Image enhancement for marine robotics applications

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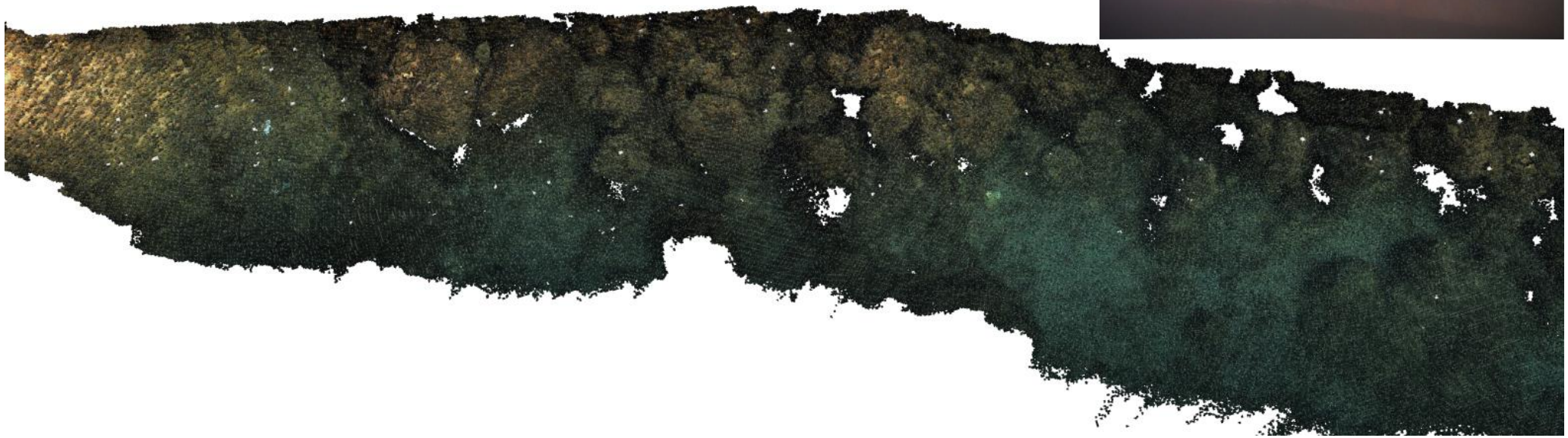
Typical marine robotics applications

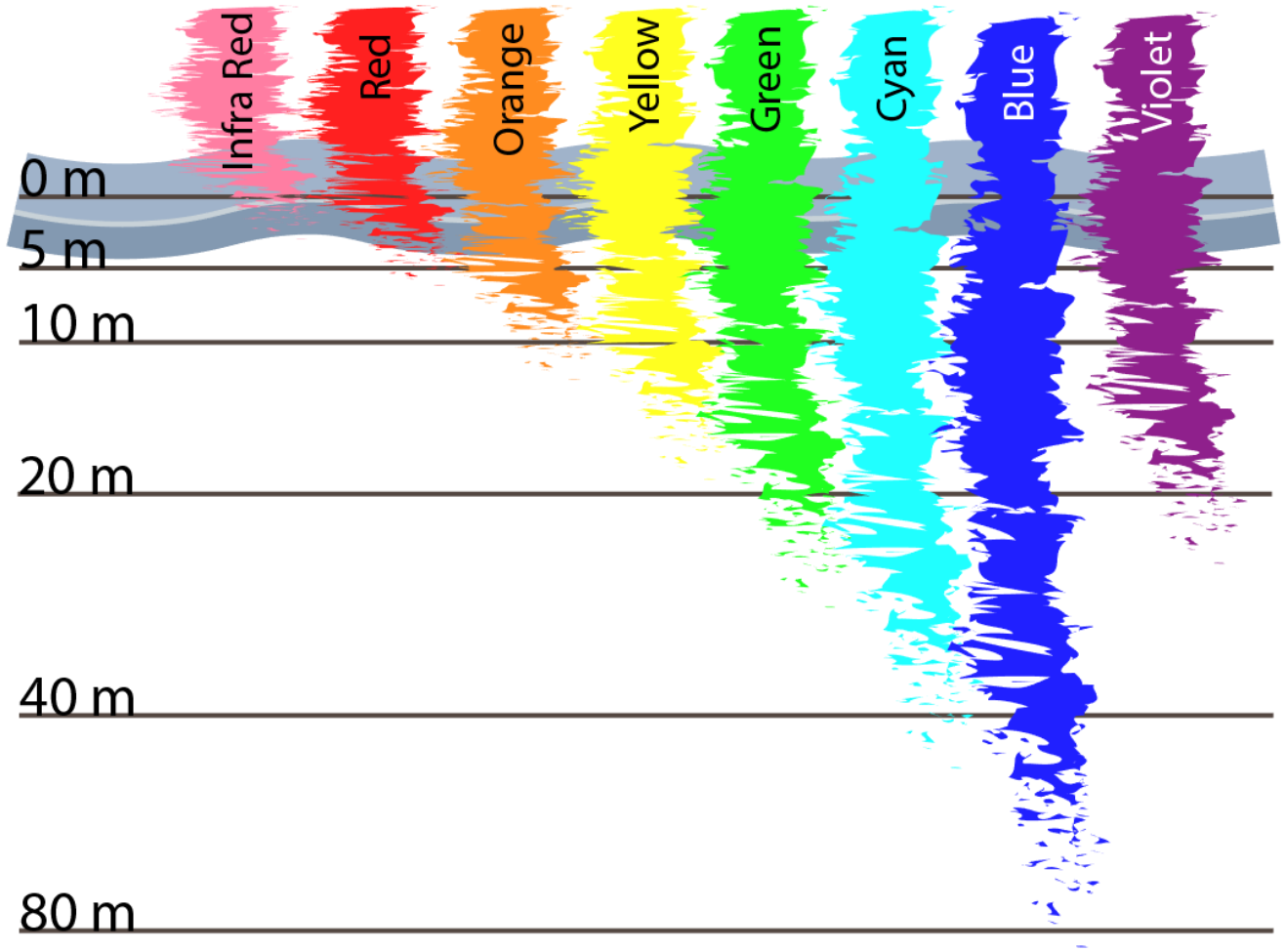
- Inspections
- Localization and Mapping
- Manipulation



Underwater image formation model: attenuation

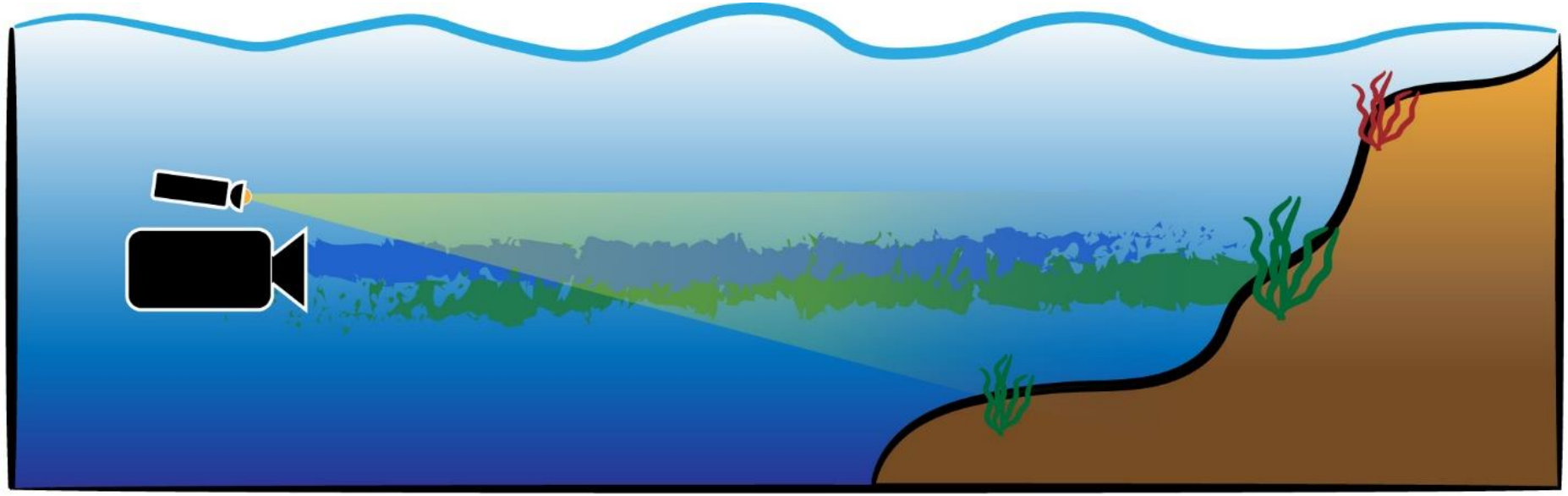
Direct transmission

$$E_d = E_o e^{-c_\lambda r}$$



Underwater image formation model: scattering

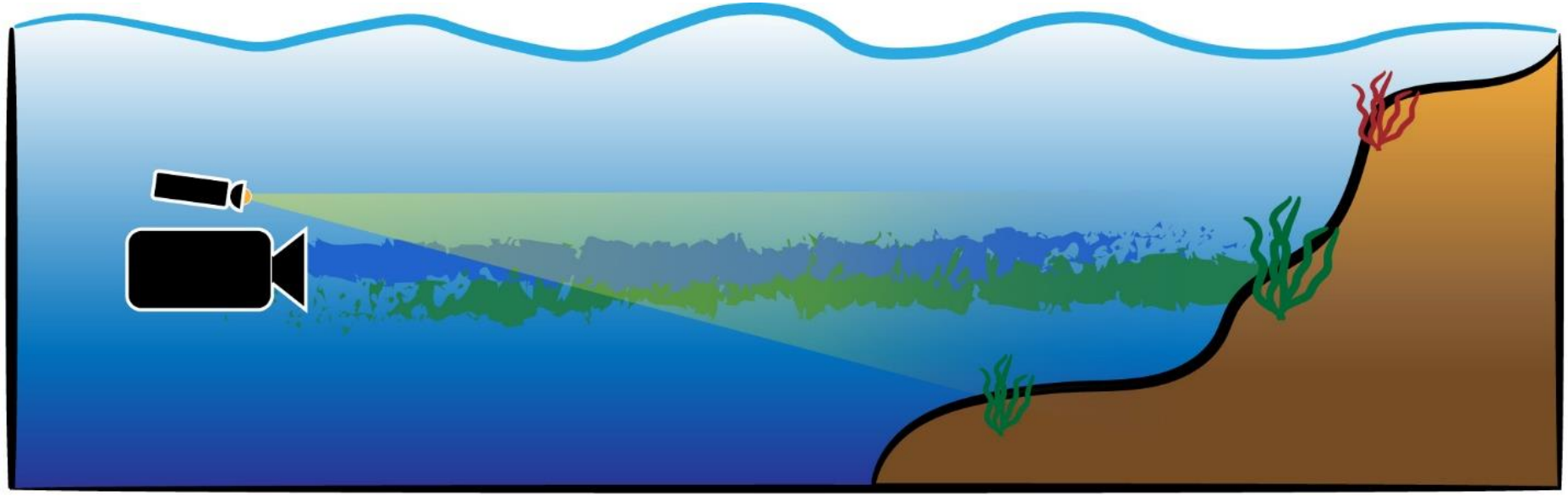
Froward scattering



$$E_f = E_d * g_r$$

Underwater image formation model: scattering

Backscatter



$$E_b = B_{\text{inf}}(1 - e^{-c\lambda r})$$

Underwater image formation model

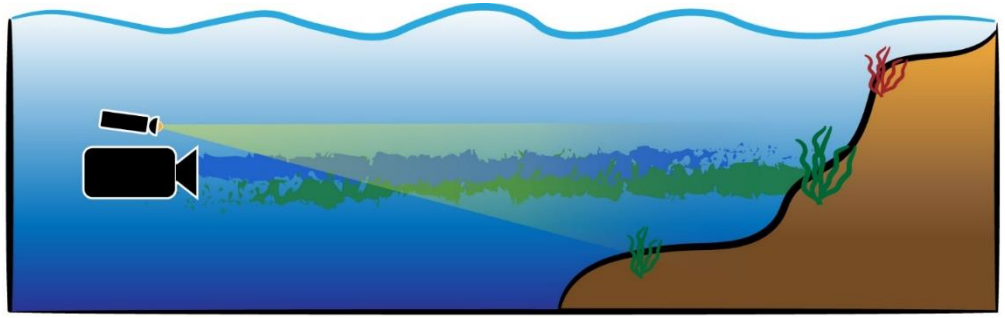
Total radiance

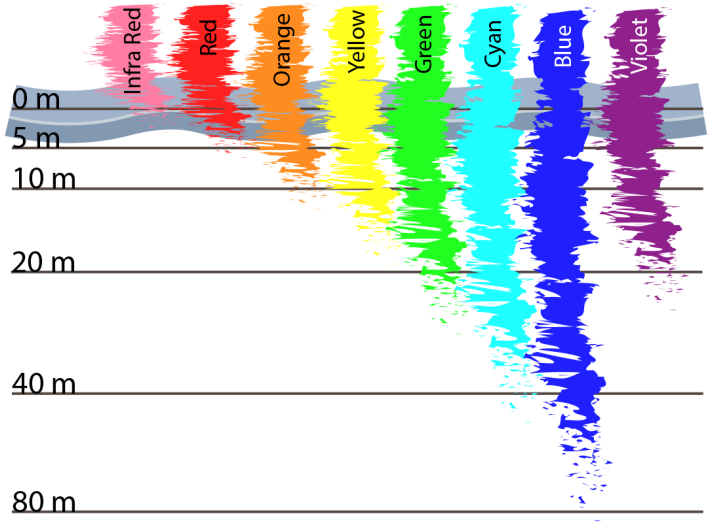
$$E_T = E_d + E_f + E_b$$

$$E_d = E_o e^{-c_\lambda r}$$

$$E_f = E_d * g_r$$

$$E_b = B_{\text{inf}}(1 - e^{-c_\lambda r})$$





Often presented as:

$$J(x) = I(x)t(x) + A(1 - t(x))$$

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Colour correction

- By colour transfer
- With the white balance
- Reversing the attenuation model:

$$E_d = E_o e^{-c_\lambda r}$$

Colour correction – reversing the attenuation model

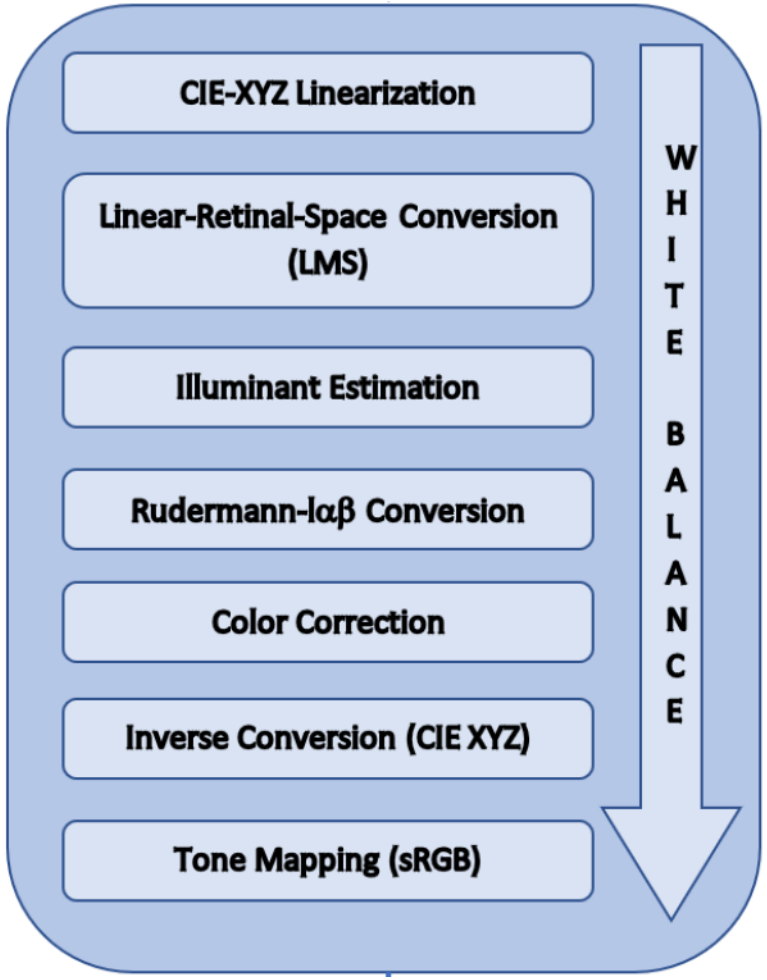
- Requires estimation of the attenuation coefficients
- Requires depth
- Assumes that the residual colour information is sufficient for the reconstruction

$$E_d = E_o e^{-c_\lambda r}$$

Colour correction – underwater white balance

Method by Bianco and Neumann

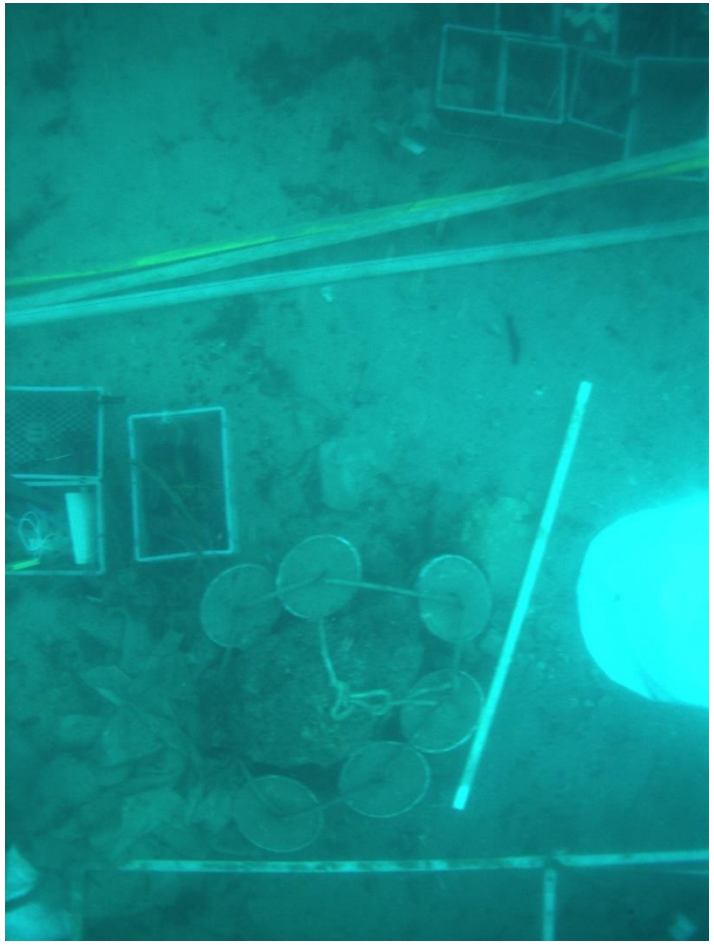
- Operates in the Rudermann Lab colour space
- Estimates the average illumination in the LMS colour space
- Uses grey-world assumption but only in the local window

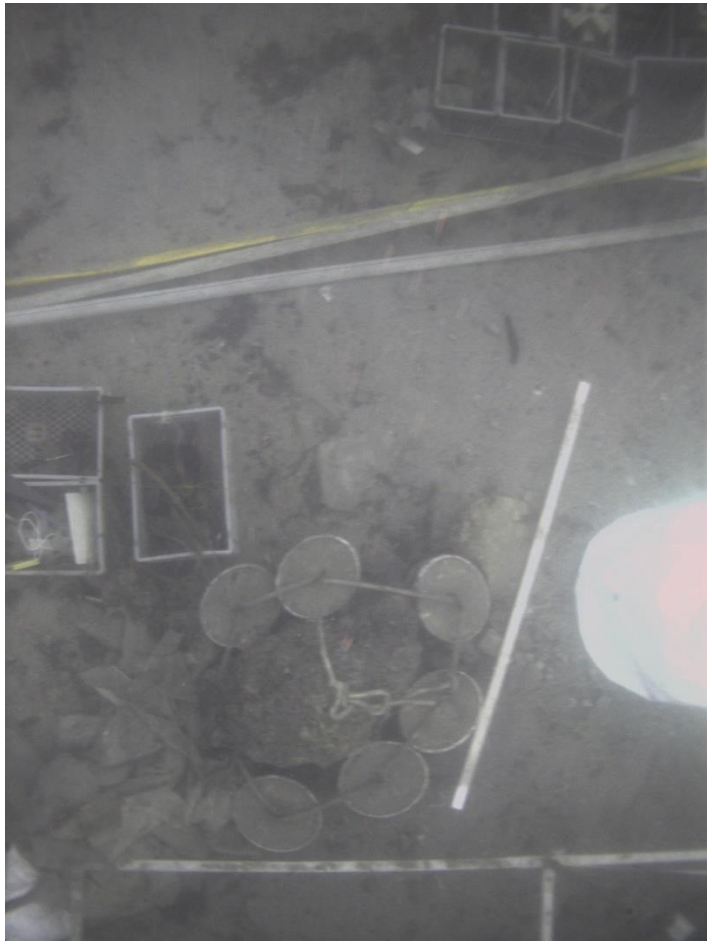


G. Bianco and L. Neumann, "A fast enhancing method for non-uniformly illuminated underwater images," in *OCEANS 2017 - Anchorage*, Sept 2017, pp. 1–6.

Colour correction – underwater white balance

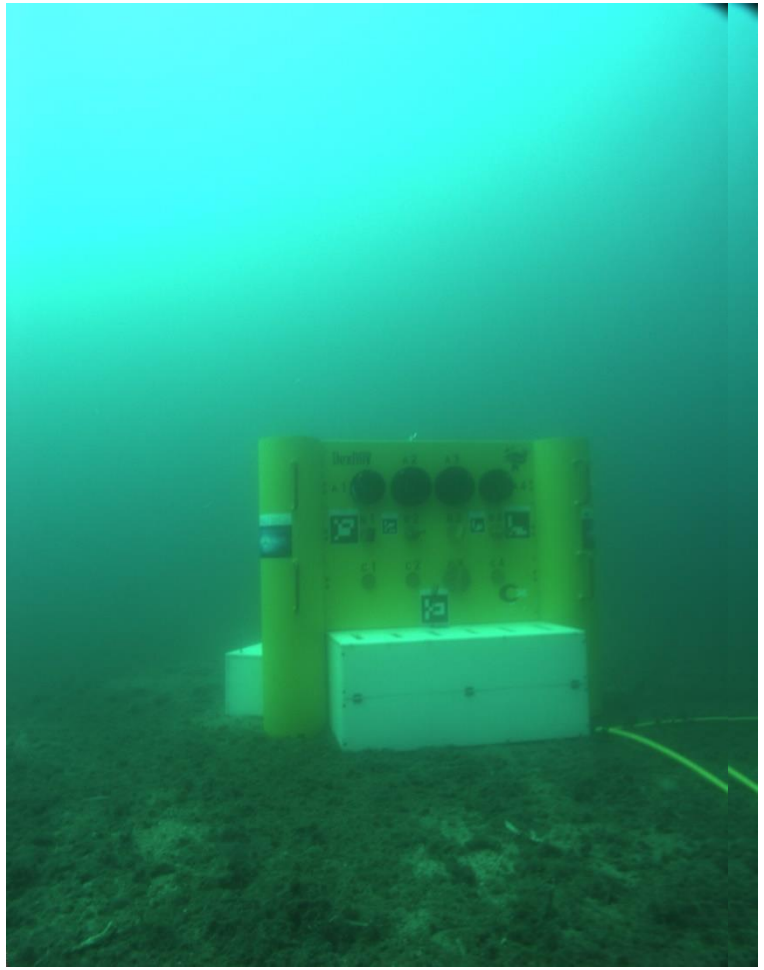
Method by Bianco and Neumann

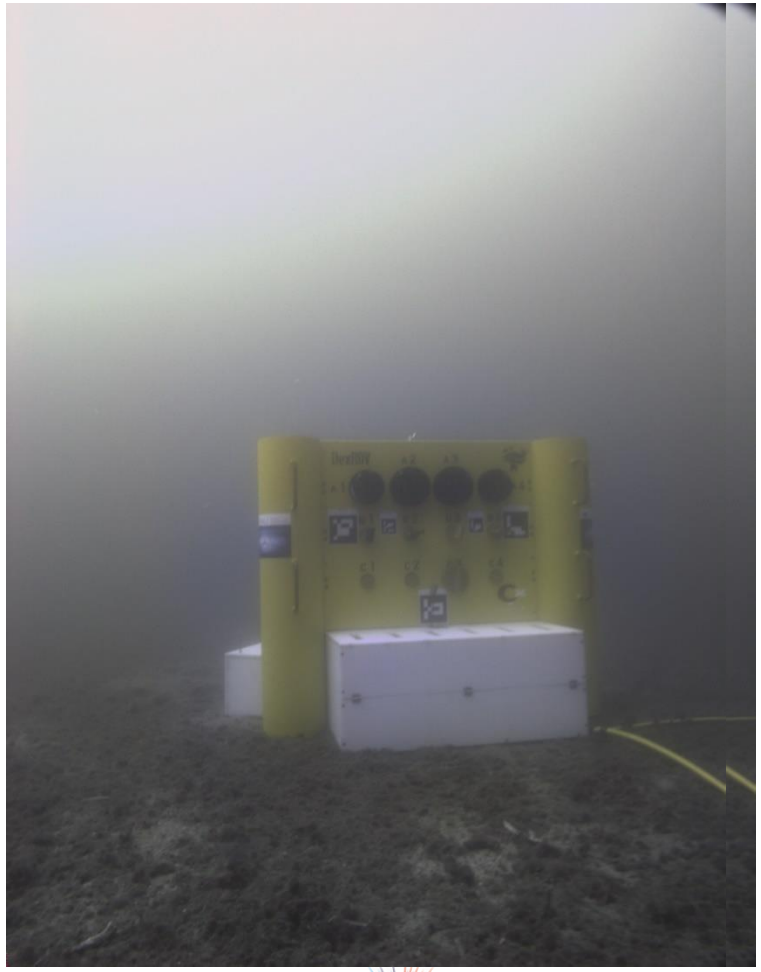




Colour correction – underwater white balance

Method by Bianco and Neumann





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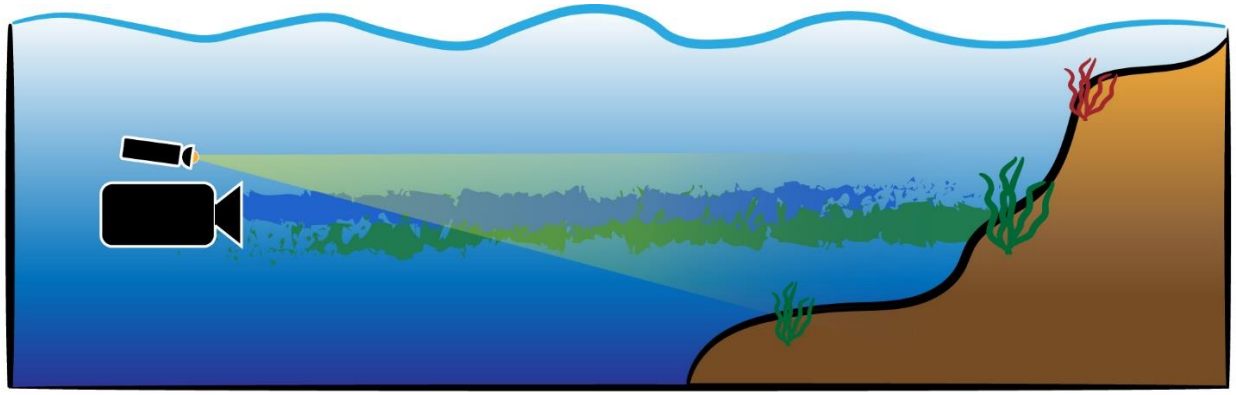
Haze removal

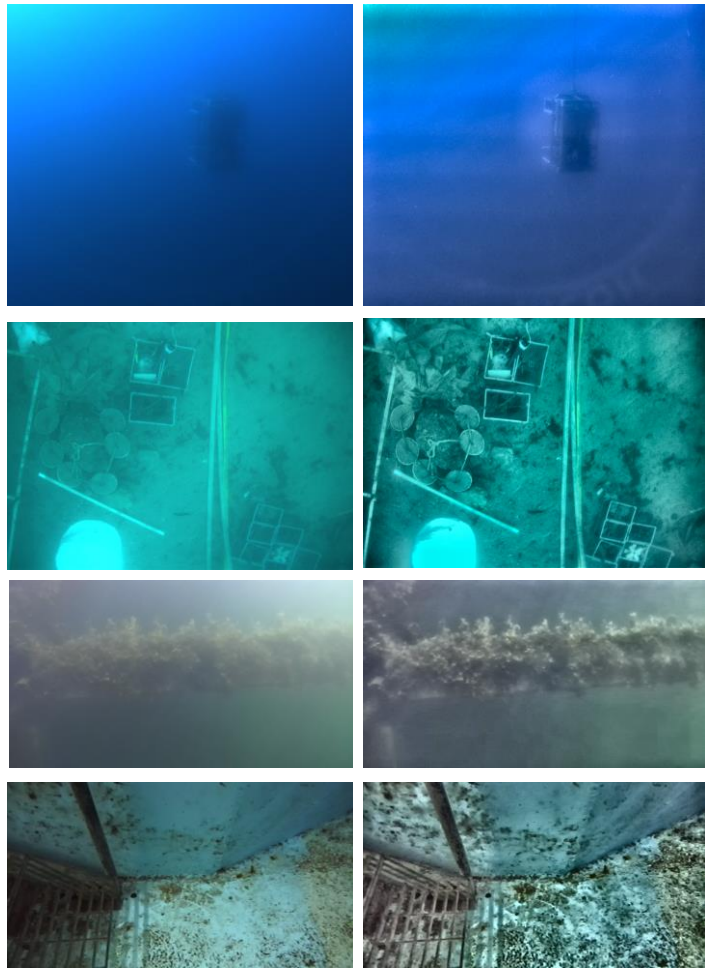
- Contrast adjustment
- Dark Channel Prior
- Polarization based methods
- Deep learning based



Haze removal

Contrast adjustment

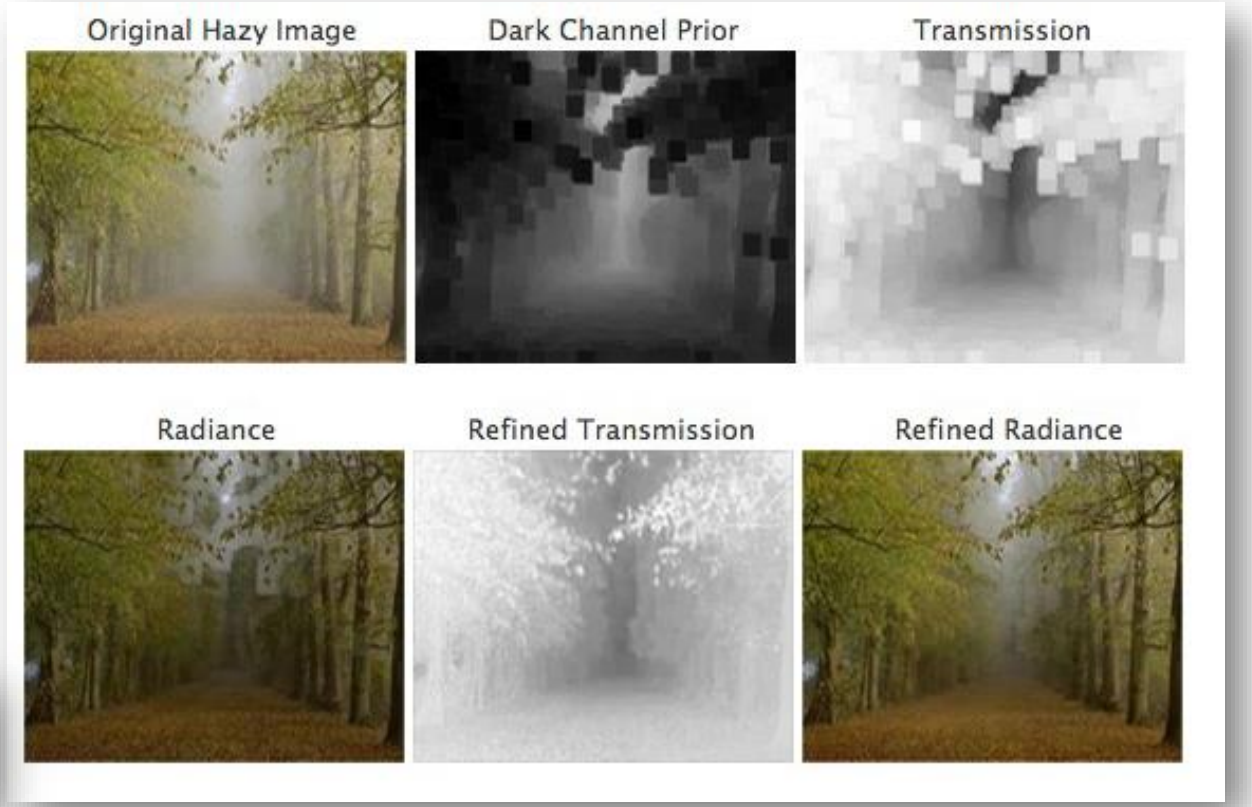
- CLAHE (usually applied to the luminance channel)
- Possible loss of feature in shadows
- Bumps the texture
- Can "create" features on bright of dark regions



Haze removal

Dark Channel Prior

$$J(x) = I(x)t(x) + A(1 - t(x))$$



K. He, J. Sun, and X. Tang, "Single image haze removal using dark channel prior," *IEEE Transactions on Pattern Analysis and Machine Intelligence*, vol. 33, no. 12, pp. 2341–2353, Dec 2011.

Dark channel of the underwater images

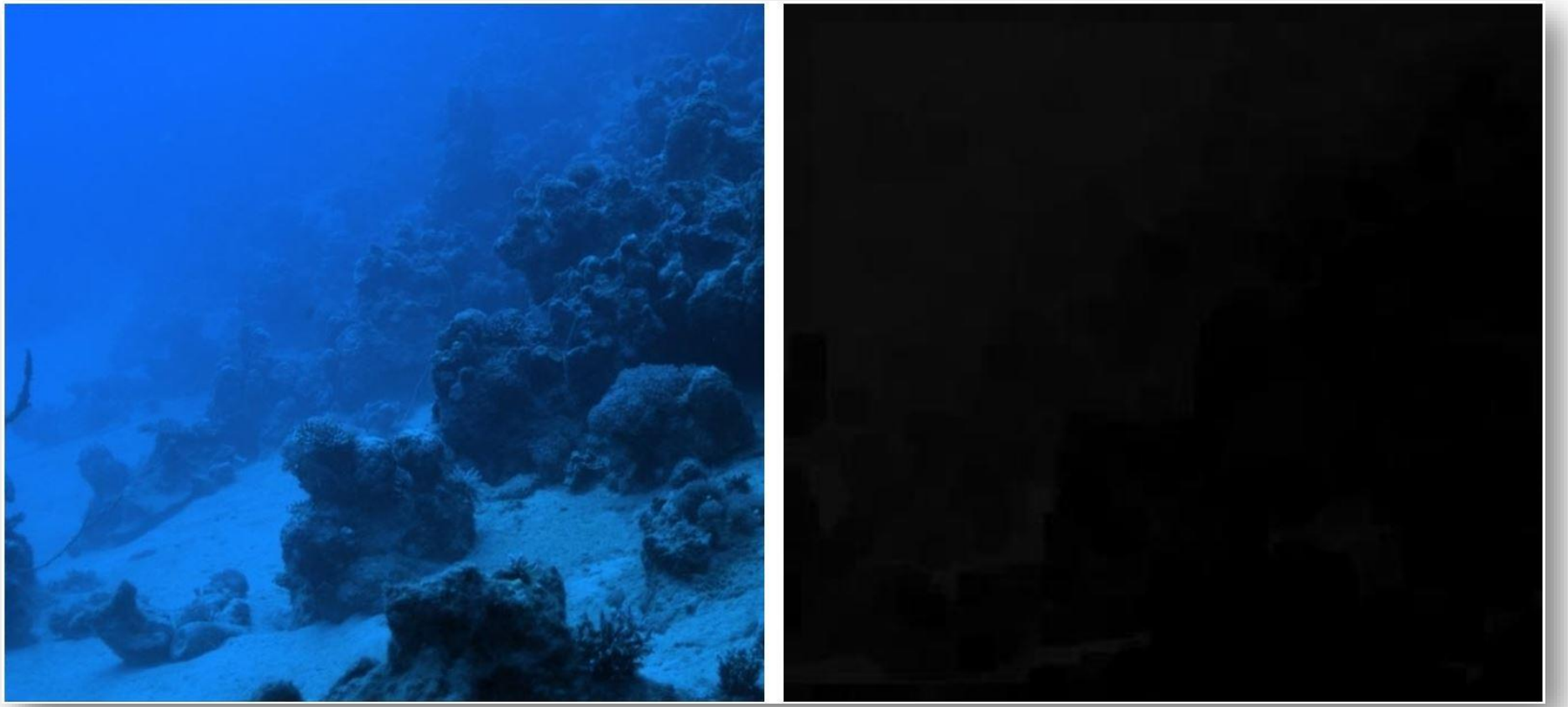


Image on th left from Y. Y Schechner and N. Karpel, „Recovery of underwater visibility and structure by polarization analysis", IEEE Joulrnal of Oceanic Engineering, 2005.

T. Łuczyński and A. Birk, "*Underwater Image Haze Removal and Color Correction with an Underwater ready Dark Channel Prior*," CoRR, vol. abs/1807.0, 2018.

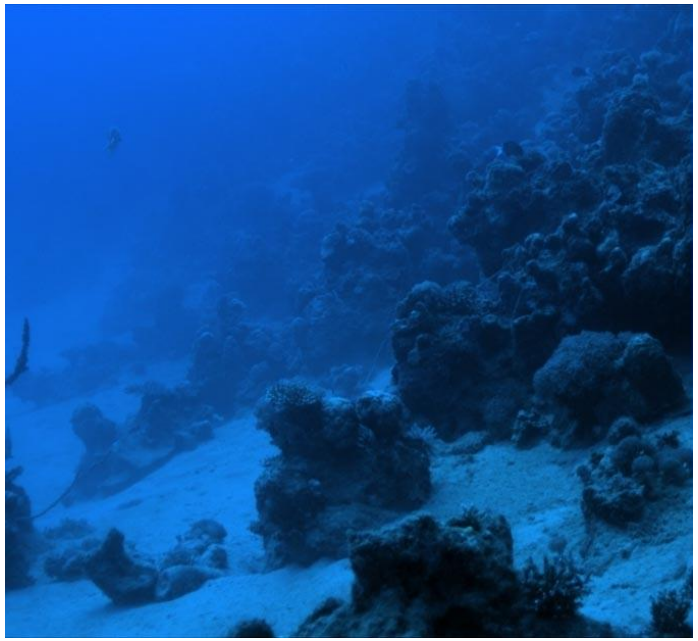
ROV cage

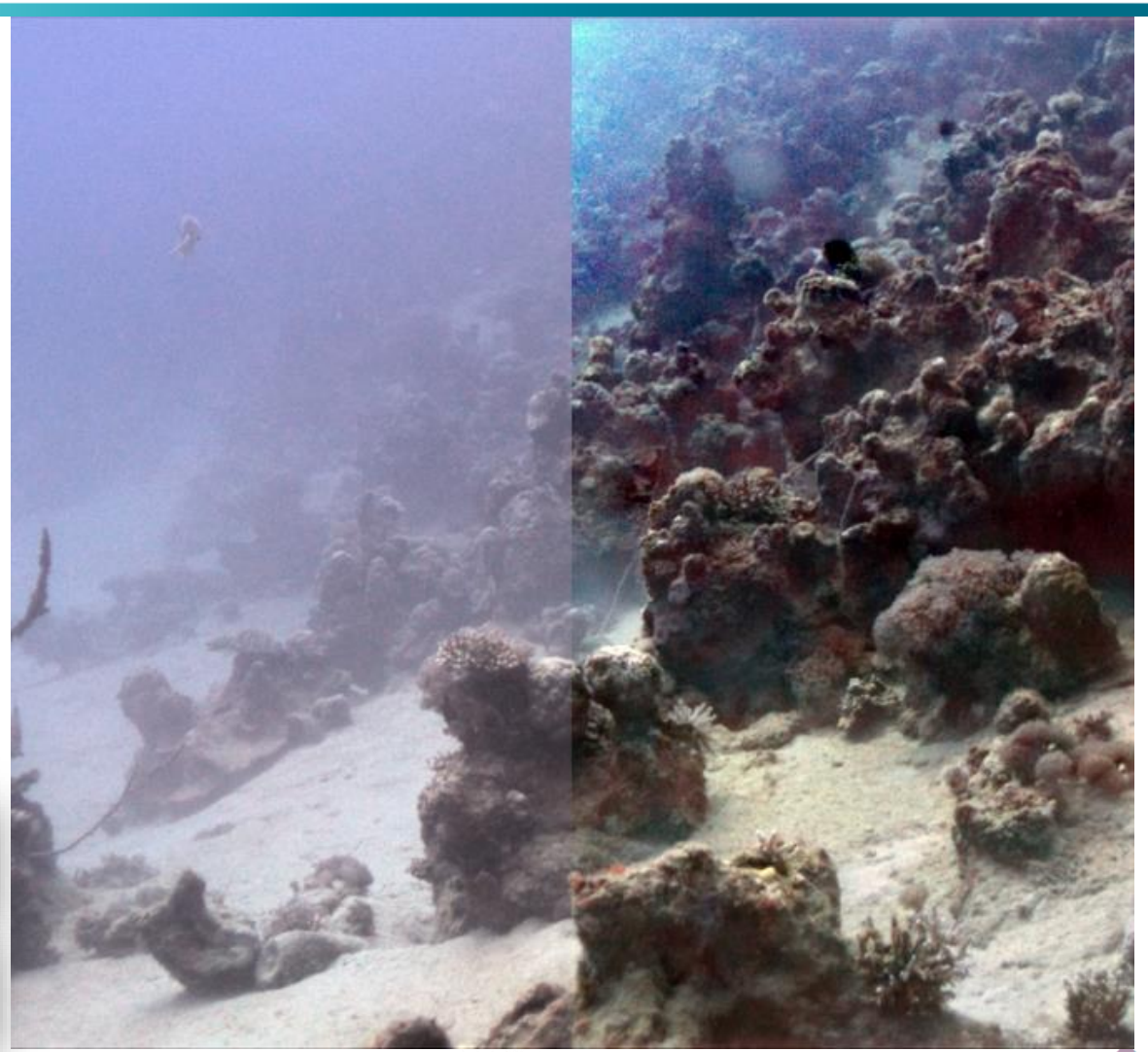
Original

Corrected

Haze removal

Polarization-based





Y. Y. Schechner and N. Karpel, "Recovery of underwater visibility and structure by polarization analysis," *IEEE Journal of Oceanic Engineering*, vol. 30, no. 3, pp. 570–587, July 2005.

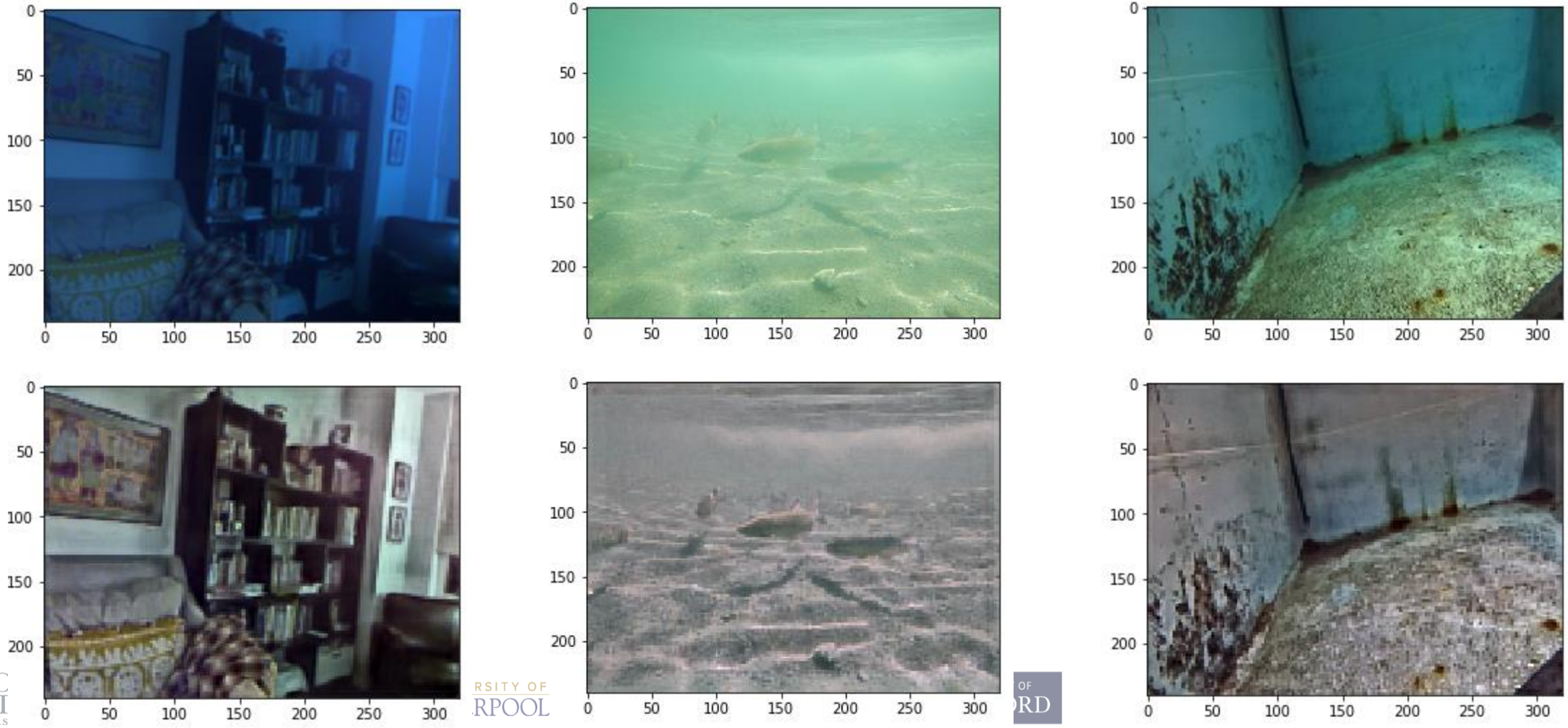
Y. Y. Schechner and Y. Averbuch, "Regularized image recovery in scattering media," *IEEE Transactions on Pattern Analysis and Machine Intelligence*, vol. 29, no. 9, pp. 1655–1660, Sept 2007.

Simulation of the underwater-like dataset based on the in-air images

Ground truth

Haze removal

Sample results



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Haze removal

Global atmospheric light