Underwater Image Dehazing with a Light Field Camera

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Motivation

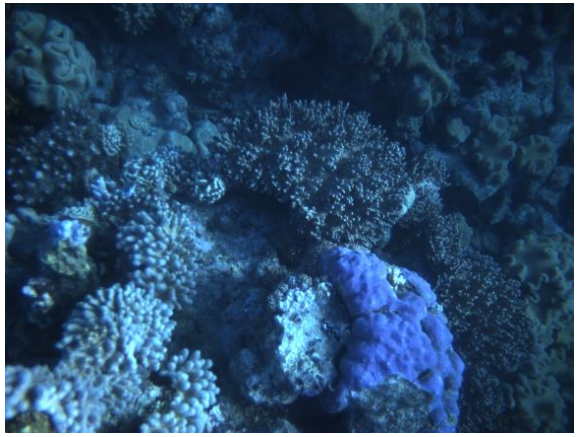


Photo: Volodymyr Goinyk

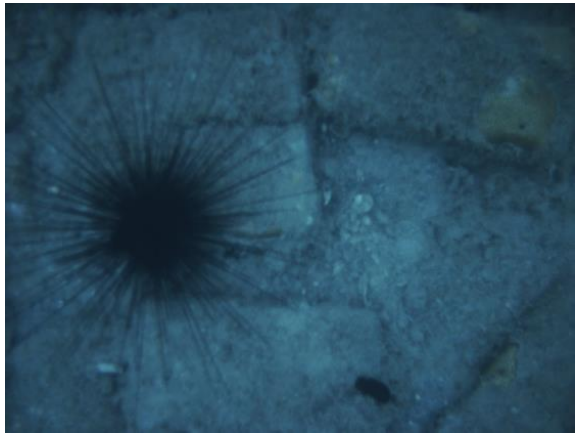
University of Michigan

DROP Deep Robot Optical Perception Lab

Motivation

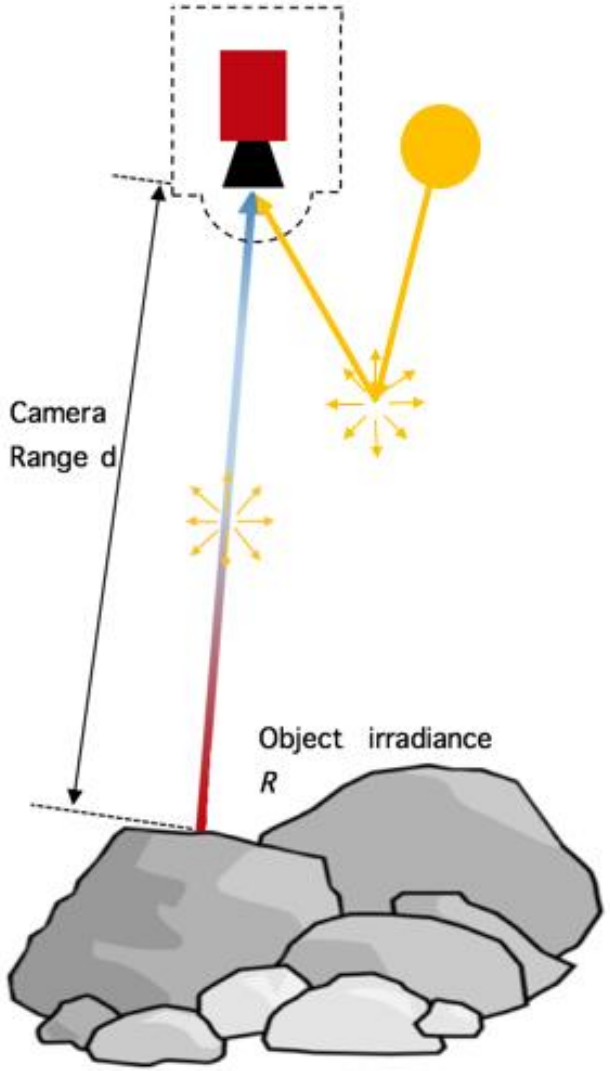


Lizard Island, Australia

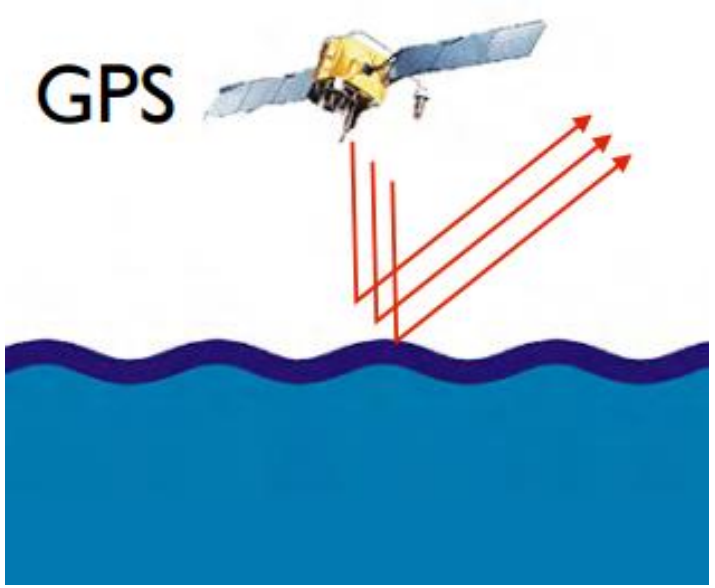


Port Royal, Jamaica





Motivation





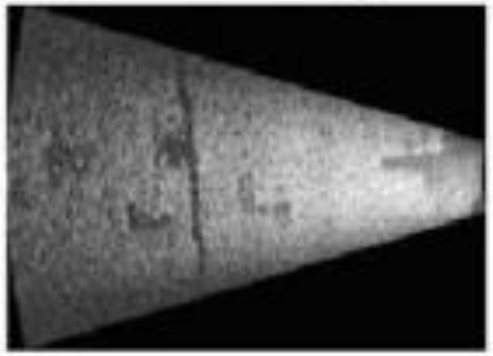




Photo: Jaffe Lab

Motivation



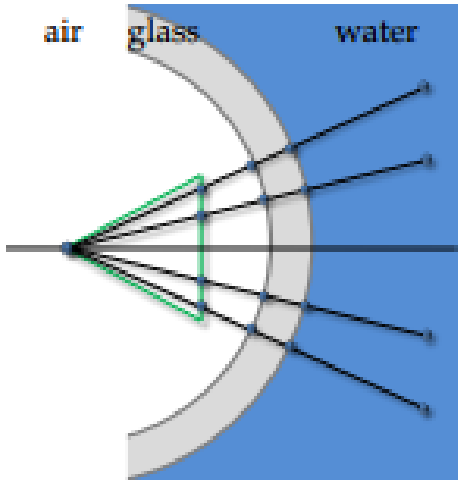
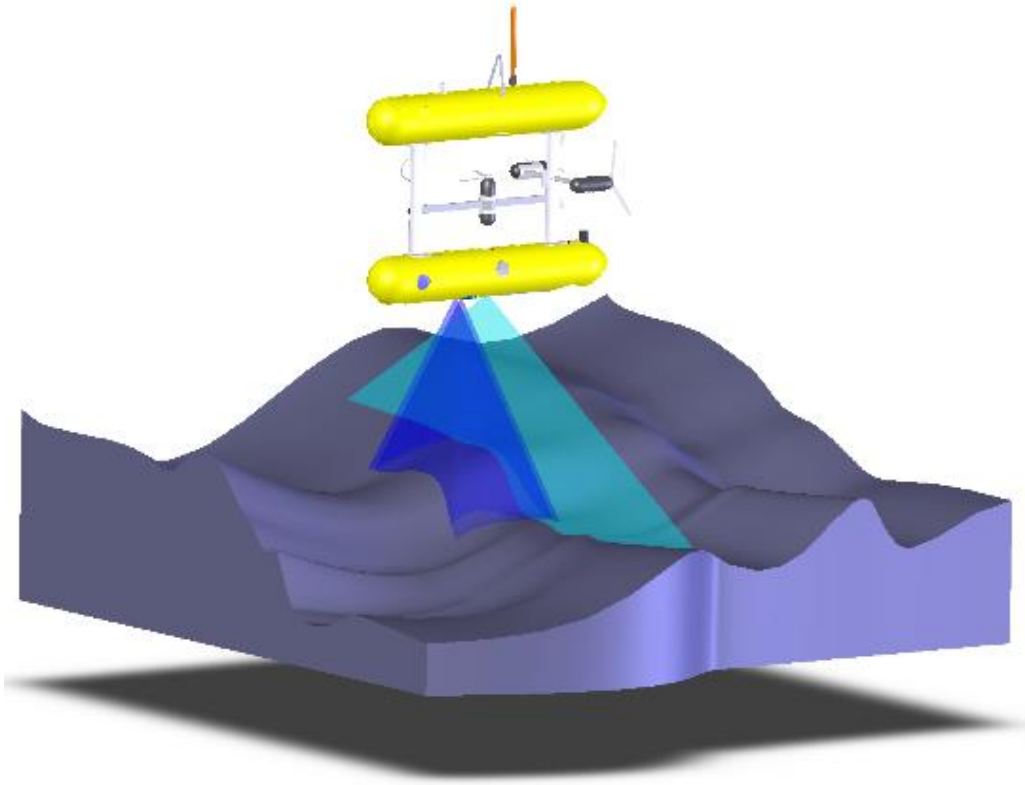


Photo: Jordt (2014)



Light Field Cameras

- Real-time RGB-D
- Passive optical sensors
- Compact form factor
- Increased depth-of-field



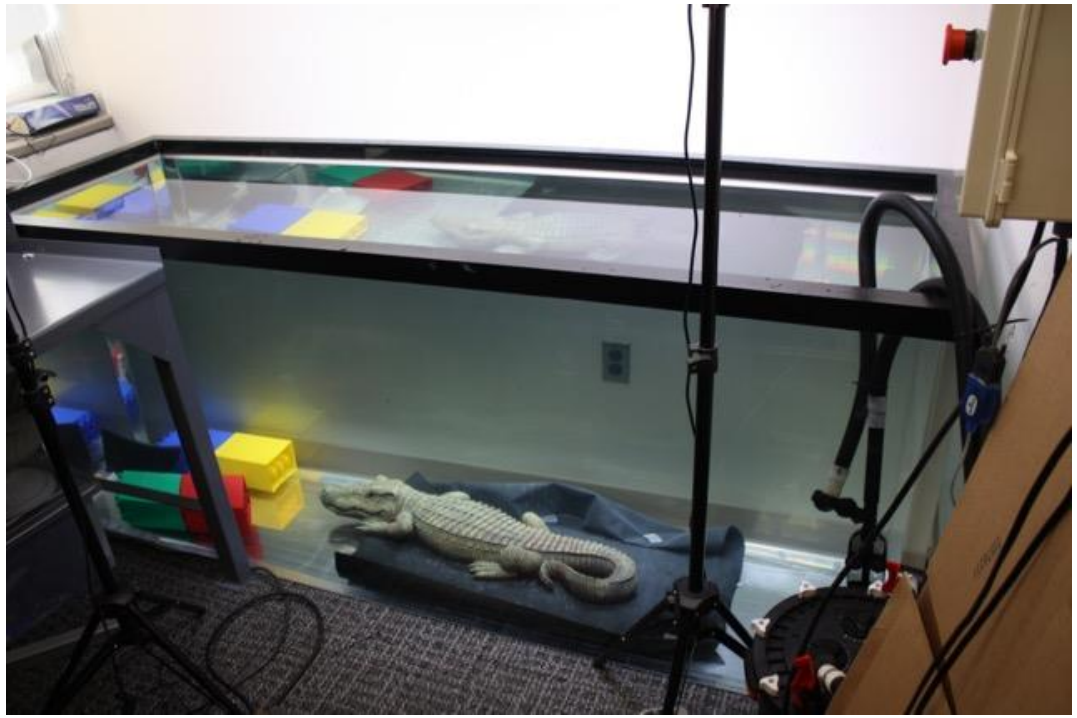
Photo: Raytrix



Photo: Lytro

Real-time Underwater 3D Reconstruction





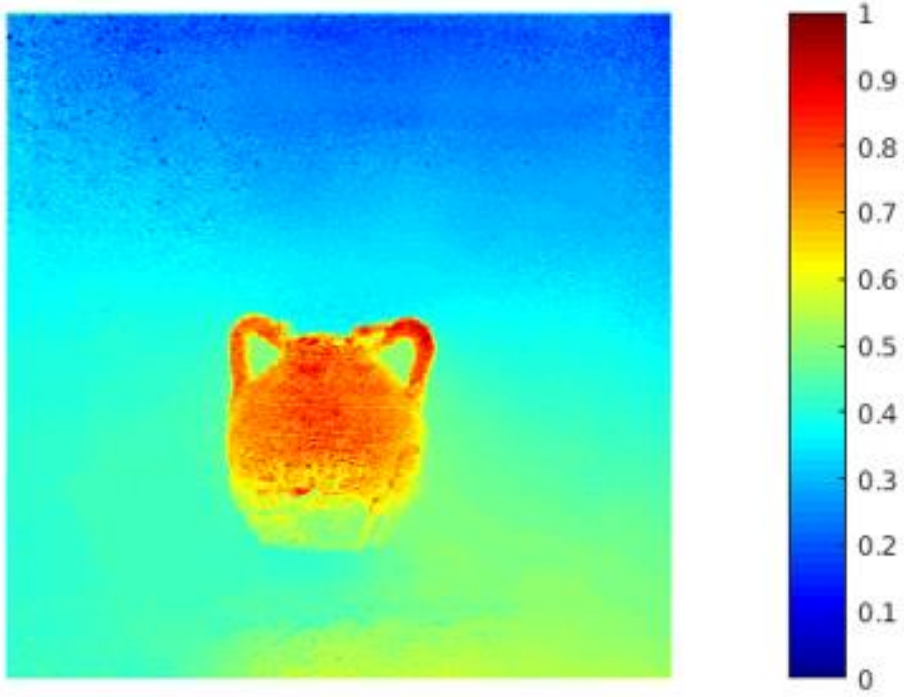
Katherine A. Skinner and Matthew Johnson-Roberson, "Towards real-time underwater 3D reconstruction with plenoptic cameras.“ IROS, 2016.

Real-time Underwater 3D Reconstruction

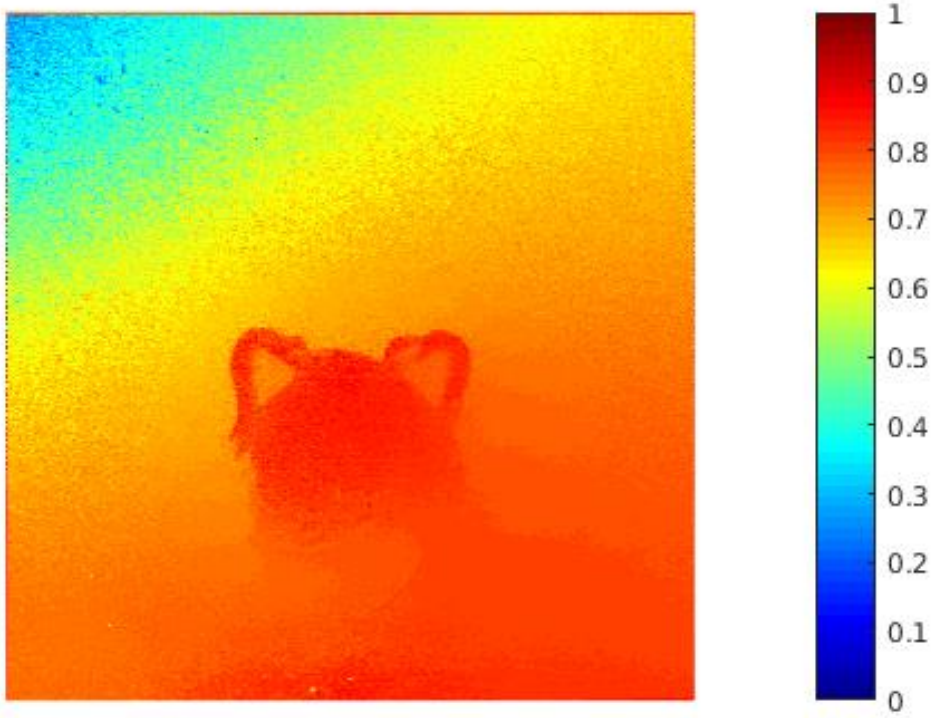


Katherine A. Skinner and Matthew Johnson-Roberson, "Towards real-time underwater 3D reconstruction with plenoptic cameras.“ IROS, 2016.

Pure vs. Turbid Water

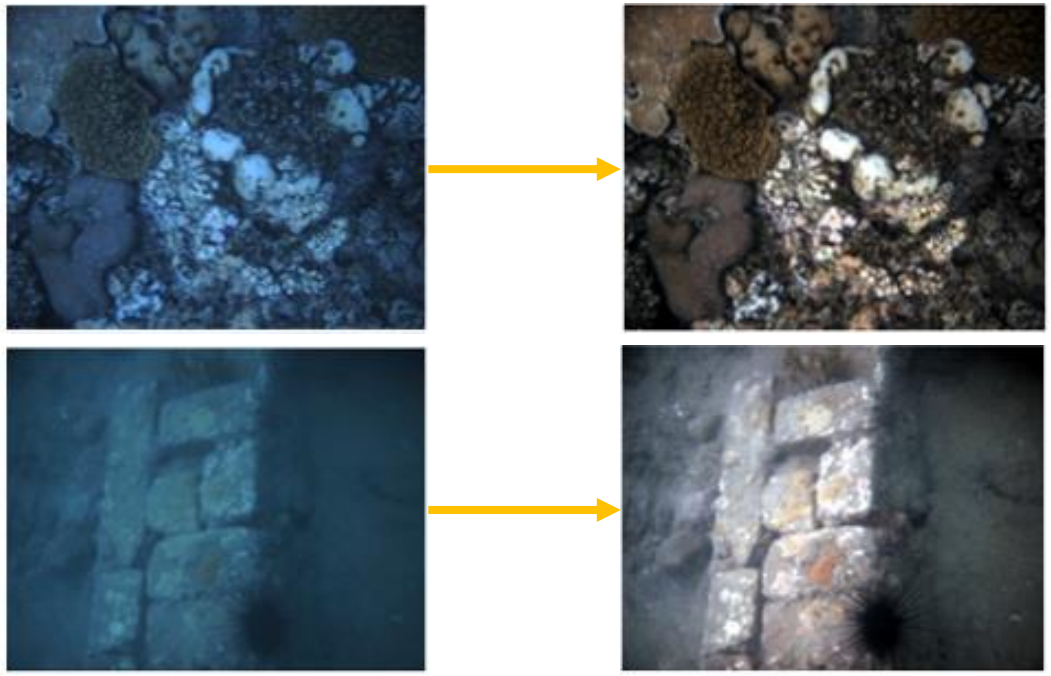


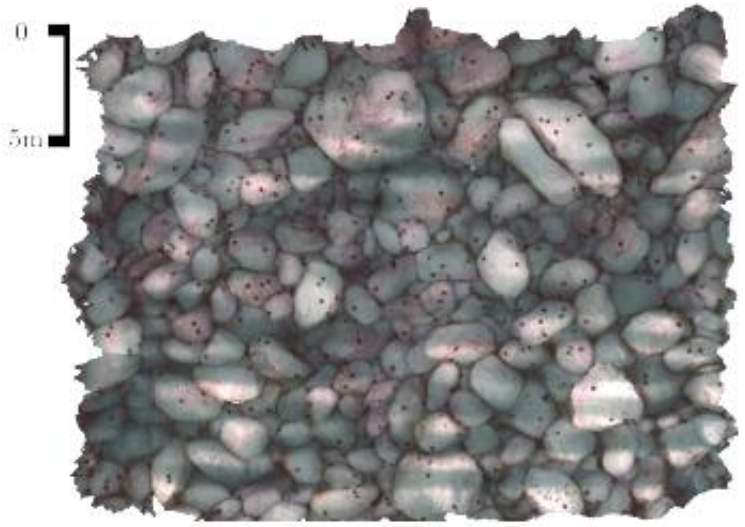
Disparity map in pure water



Disparity map in turbid water

Underwater Image Restoration





Contribution: We present a pipeline for dehazing of underwater light field images incorporating a physical model of underwater light propagation.

Underwater Light Field Image Dataset





https://github.com/kskin/data

Contribution: Provide a comprehensive light field dataset for underwater image dehazing.

Technical Approach

Algorithm 1 Proposed approach for dehazing an underwater light field image.

Input: $L(x, y, u, v)$

Output: $\widetilde{L}(x, y, u, v)$

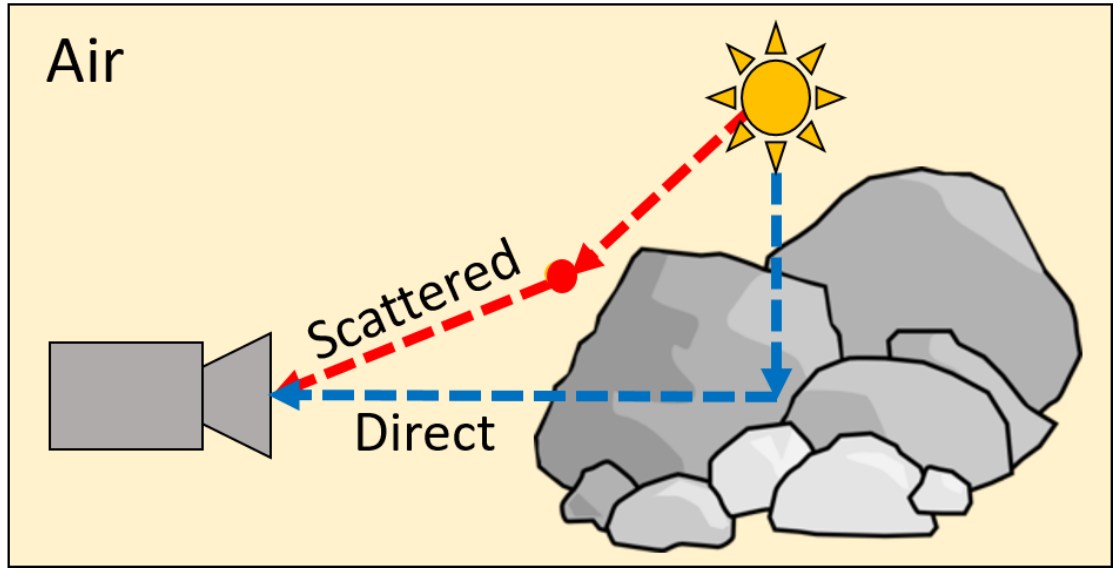
1: $J(x, y, u, v) \leftarrow \text{InitialDehaze}(L(x, y, u, v))$

2: $\widetilde{J} \leftarrow \text{SynthesizeViews}(J(x, y, u, v))$

3: $\widetilde{L}(x, y, u, v) \leftarrow \text{GuidedImageFiltering}(\widetilde{J}, J(x, y, u, v))$

Dehazing Model

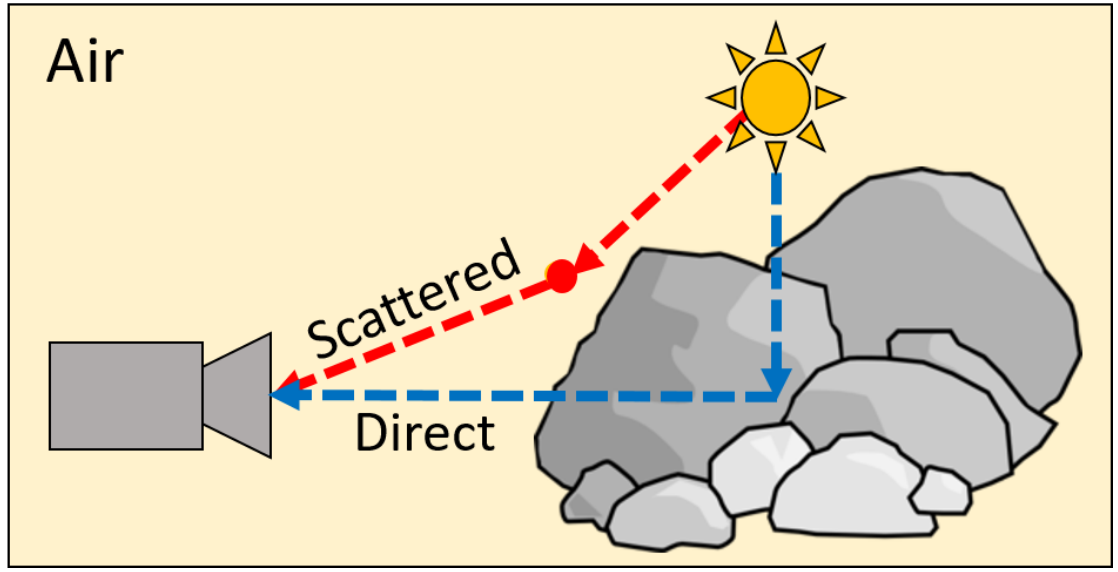
$$I(\boldsymbol{x}) = J(\boldsymbol{x})e^{-\eta d(\boldsymbol{x})} + A(1 - e^{-\eta d(\boldsymbol{x})})$$





Dehazing Model

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

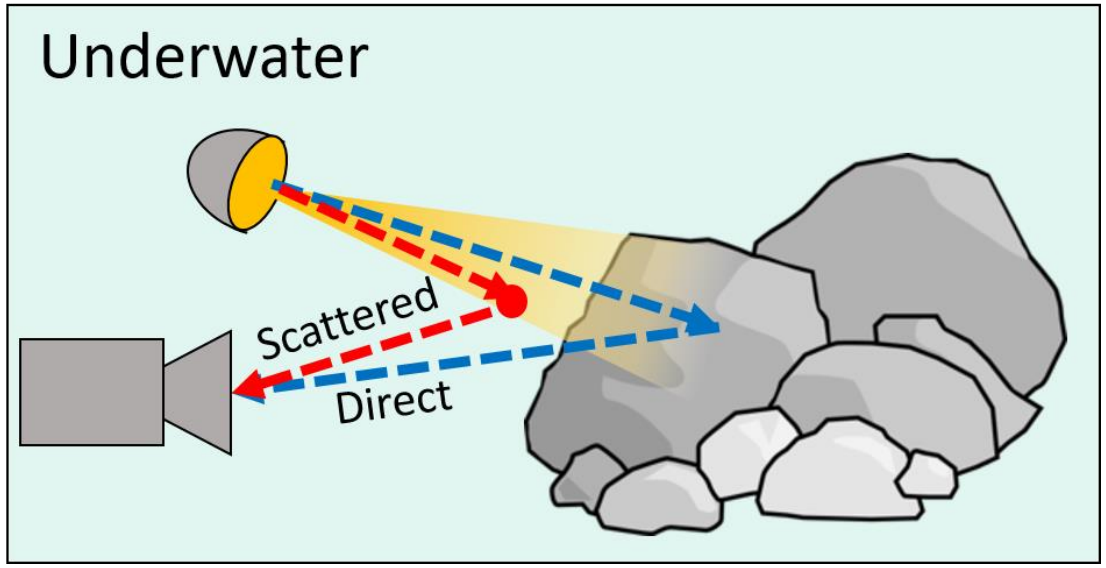




Dehazing Model

$$I(\boldsymbol{x}) = J(\boldsymbol{x})t(\boldsymbol{x}) + A(\boldsymbol{x})\big(1 - t(\boldsymbol{x})\big) + L_{\alpha}(\boldsymbol{x}) * \boldsymbol{APSF}$$

- Non-uniform illumination
- Glow patterns



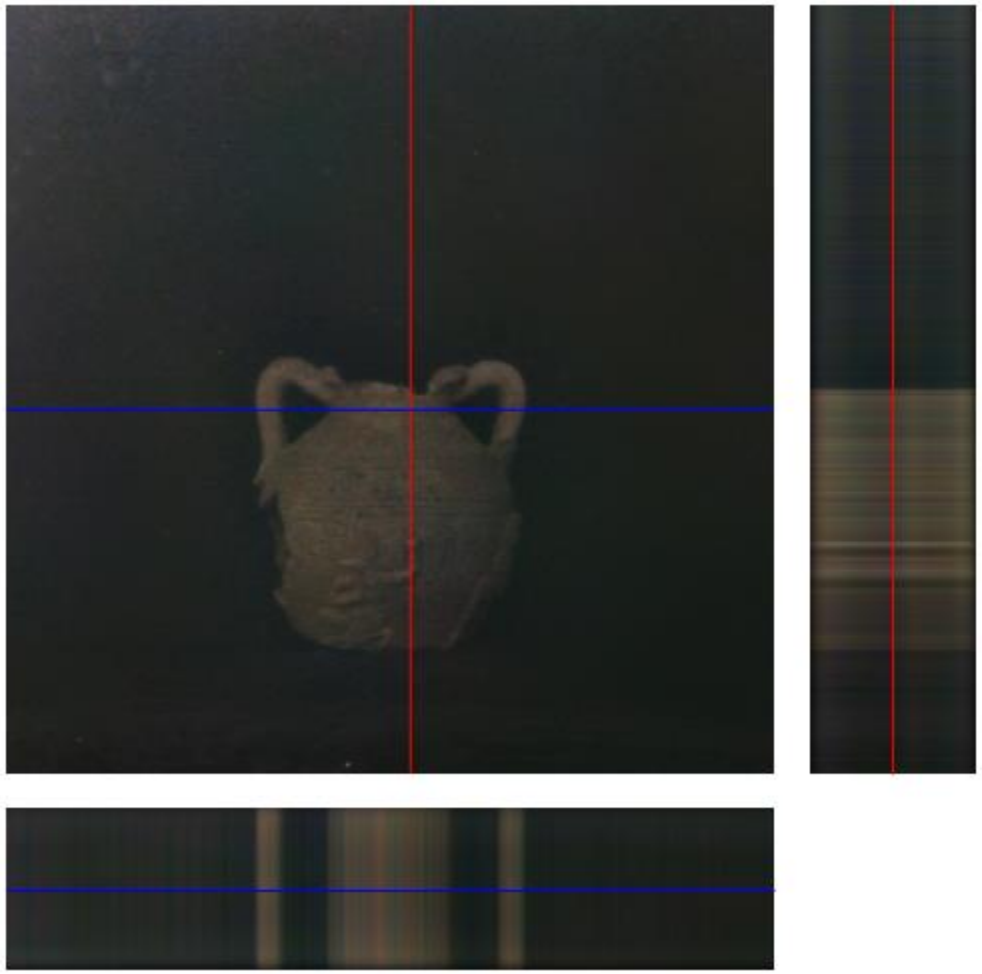


Reference: Y. Li et al. “Nighttime haze removal with glow and multiple light colors”. ICCV 2015.

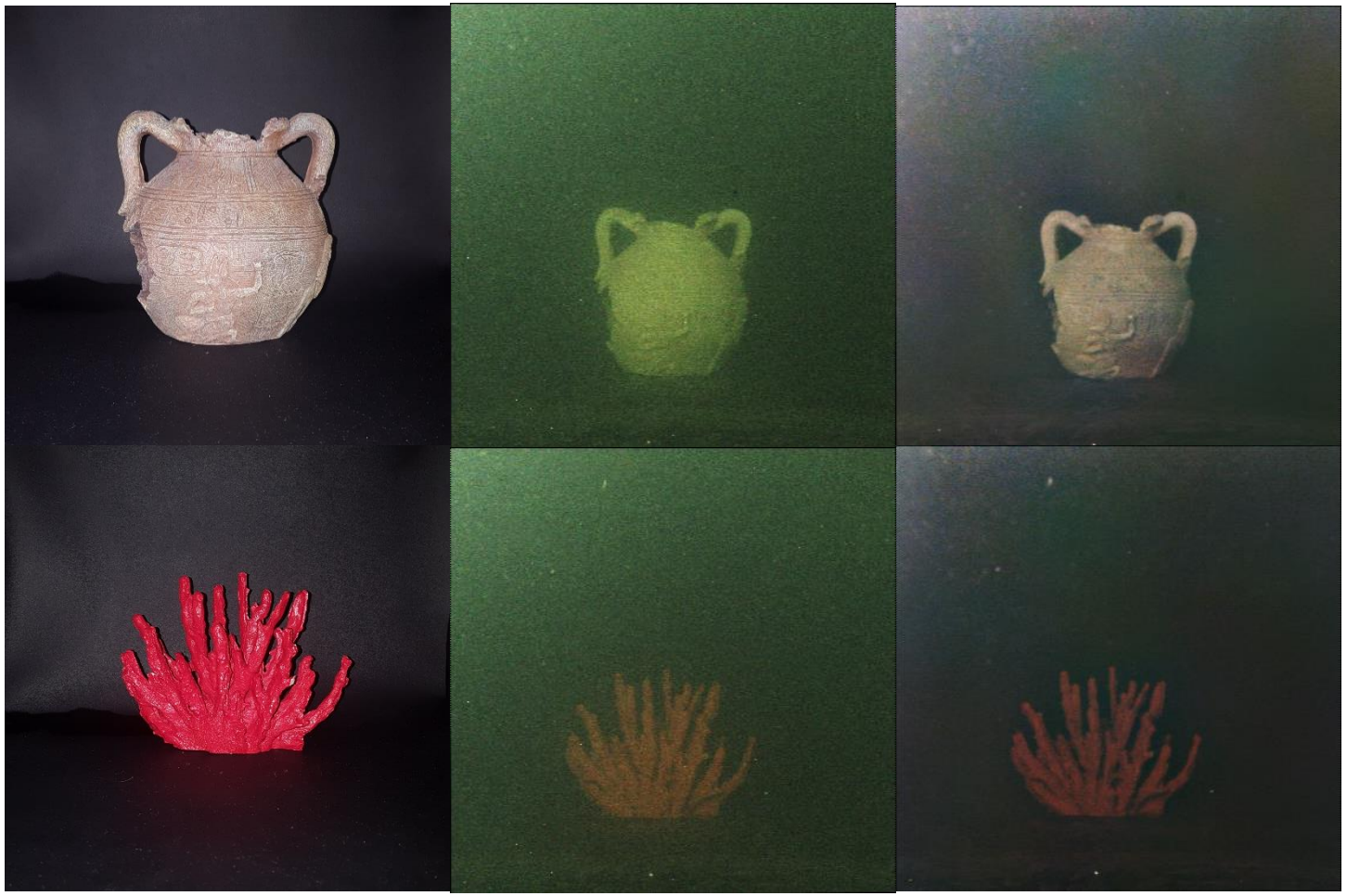
Synthesizing Views



Recovering Epipolar Images

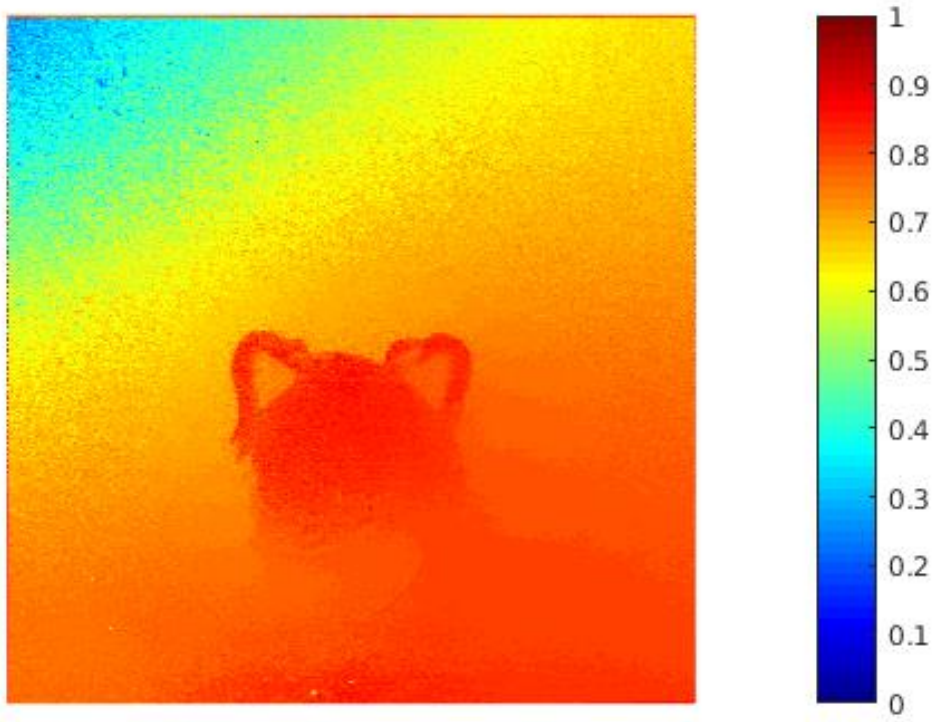


Results

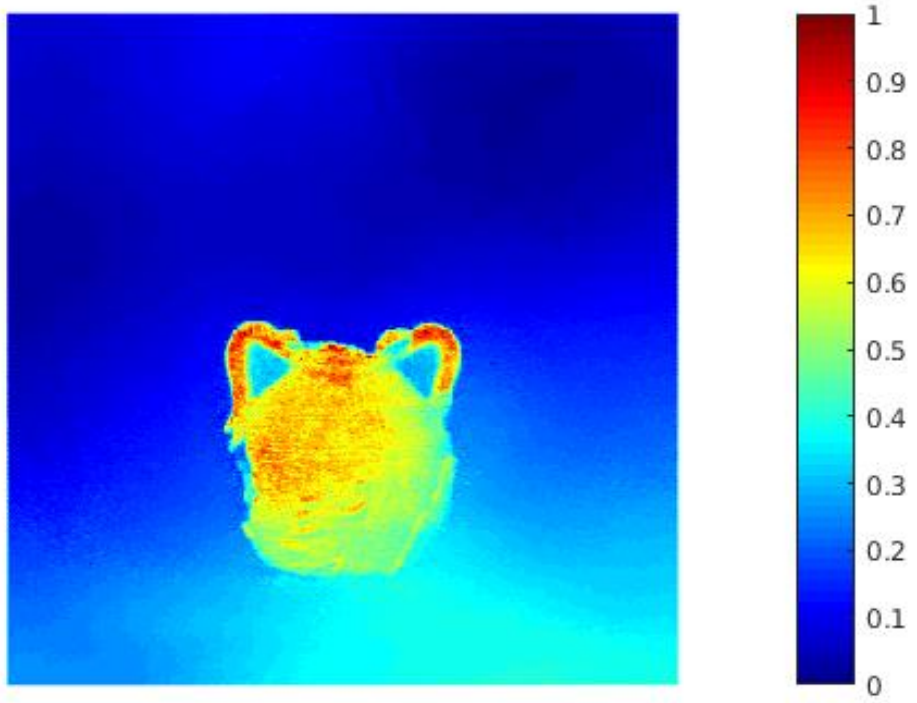


In air | Raw underwater | Our result

Results



Disparity map using raw underwater image



Disparity map using corrected image

Conclusions

- Presented an underwater light field image dehazing pipeline that incorporates a physical model of light propagation
- Provided an underwater light field image dataset

Future Work

- Gather light field images of more complex scenes
  - Greater depth disparity
  - Varying turbidity
- Further leverage light field structure
  - All-in-focus filter [1]
  - Consistent motion between sub-aperture images
- Incorporate more components of physical model for underwater light propagation
  - Recovering range in underwater imaging

[1] Dansereau, et al. Light field image denoising using a linear 4D frequency-hyperfan all-in-focus filter. Computational Imaging, 34(2):15–1, 2013.

Final Thoughts

- Underwater light field camera – contact kskin@umich.edu
- Deep learning approach to underwater image restoration

