Double-click Imaging

Yoav Y. Schechner

Technion, Israel

Joint studies with: Tali Treibitz, Yael Erez, Dan Adam, Nir Karpel, Einav Namer, Sarit Swartz, Srinivas Narasimhan, Shree Nayar

Support: ISF, Ollendorff center, Taub Foundation, EIOp
Daylight underwater

Dehazing

Ultrasound imaging

Active lighting
Underwater Imaging

• Poor visibility
• Distance dependent

Schechner, Karpel, *underwater vision*
Blind Haze Separation

Raw images,
Best polarization state

Shwartz, Namer, Schechner
Blind Haze Separation

Dehazed images

Shwartz, Namer, Schechner
$$I(x, y) = \frac{D}{L_{\text{object}}(x, y) \cdot t(z)}$$

Schechner, Narasimhan, Nayar
\[ I(x, y) = L_{\text{object}}(x, y) \cdot t(z) + A(x, y) \]

Separating \( A(x, y) \) from \( D(x, y) \)

Modulating \( A(x, y) \) or \( D(x, y) \)

- Modulating \( A \) by polarization
- Modulating \( A \) temporally (gated light)
- Modulating \( A \) and \( D \) by structured light
- Modulating \( A \) and \( D \) by lighting direction
- Spectral modulation
2 images: by polarization

Best polarized image

\[ I_{\text{min}}(x, y) = \frac{D(x, y)}{2} + A(x, y) \frac{1 - p}{2} \]

ICA-based analysis

Shwartz, Namer & Schechner, *Blind Haze Separation*
2 images: by polarization

\[ I_{\text{max}}(x, y) = \frac{D(x, y)}{2} + A(x, y)\frac{1+p}{2} \]

Worst polarized image

ICA-based analysis

Shwartz, Namer & Schechner, *Blind Haze Separation*
Underwater (natural light)

Eilat (Red Sea), -26 meters

Schechner, Karpel
Naive White Balancing

26m underwater

Schechner, Karpel
Not a “difference image”

Schechner, Karpel

26m underwater
3D Surface

Schechner, Karpel
Dehazing Experiment

Best polarized image

Schechner, Narasimhan, Nayar, *Instant Dehazing*
Naïve Inversion of the Image Formation Process

Schechner, Narasimhan, Nayar, *Instant Dehazing*
Adaptive Regularization (while Dehazing)

Schechner, Averbuch, *Regularized Dehazing*
Regularization

Schechner, Averbuch, *Regularized Dehazing*
Adaptive Regularization

\[ W = (1 - t) \]

Schechner, Averbuch, *Regularized Dehazing*
- Natural light: **inapplicable** to dark environments
- Spontaneous polarization: haze, **not** fog
- Natural light: **unpredictable**
- Uniform conditions: horizontal photography
Fog = Cloud

Artificial Illumination: LIDAR

Backscatter @ narrow baseline: LIDAR


- Backscatter polarization induced by illumination
- Depolarization: Backscatter cannot be fully blocked
- Dependency on the type of particles
polarizer

lamp head

camera

underwater housing

polarizer

analyser

Treibitz, Schechner, *Instant 3Descatter*
Treibitz, Schechner, *Instant 3Descatter*
Treibitz, Schechner, *Instant 3Descatter*
Mediterranean (night)
Caesaria
Mediterranean (night)
Caesarea

De-scattered image

Treibitz, Schechner, *Instant 3Descatter*
Mediterranean (night)
Caesarea

Treibitz, Schechner, *Instant 3Descatter*
Mediterranean (night)
Caesarea

De-scattered image

backscatter

Treibitz, Schechner, *Instant 3Descatter*
First frame: lower source

Caesarea (Mediterranean)
Second frame: upper source

Caesarea (Mediterranean)
Bidirectional-illumination contrast

Treibitz, Schechner

Caesarea (Mediterranean)
Sonar (ultrasound) Problems

- Blurring
- Speckle noise
- Attenuation
- System noise

Erez, Schechner & Adam, Proc. DAGM 2006
Input: Dual Acoustic Frequency

Low acoustic freq

High acoustic freq

Erez, Schechner & Adam, Proc. DAGM 2006
Stochastic Freq. Compounding

Arithmetic mean

Stochastic reconstruction

Erez, Schechner & Adam, Proc. DAGM 2006
Speckle Noise

Low acoustic freq

High acoustic freq

Erez, Schechner & Adam, Proc. DAGM 2006
Wave phenomenon

Object

Object blur:

as if no interference

Wave interference

Erez, Schechner & Adam, Proc. DAGM 2006
PSF

Depends on:
- Radial distance
- Acoustic frequency

Erez, Schechner & Adam, Proc. DAGM 2006
Attenuation

- Radial distance from probe
- Acoustic frequency

\[ a_{\text{object}}(r) = e^{-\alpha f_{\text{acoustic}} r} \cdot a_{\text{acoustic}}(r) \]
Model

\[
\begin{bmatrix}
\log(\cdot) \\
\log(\cdot)
\end{bmatrix}
= 
\begin{bmatrix}
\log(\alpha_1) \\
\log(\alpha_2)
\end{bmatrix}
+ 
\begin{bmatrix}
\log(\cdot) \\
\log(\cdot)
\end{bmatrix}
\]

correlated noise !!!
Quick 2 frames → Modulate effects → Compute