Optical image visibility enhancement for turbid underwater SLAM

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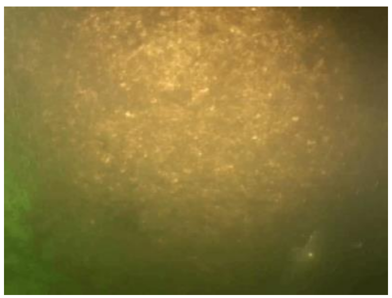
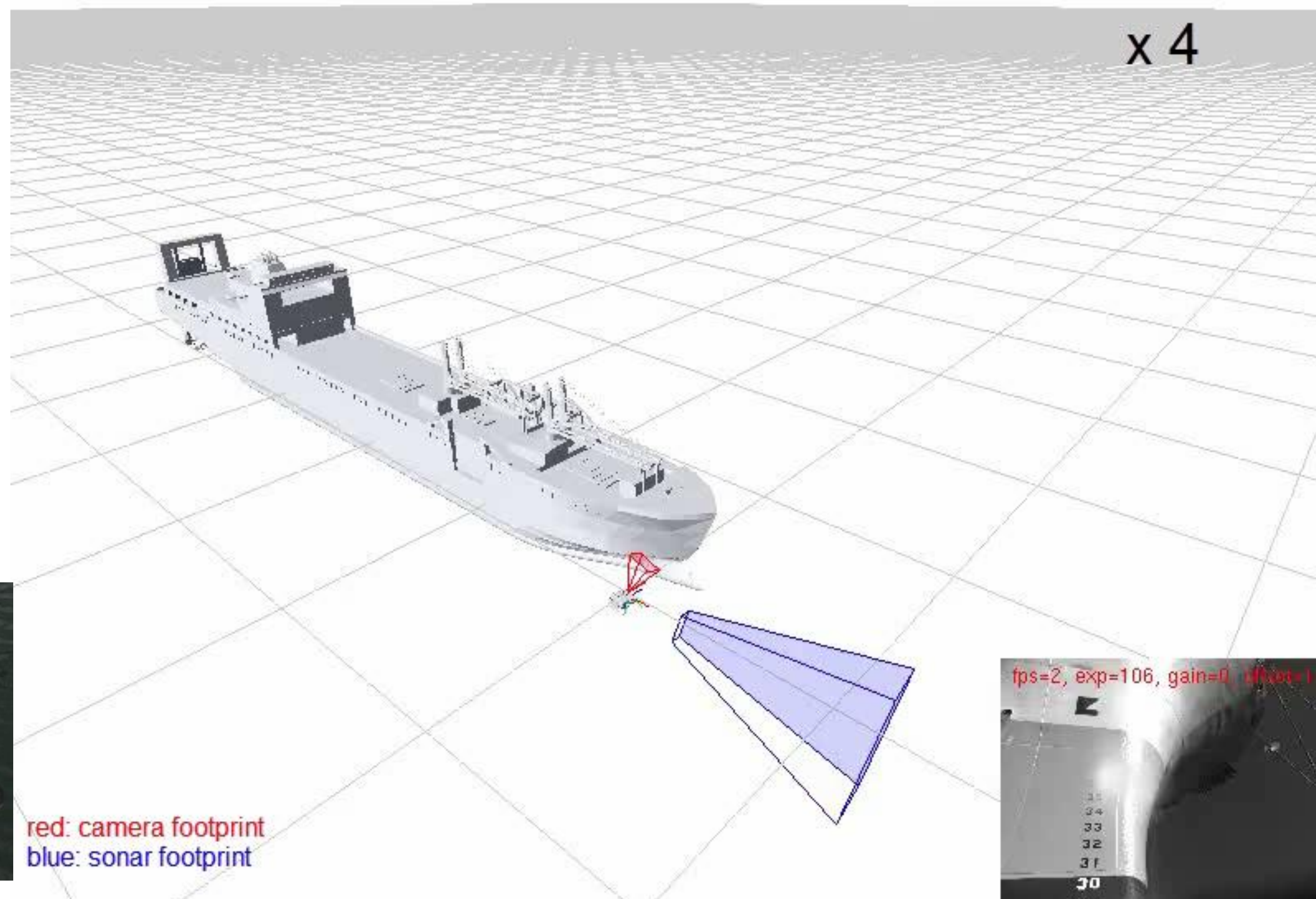
Underwater Visual SLAM

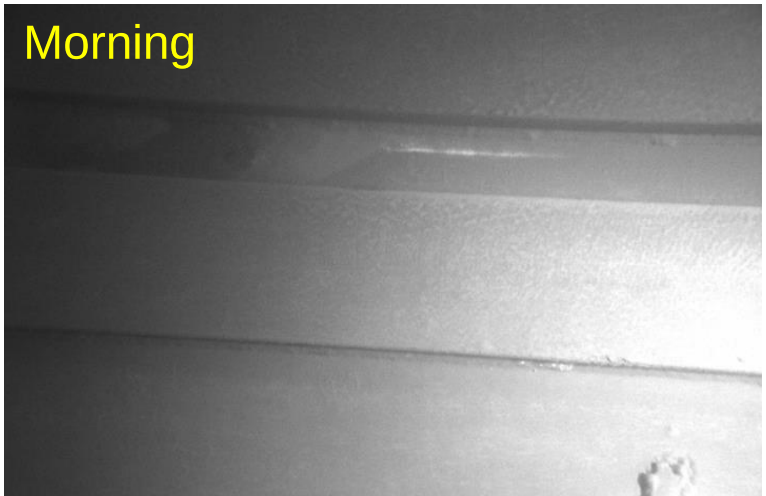




F. Hover, R. Eustice, A. Kim, B. Englot, H. Johannsson, M. Kaess, and J. Leonard. Advanced perception, navigation and planning for autonomous in-water ship hull inspection. Intl' J. of Robotics Research, 31(12):1445-1464, Oct. 2012

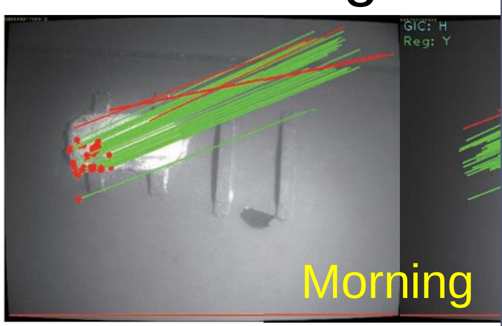
Visibility of Underwater Robotics

- Rapid Change of Underwater Visibility

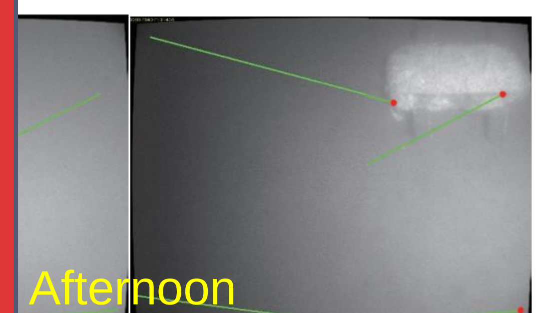


Sameday, morning and afternoon. Only 3 hours later.

- Visual navigation fails in turbid medium



How can we use
visual information
in turbid environment?

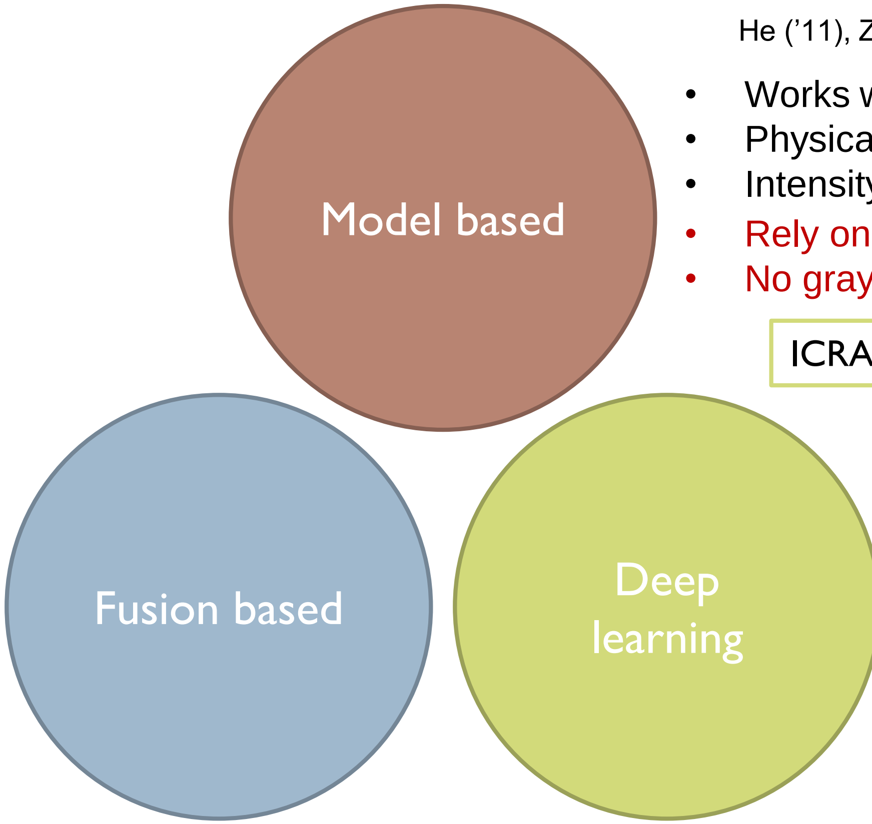


Approaches

He ('11), Zhu ('15), Berman ('16)

- Works well if the model is known
- Physical Meaning
- Intensity restoration
- Rely on priors
- No gray images

ICRA 2017 & JFR 2018



Ancuti ('13), Choi ('15)

- Works faster without knowing the model
- No Priors
- Detail enhancement
- Weak restoration

RAL 2018 (with IROS)

- No model needed
- Learnt from data

DehazeNET (`16) WaterGAN (`17)

Younggun Cho

Young-Sik Shin

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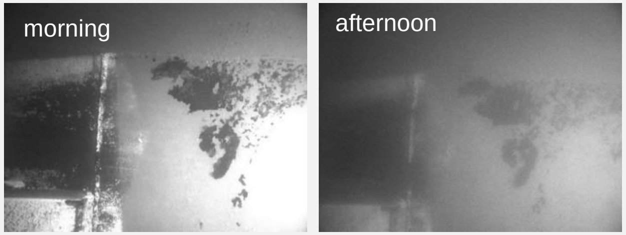
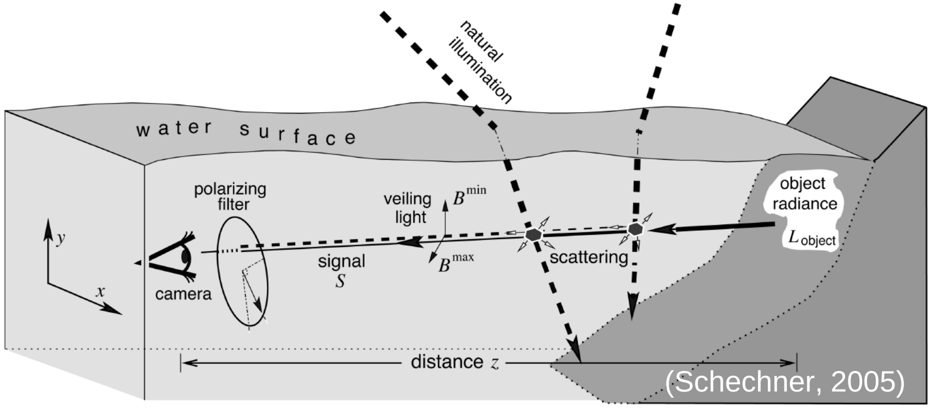
Model based Dehazing

Motivation

Typical underwater images





Basic modeling and focus

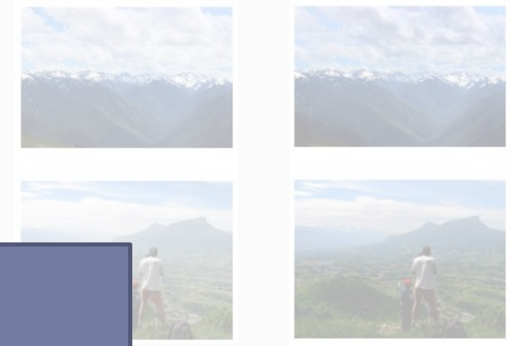
$$I(x) = J(x)T(x) + A(1 - T(x))$$

$$T(x) = e^{-\beta d(x)}: \text{ amount of light transmitted from surface to observer}$$

estimate airlight A and transmission map T

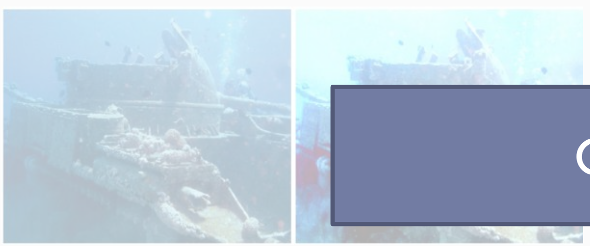
Other Studies

(He 2008) Dark channel prior



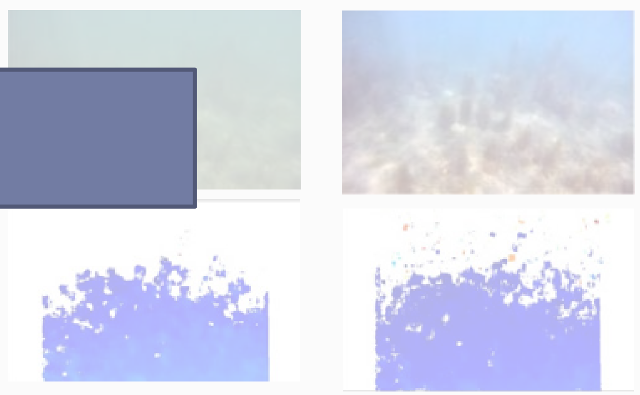
(Cai 2016) Dehazenet (CNN)

Computation Speed



(Carlevaris-Bianco, 2010) MRF modeled scene

Channel Independence



(Roser 2014) Stereo + Dehazing

(Ancuti, 2012) Multiscale Fusion

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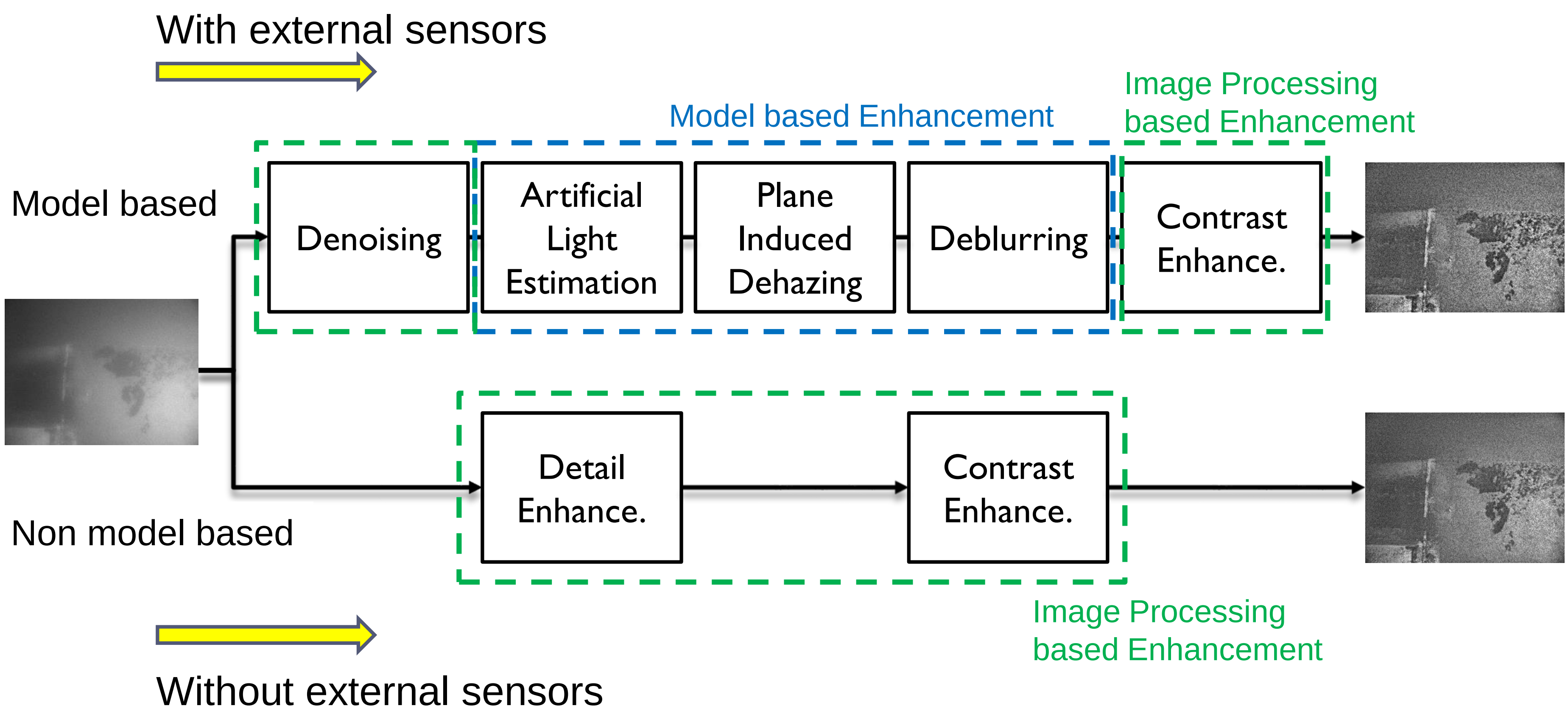
Proposed Method

- Two selective methods according to external sensors



Y. Cho and A. Kim, Visibility Enhancement for Underwater Visual SLAM based on Underwater Light Scattering Model. In Proceedings of the IEEE International Conference on Robotics and Automation, Singapore, May. 2017.

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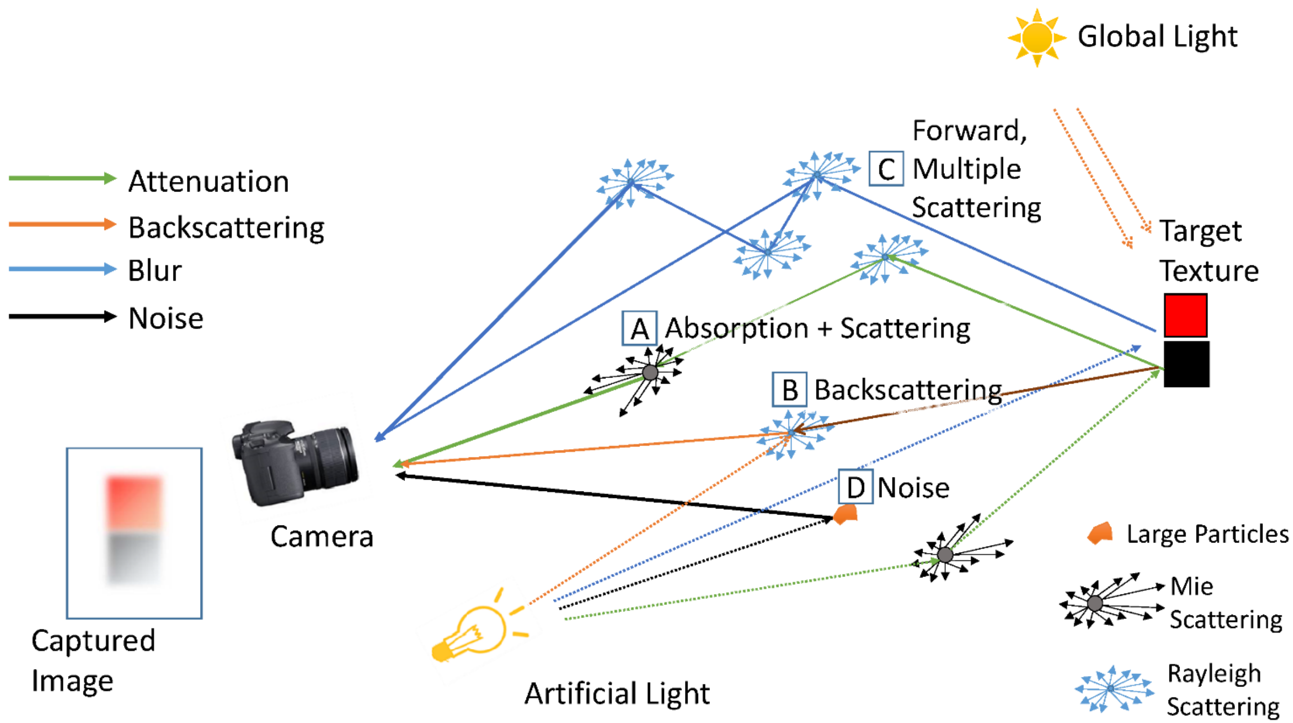
Model based Enhancement

- Complex image model of underwater environment



$$I(\mathbf{x}) = \underbrace{\overbrace{[(E_A + E_L(\mathbf{x}))\cdot\rho(\mathbf{x})]}^{\text{Reflected Radiance}} * \overbrace{h_{\text{psf}}(\mathbf{x})}^{\text{Blur}} \cdot e^{-\beta d(\mathbf{x})}}_{\text{Attenuation and Forward Scattering}} + \underbrace{(1 - e^{-\beta d(\mathbf{x})})\cdot(E_A + E_L(\mathbf{x}))}_{\text{Backscattering}} + \underbrace{N}_{\text{Noise}}$$

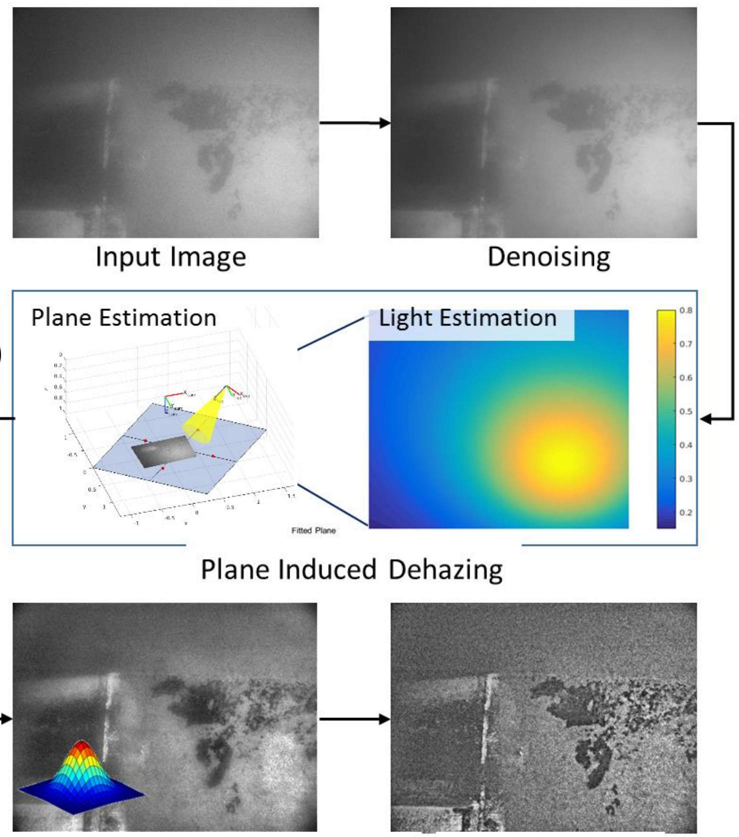
$$= J(\mathbf{x}) * h_{\text{psf}}(\mathbf{x}) \cdot e^{-\beta d(\mathbf{x})} + (1 - e^{-\beta d(\mathbf{x})})\cdot(E_A + E_L(\mathbf{x})) + N$$

Model based Enhancement

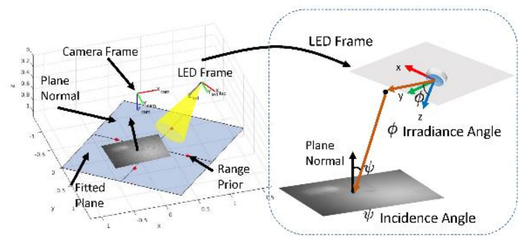
- Solving complex model sequentially

$$I(\mathbf{x}) = J(\mathbf{x}) * h_{\text{psf}}(\mathbf{x}) \cdot e^{-\beta d(\mathbf{x})} + (1 - e^{-\beta d(\mathbf{x})}) \cdot (E_A + E_L(\mathbf{x})) + N$$

- Light distribution estimation using range information



$$L(\mathbf{x}) = \frac{U_0 \cos^m \phi(\mathbf{x}) \cdot e^{-\beta l(\mathbf{x})}}{l(\mathbf{x})^2 \cdot \cos(\psi(\mathbf{x}))}$$



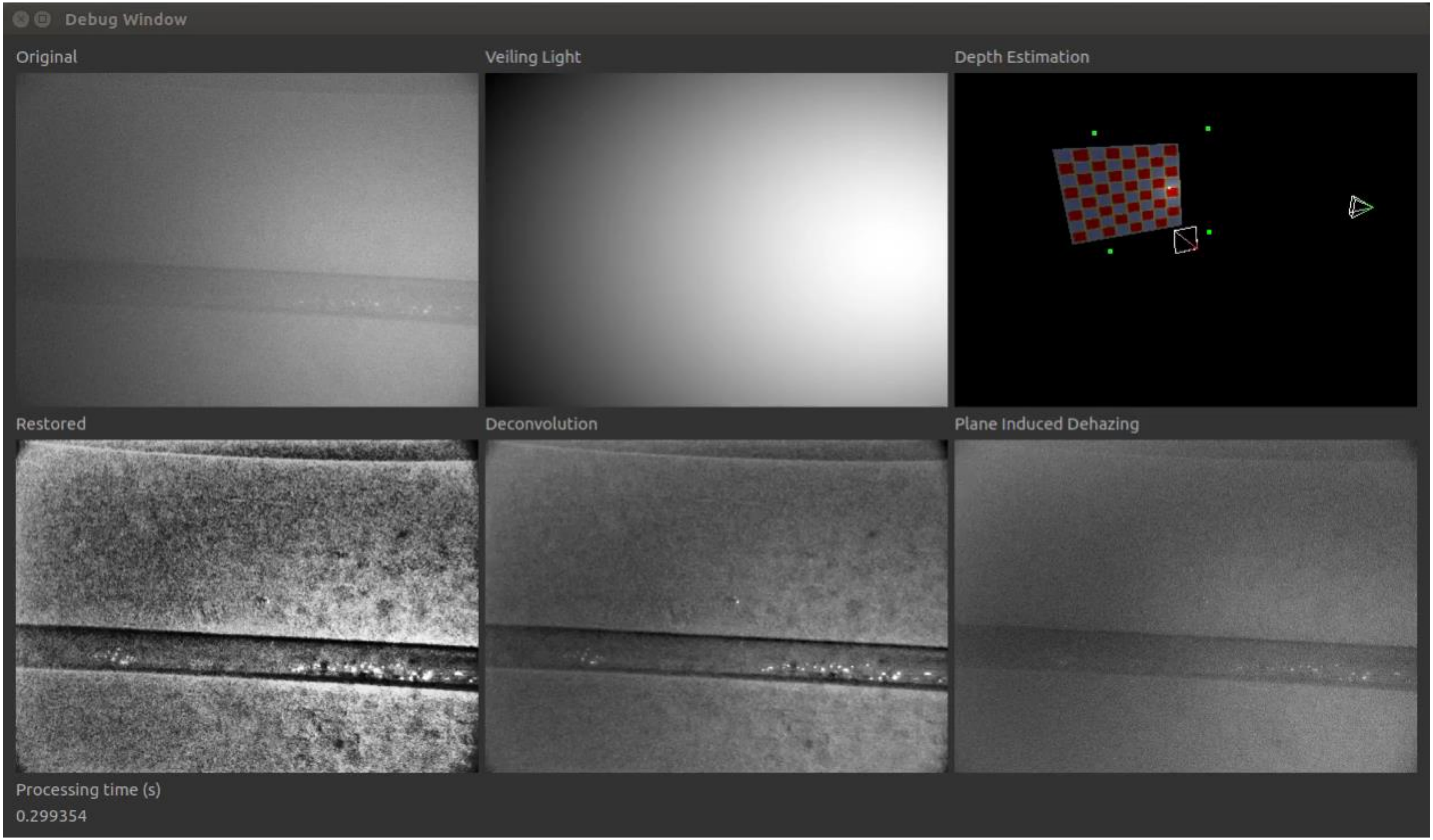
$$J_{\text{plane}} = J(\mathbf{x}) * h_{\text{psf}} = \frac{I_{\text{de}} - E_L(\mathbf{x})}{e^{-\beta d(\mathbf{x})}} + E_L(\mathbf{x})$$

$$h_{\text{psf}}(u, v, \eta, p, \sigma) = \frac{e^{-\left(\frac{u^2+v^2}{A(p,\sigma)}\right)^{0.5p}}}{2\Gamma(l + 1/p)A(p,\sigma)}$$

Deblurring & Contrast Enhancement
(PSF deconv, Rayleigh CLAHE)

Restored Image

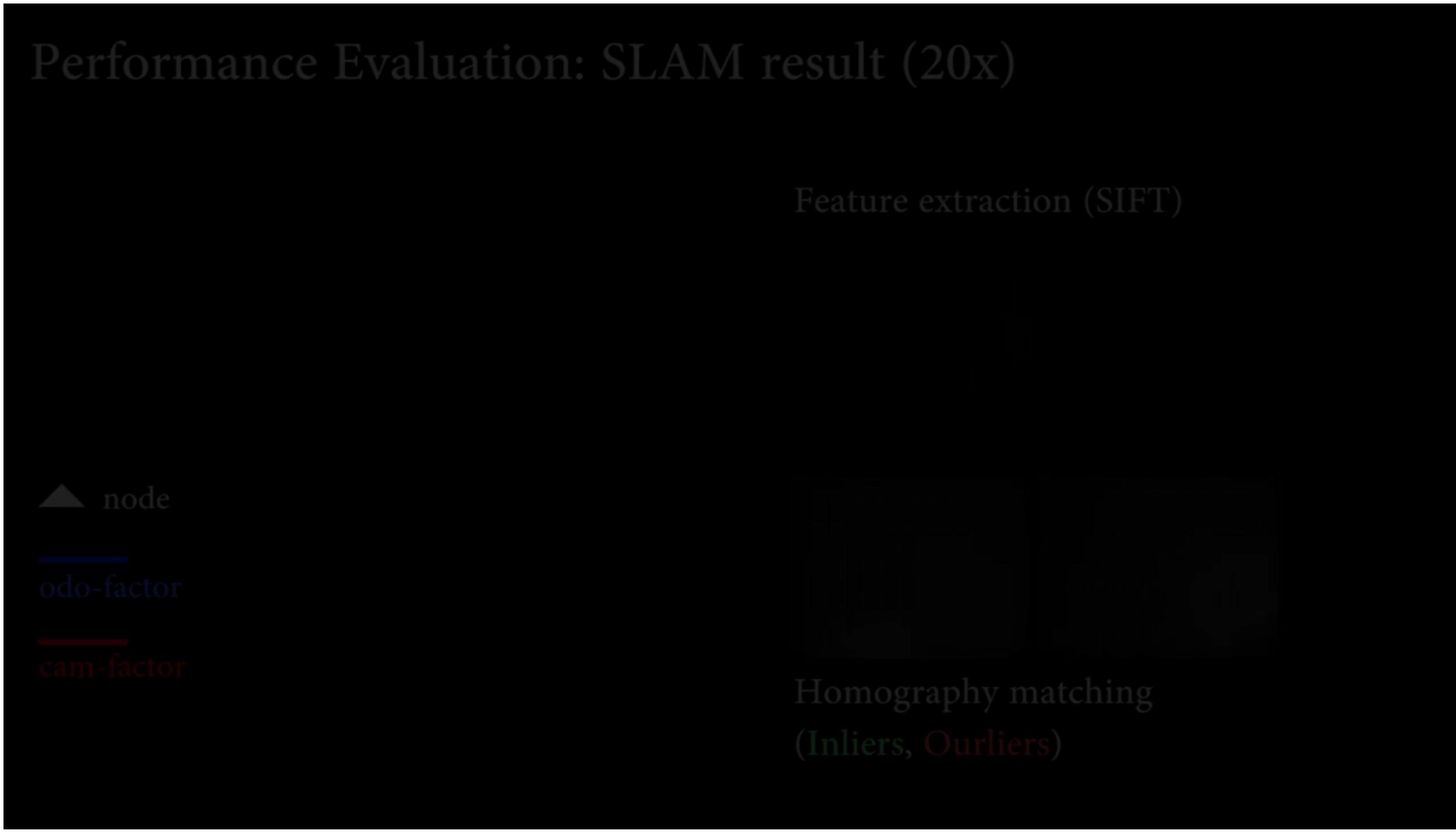
Model based Enhancement Details



Model Free Enhancement Details

GitHub https://github.com/irapkaist/visibility_enhancement

SLAM Result



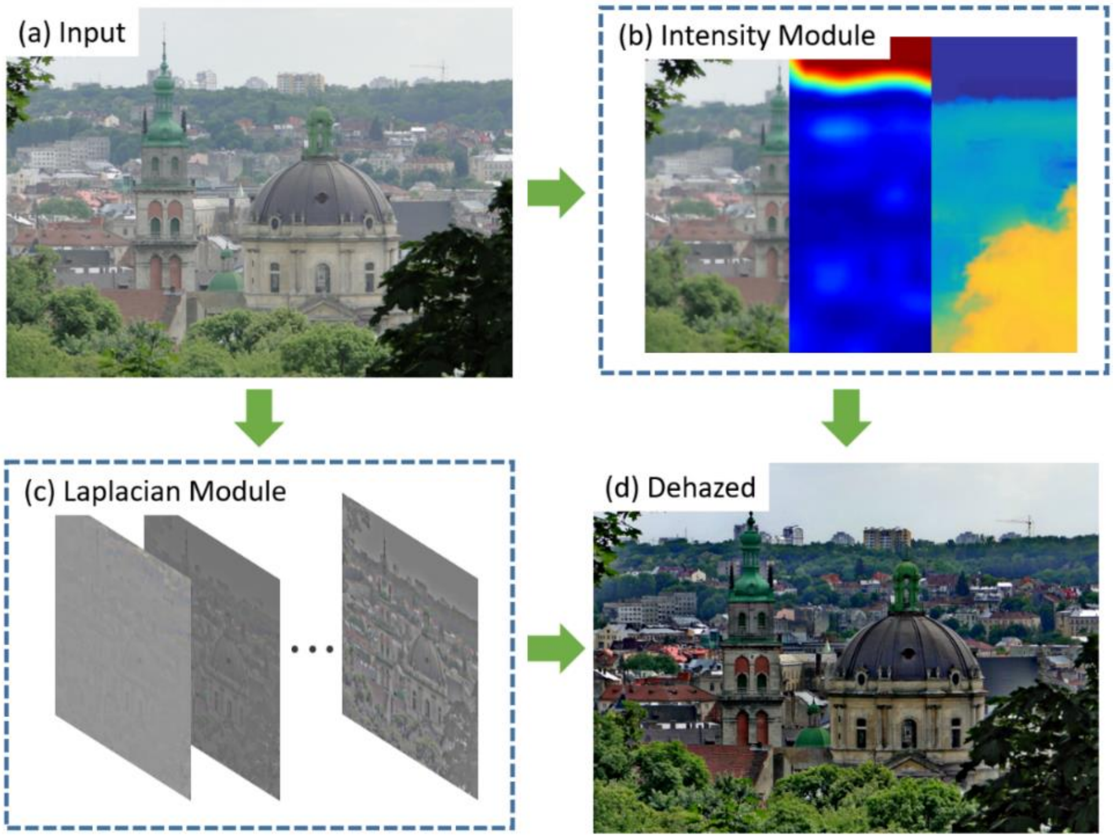
Younggun Cho and Ayoung Kim, Channel Invariant Online Visibility Enhancement for Visual SLAM in a Turbid Environment. Journal of Field Robotics, 35(7):1080-1100, 2018.

Model & Fusion-based Dehazing

Model vs Fusion

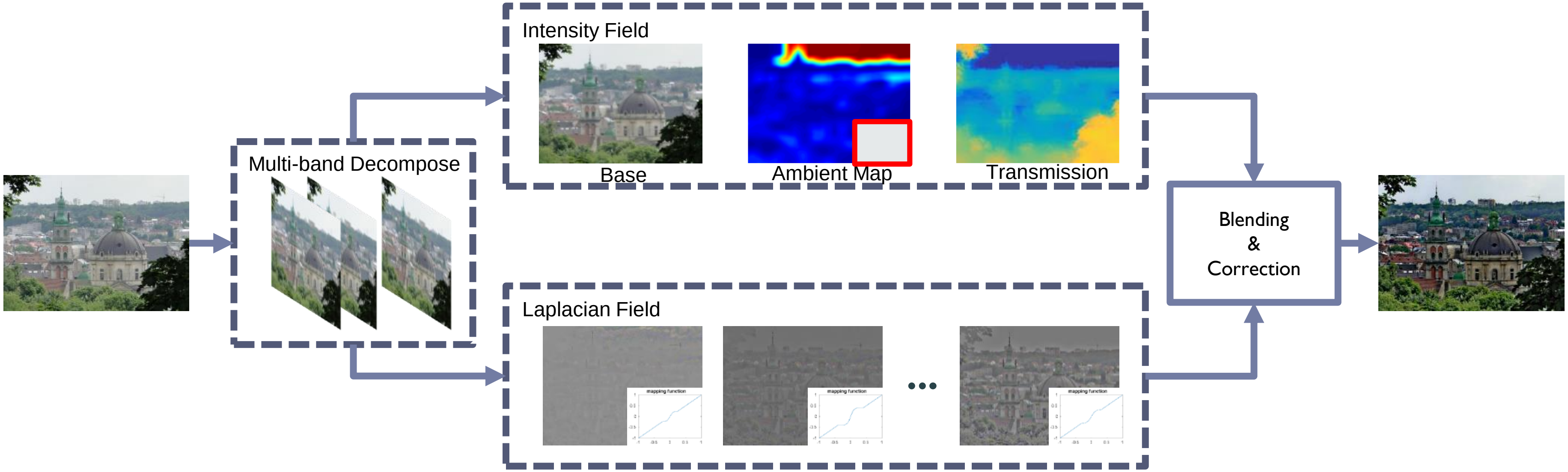
Our Objectives

1) Fast to use
2) Well-detailed images
3) Working on both color and gray images



Overview

- Multi-band decompose
- Balanced dehazing between far and near objects
- No prior needed

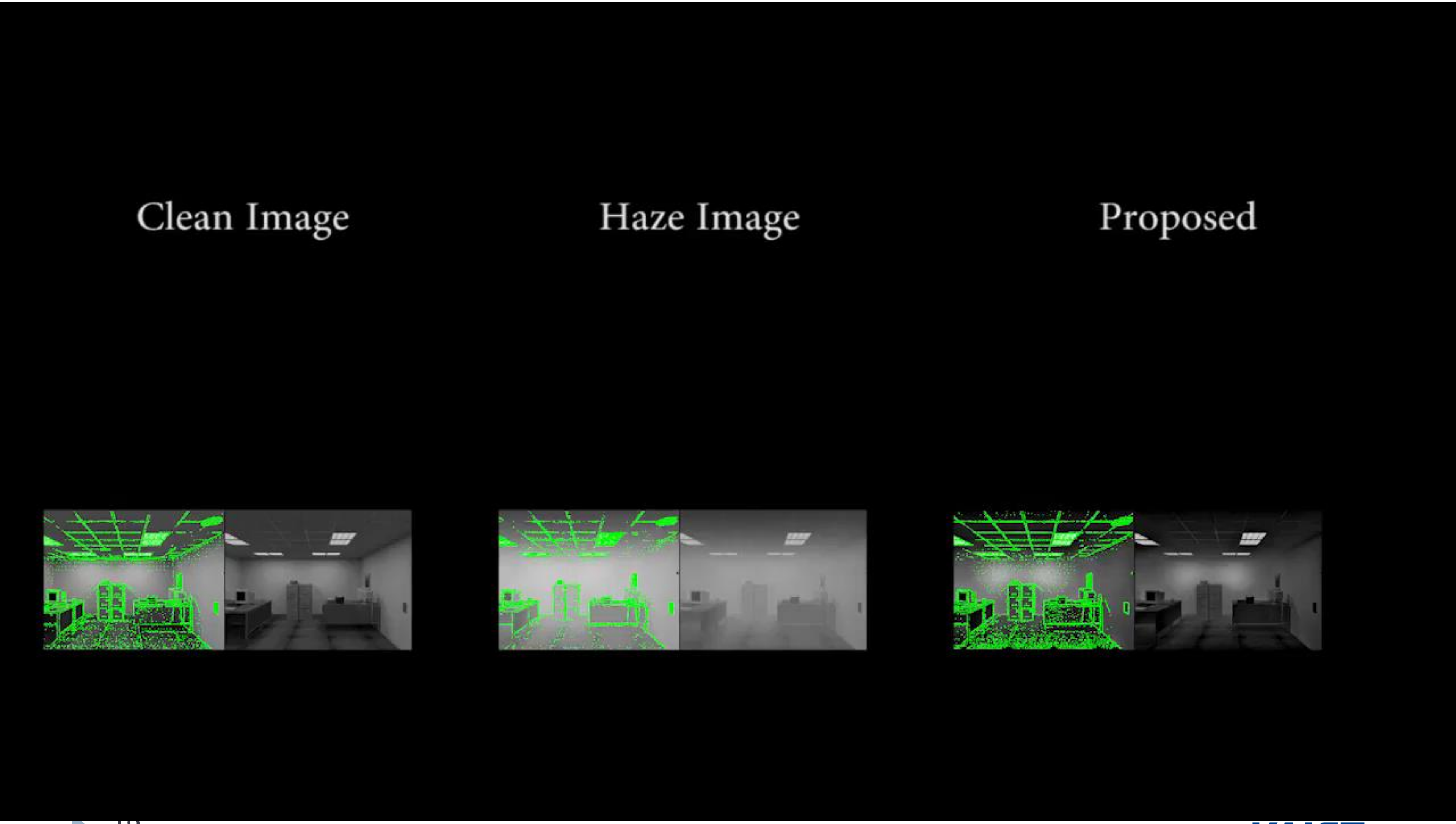


Younggun Cho, Jinyong Jeong and Ayoung Kim, Model Assisted Multi-band Fusion for Single Image Enhancement and Applications to Robot Vision. IEEE Robotics and Automation Letters (RA-L) (with IROS), 3(4):2822-2829, 2018.

Channel Invariant Dehazing

Video Results

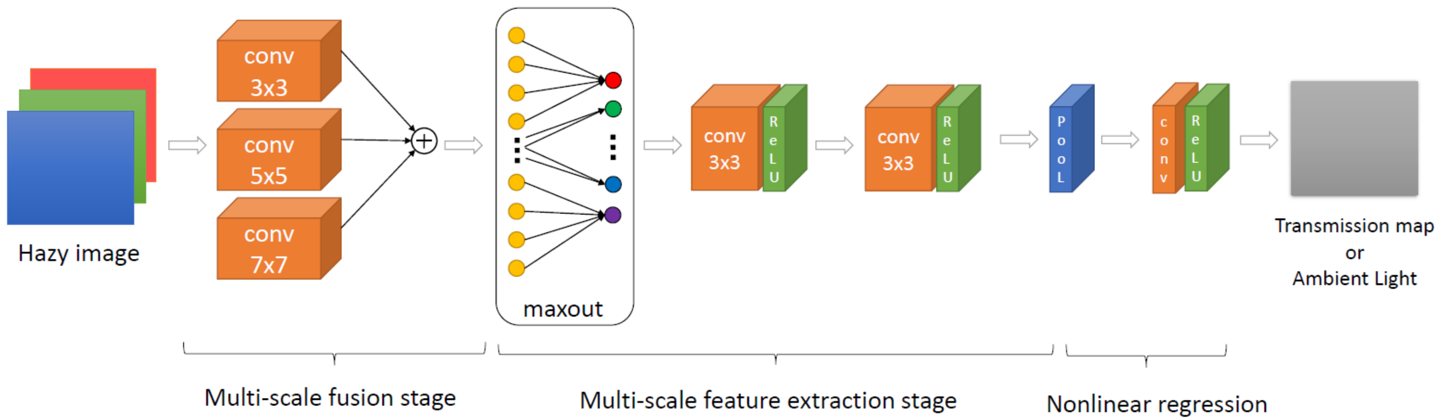
SLAM Results

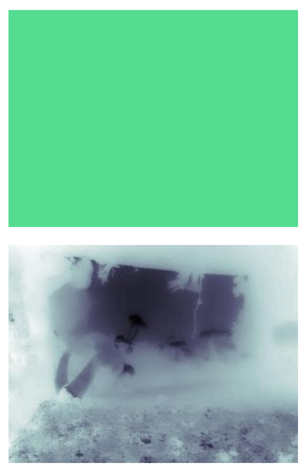


Deep Learning based Dehazing

Ambient Light Estimation and Dehazing

- Deep learning algorithm





Y. Shin, Y. Cho, G. Pandey and A. Kim, Estimation of Ambient Light and Transmission Map with Common Convolutional Architecture. In Proceedings of the IEEE/MTS OCEANS Conference and Exhibition, pages 1-7, Monterey, CA, Sep. 2016.

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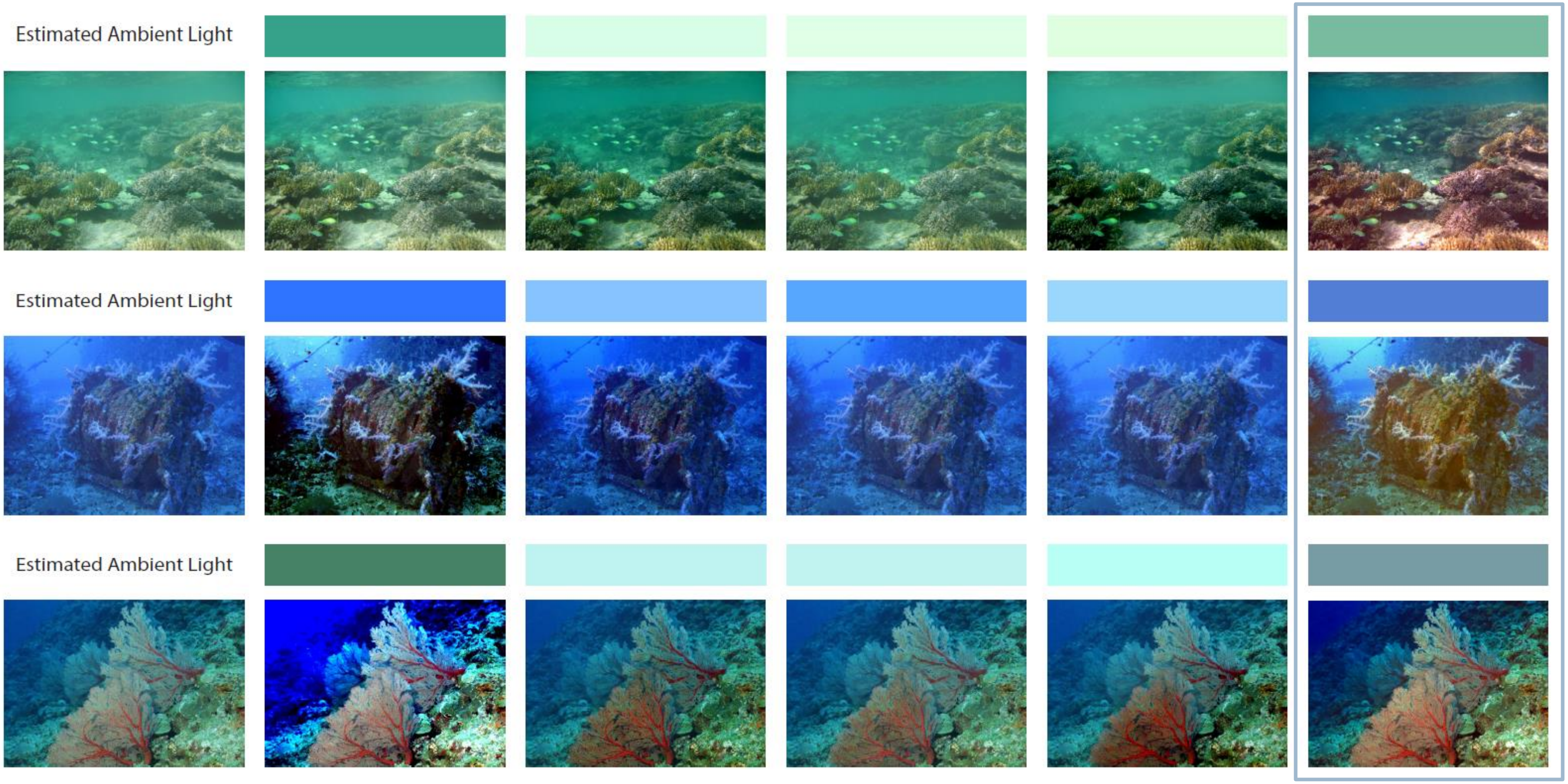
Dehazing Results



(a) Original Image. (b) Carlevaris-Bianco (c) He (d) Zhu (e) Cai (f) proposed

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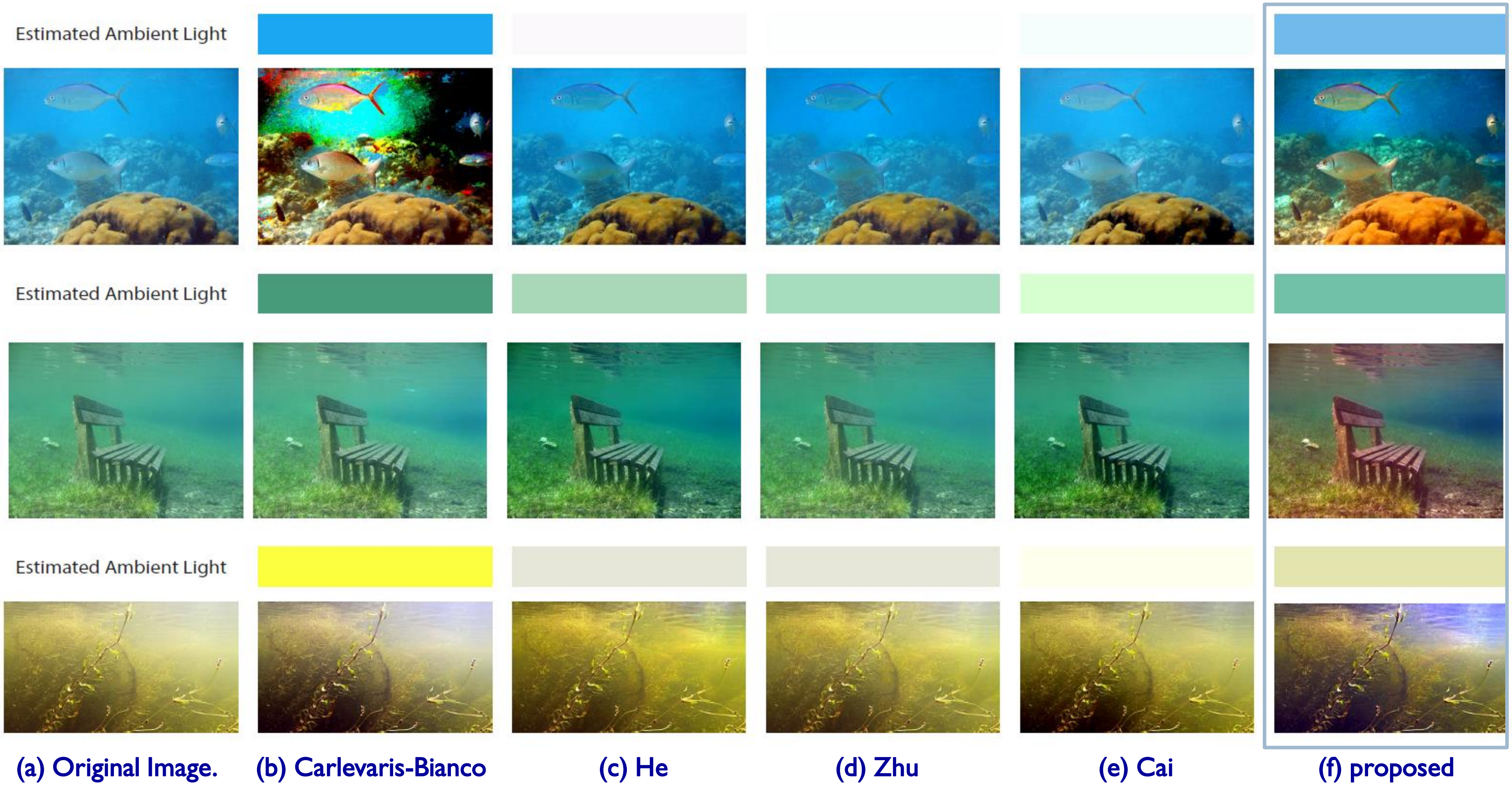
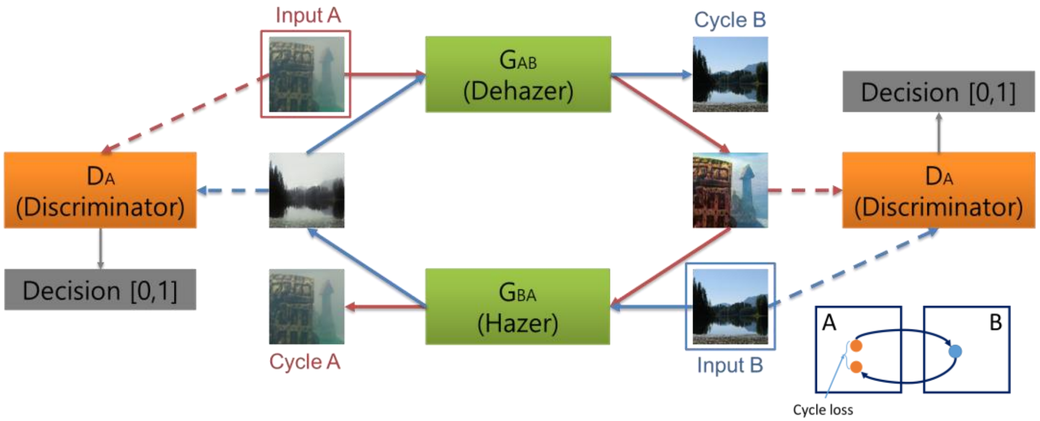
Dehazing Results

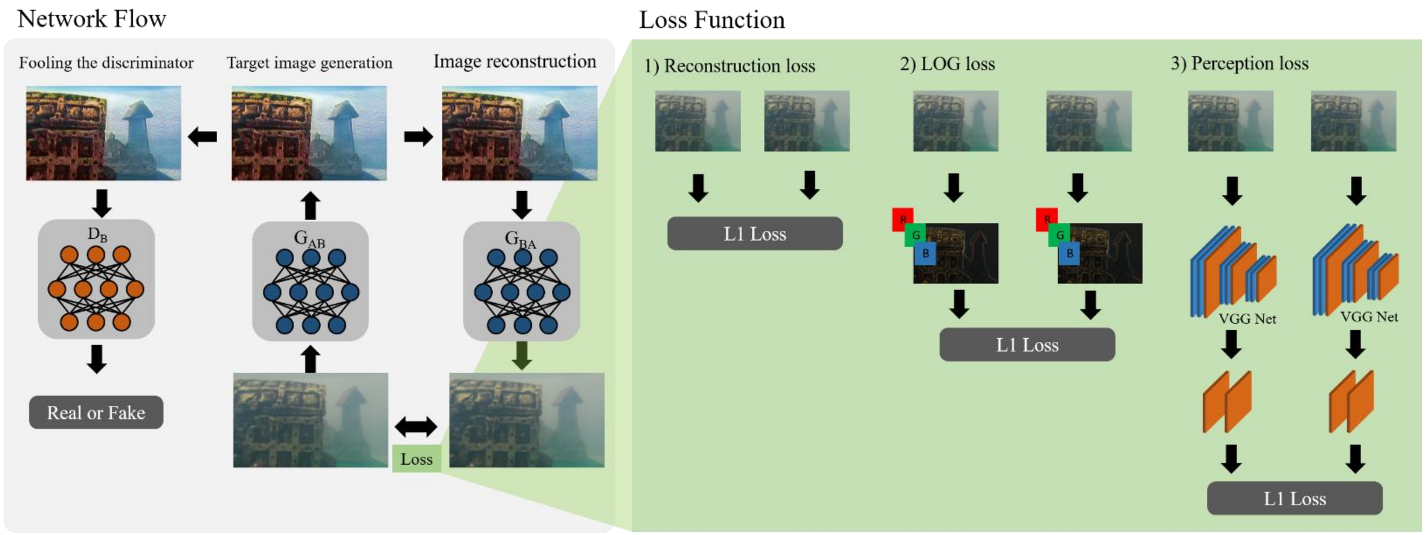


DehazeGAN

- Overall network[1]

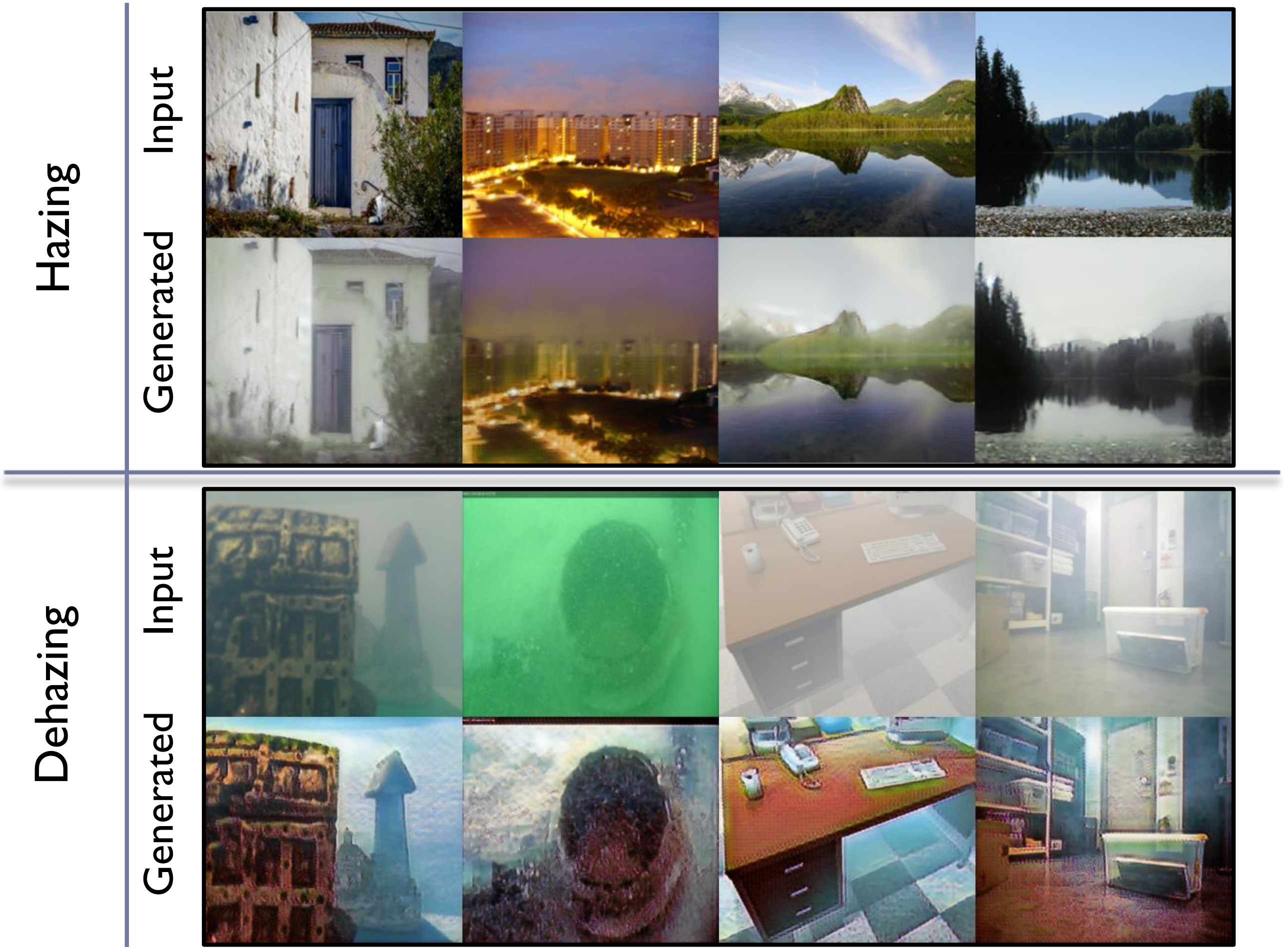


- Detail enhanced image restoration via multiple loss functions



[1] J. Zhu, et al. "Unpaired image-to-image translation using cycle-consistent adversarial networks." arXiv , 2017.

Preliminary Results



Y. Cho, R. Malav, G. Pandey, A. Kim, DehazeGAN: Simultaneous Hazing and Dehazing Networks Using Unpaired Image-To-Image Translation, IROS poster session 2017.

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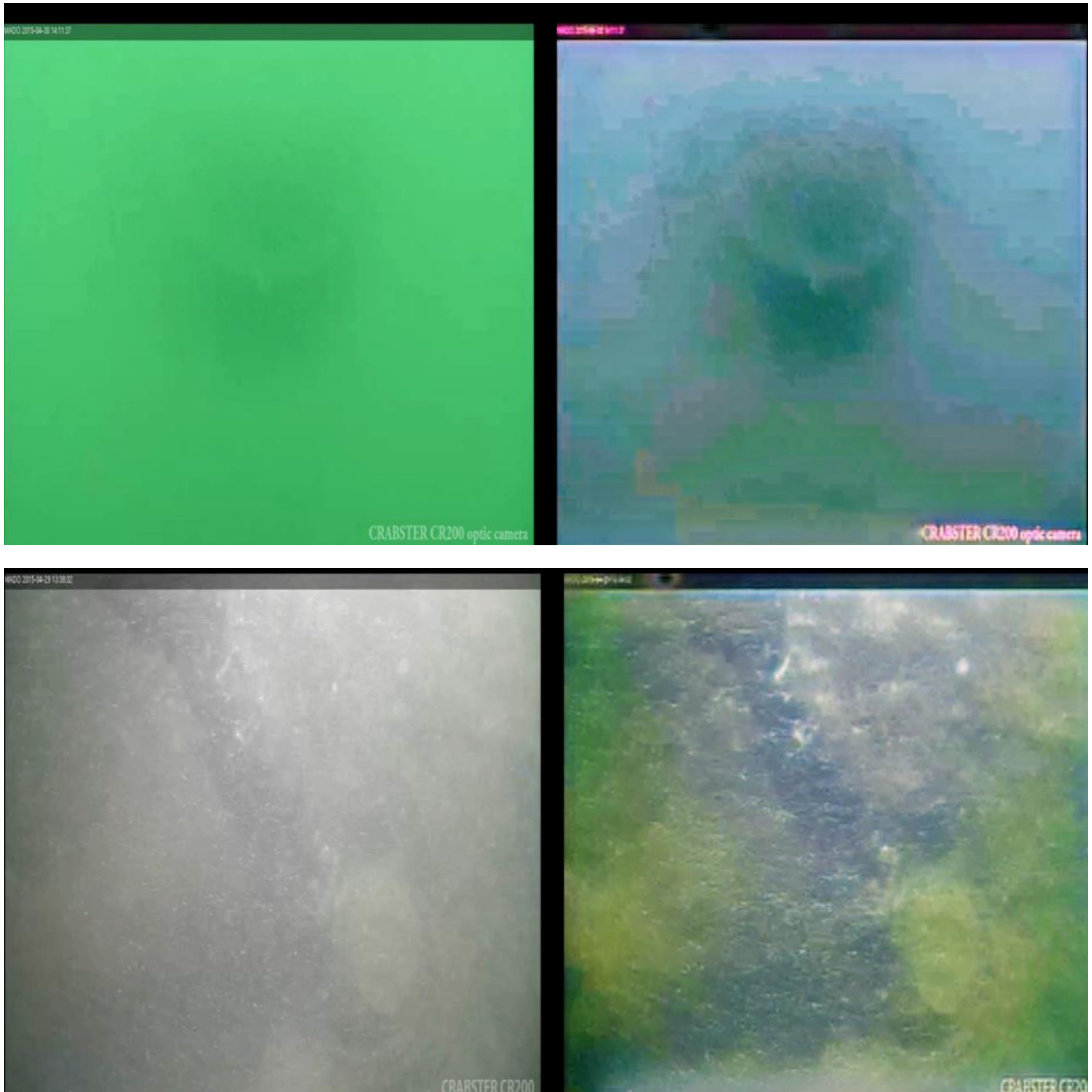
Preliminary Results



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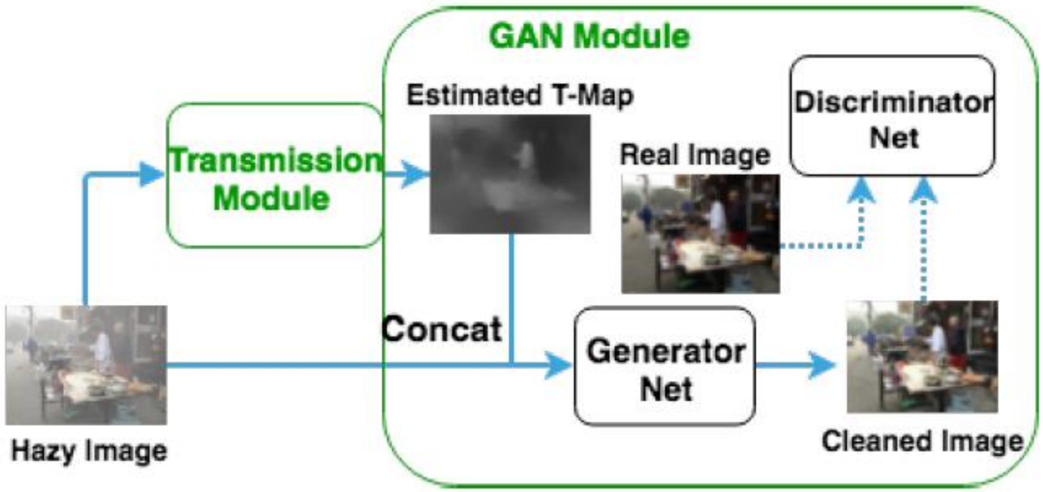
DHSGAN: De-Haze and Smoke GAN



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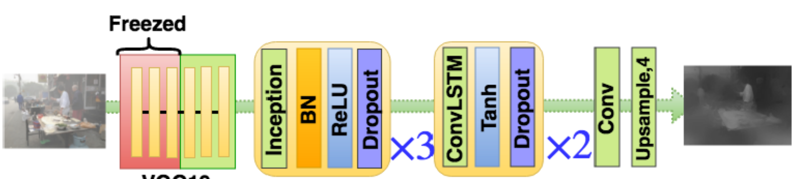
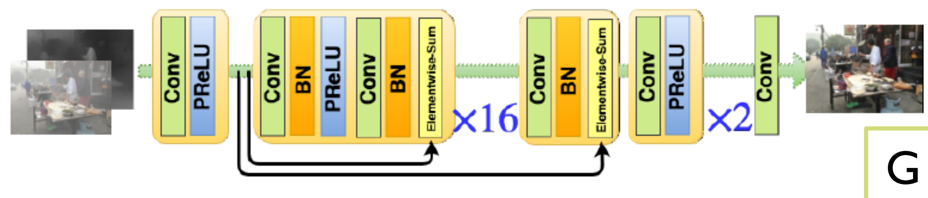
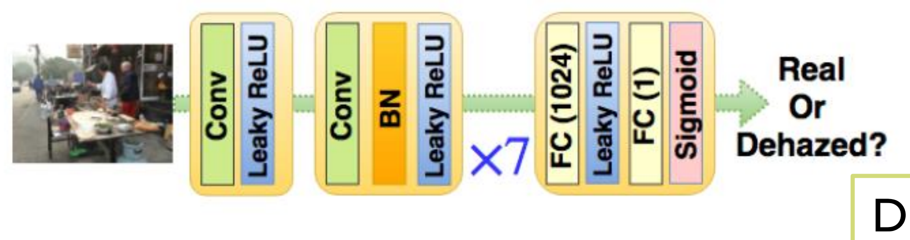


Transmission module (T)





Ramavtar Malav, Ayoung Kim, Soumya Ranjan Sahoo and Gaurav Pandey, DHSGAN: An End to End Dehazing Network for Fog and Smoke. In Asian Conference of Computer Vision (ACCV), Perth, Dec. 2018.

DHSGAN: De-Haze and Smoke GAN

GitHub https://github.com/rmalav15/DHSGAN

Concluding Remarks

- Visual enhancement for visual SLAM
  - Dehazing from image processing
  - Model based image enhancement
  - Deep learning toward image enhancement

- Consideration for robotics application
  - Computational speed (1 – 2Hz)
  - Channel invariance (grayscale)
  - Color consistency (direct SLAM)

- Codes
  - https://github.com/irapkaist/visibility_enhancement
  - https://github.com/rmalav15/DHSGAN

Acknowledgement

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- Works from our groups are by

Youngsik Shin
(Ph.D. Program)

Younggun Cho
(Ph.D. Program)

- Collaborators

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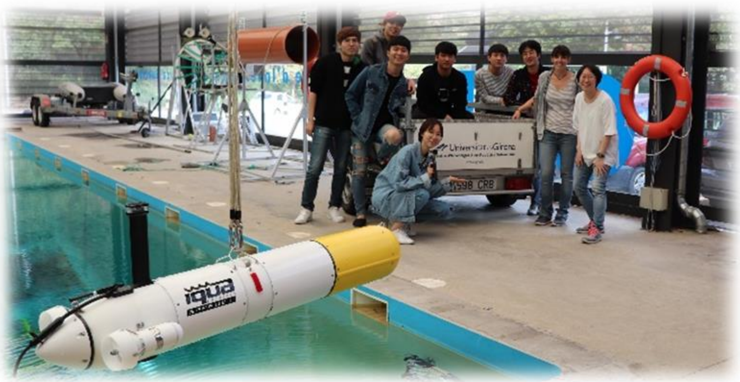

Thank you very much !!