \left( \frac{I^c(y)}{A^c} \right) \right)
\]
Soft Matting
Soft Matting

\[ E(t) = t^T L t + \lambda (t - \tilde{t})^T (t - \tilde{t}) \]

- Smooth term
- Data term

\[ L(i, j) = \sum_{k \mid (i, j) \in w_k} \left( \delta_{i,j} - \frac{1}{|w_k|} (1 + (I_i - \mu_k)^T \left( \sum_k + \frac{\epsilon}{|w_k|} U_3 \right)^{-1} (I_i - \mu_k)) \right) \]
Finished?

\[ I = J \cdot t + A \cdot (1 - t) \]

\[ \tilde{t}(x) = 1 - \min_c \left( \min_{y \in \Omega(x)} \left( \frac{I^c(y)}{A^c} \right) \right) \]
Finished?

\[ I = J \cdot t + A \cdot (1 - t) \]

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

What if \( t = 0 \)?

What does it mean if \( t = 0 \)?
Heaviest Haze is the brightest place in dark channel
Applications in other De...

• Restoration of Underwater Vision Using a Two-phase Regularization Mechanism
• Computergraphical Model for Underwater Image Simulation and Restoration
• Under-exposed Image Enhancement Using Exposure Compensation
• Spaceborne Underwater Imaging
• A fusion-based enhancing approach for single sandstorm image
• Review on Raindrop Detection and Removal in Weather Degraded Images
• Content-Based Photo Quality Assessment
• A Piecewise-based Contrast Enhancement Framework for Low Lighting Video
Some results

Underwater Image enhancement

Sandstorm Image enhancement

Under-exposed Image enhancement