Underwater image processing, how to improve visibility?

Mohine Boudhane, Ojars Balcers

Vidzeme University of Applied Sciences

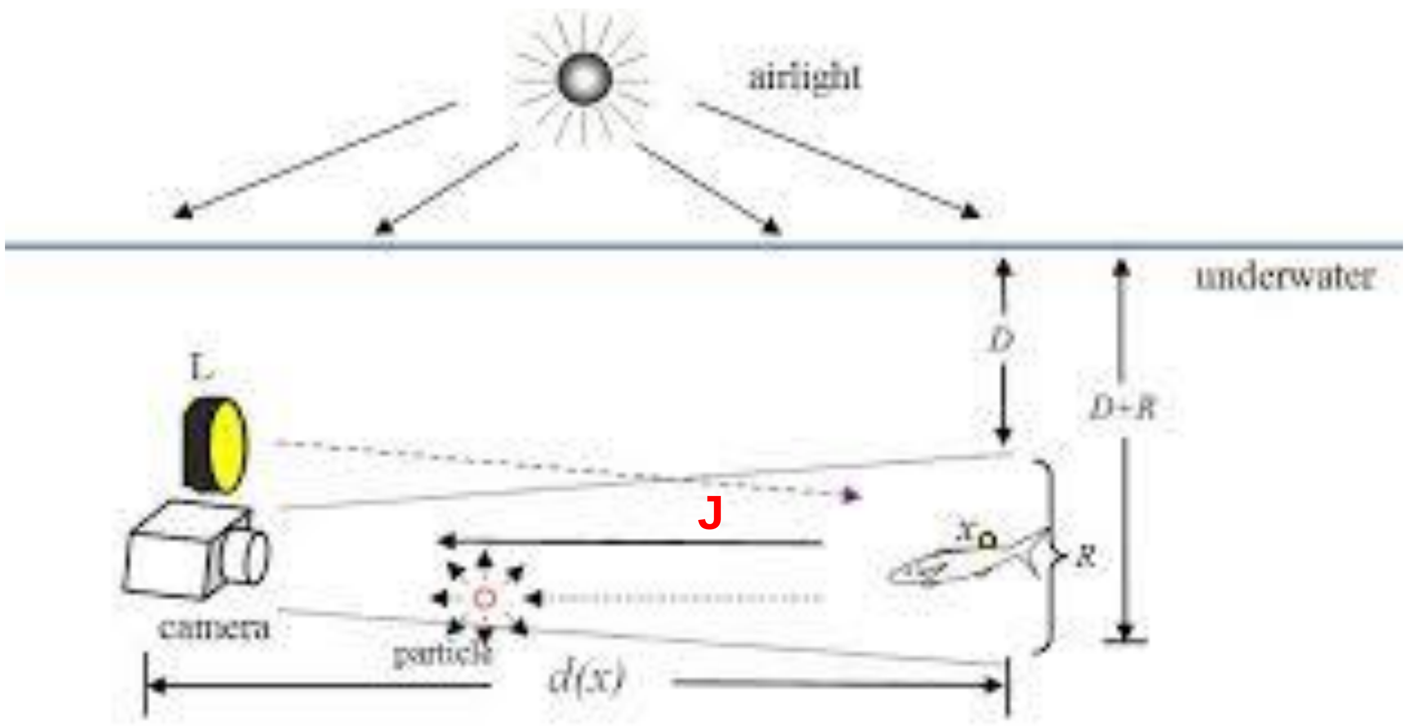
Exploring the underwater world (issues)

Oceans cover about 70% of the earth's surface. It contains animal, mineral and raw material resources. Exploring its resources is a key topic around the world.

- Latvia has a coastline stretching over 531 km
- 12,500 rivers, which stretch for 38,000 km. Major rivers include the Daugava River, Gauja, and Salaca, the largest spawning ground for salmon in the eastern Baltics.
- Fishing potential estimated by FAO (Food and Agriculture Organization) at around 82,300 tonnes/year.
- The sector employs 13 900 people, which is 1.2% of the total economically active population of Latvia.

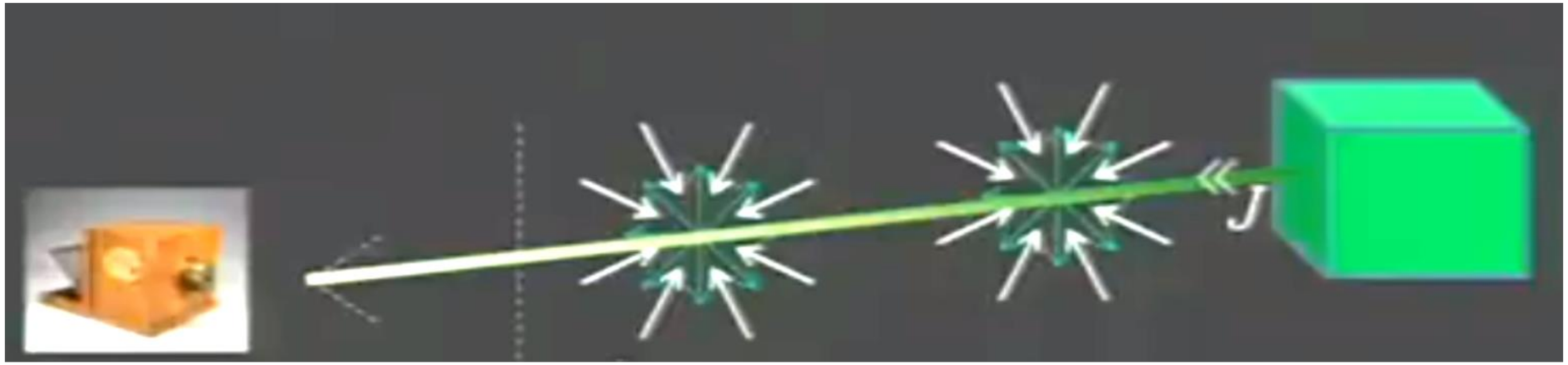
2

Problem



- **Light reflected by an object (*noted J*) undergo scattering along its way to the camera.**

Problem

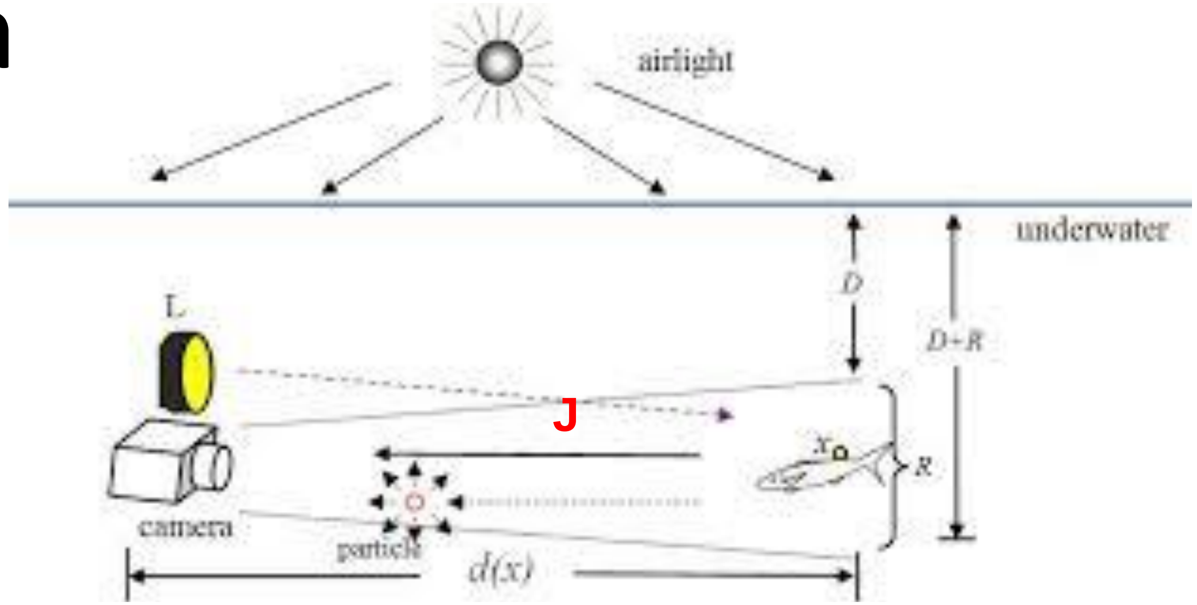


J is the original light
B scattering effect

Effects : light produce a distinctive gray or bluish hue and affects visibility

How to restore the original penetrated light ?

Problem



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

- I(x) : raw image
- t(x)J(x): light reflected by the object
- A : environment light (Air light)
- t(x): transmission

$$t(x) = e^{-\beta d(x)}$$

Proposed model

__Mathematical Model:__

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

$$t(\mathbf{x}) = e^{-\beta d(\mathbf{x})}$$

- **I**(**x**) is the observed radiance at **x**
- **J**(**x**) is the original scene radiance at **x**
- **A** is the ***environmental light***
- t(**x**), scalar called ***transmission****:* describes how the radiance of a point in the scene is attenuated according to its distance *d* from the observer
- Note that **I, J, A** are (R,G,B) triplets

The Atmospheric Scattering Model

Mathematical Model:

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

$$t(\mathbf{x}) = e^{-\beta d(\mathbf{x})}$$

- In order to remove these effects, we must recover J(x)
- **I**(**x**) is known
- Quantities **A** and *t* are typically unknown

State of the art

- Can be grouped into several categories
  1. *With multiple images*
  2. *With one image + depth-map*
  3. *Single image*
- We are mostly interested in Single-Image methods

Summary

Multiple image methods

- require special equipment (polarizers) or same scene under different weather conditions.
- They don’t necessarily produce better results than single-images approaches

Summary

Single-Image methods

- do not require special equipment, nor extra information
- They either make assumption on the nature of the scene, or require little interaction by the user

Multiple Image Approaches

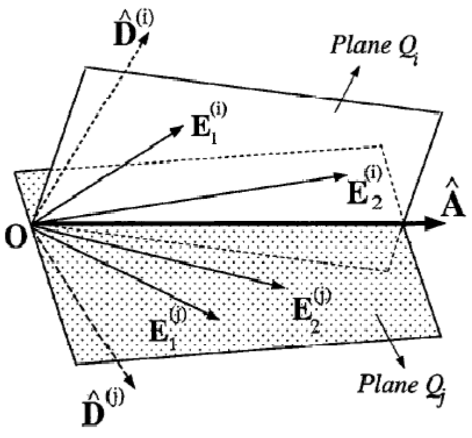


Figure 13. Intersection of two different dichromatic planes yields

Narasimhan & Nayar's method

- Assumes 2+ bad weather images are given
- Uses geometric constraints to estimate **A**
- The airlight component [1-t(**x**)] is estimated from corresponding pixels of the two bad weather images

One Image + Depth + Texture

Kopf et al. Method: *Deep Photo* **project from SIGGRAPH 2008**

- Assumes a 3D model of the scene is given (e.g.: from Google Maps)
- Assumes textures of the scene are given (from satellite or aerial photos)
- Requires user interaction to align the 3D model with the scene
- Very accurate results

Proposed approach

- **Limitation:**

Different equations with different unknowns.

I_1= t_1J + (1 - t_1)A

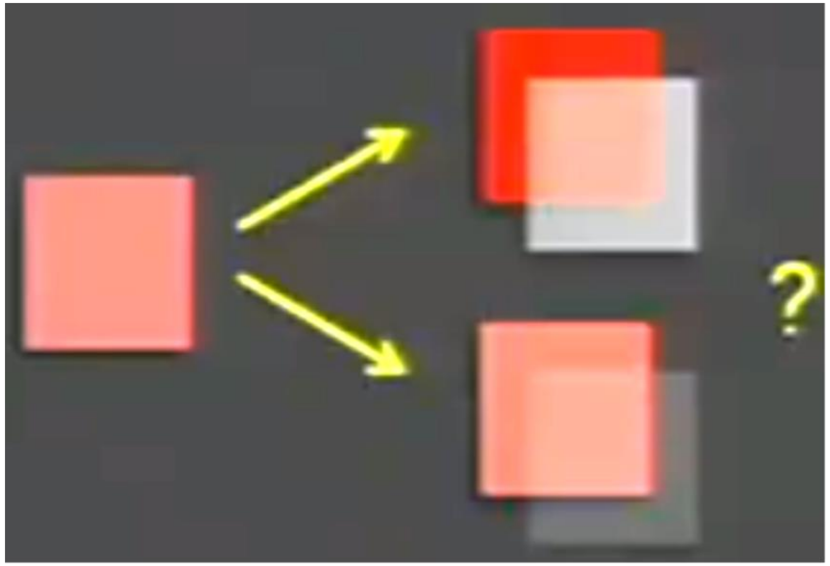
I_2= t_2J + (1 -t_2)A

In this case we have 5 unknowns (t_1, t_2, J_R, J_G, J_B) and 6 equations

Proposed approach

- **Airlight-albedo ambiguity**

- Deeply structured red color
- Masked with tiny layer of haze



Proposed approach

- In this model we suppose that the original image is composed by two components: shading *l (scalar)* and reflectance R (3D vector).

$$J(x) = l(x)R(x) \tag{3}$$

Redefined model:

$$I(x) = t(x)l(x)R(x) + (1 - t(x))A \tag{4}$$

Proposed approach

$$I(x) = t(x)l(x)R(x) + (1 - t(x))A \qquad (4)$$

- We assume that the reflectance R is constant in each region.

$$R(x) = R(const)$$

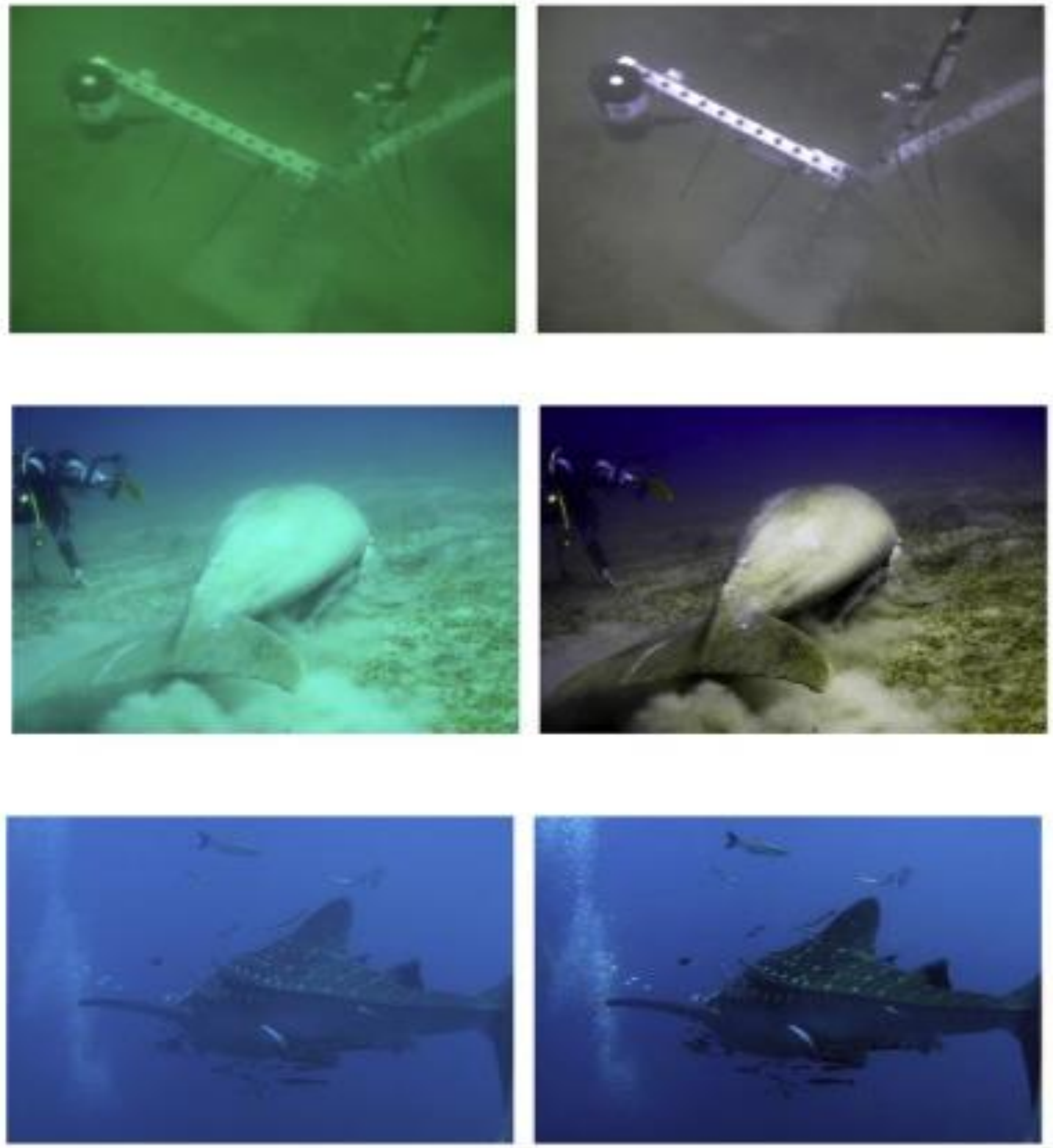
In order to measure the two unknowns (shading l and medium light A) independently, we proceed by multiple derivation using **Piece-wise constant albedo**. The above calculation process is described by the following formula.

$$I_A(x) = < I(x), A > = t(x)l'(x)\eta + (1 - t(x))(A) \qquad (5)$$

$$I_{R'}(x) = < I(x), R' > = t(x)l'(x) \qquad (6)$$

Simulation results

The proposed algorithm is tested in ordinary computer (Core i5, 2.3GHz, RAM: 4Go). The input images are in JPG format (600×400 images). This figure presents simulation results applied on underwater images.



(a) (b)

Simulation results

Raw image

By **Narasimhan** et.al

By **the proposed approach**

THANK YOU