Underwater camera calibration

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1. Introduction

The underwater 3D scanning systems have applications in underwater mapping of the archaeological sites, as sensors on the autonomous underwater vehicles, and for the tracking of the underwater life in aquaculture.

An underwater camera scans an object through the protective glass which causes the light to refract on both the air-glass and the glass-water boundaries making the design process of such systems a challenging task.

2. Refraction

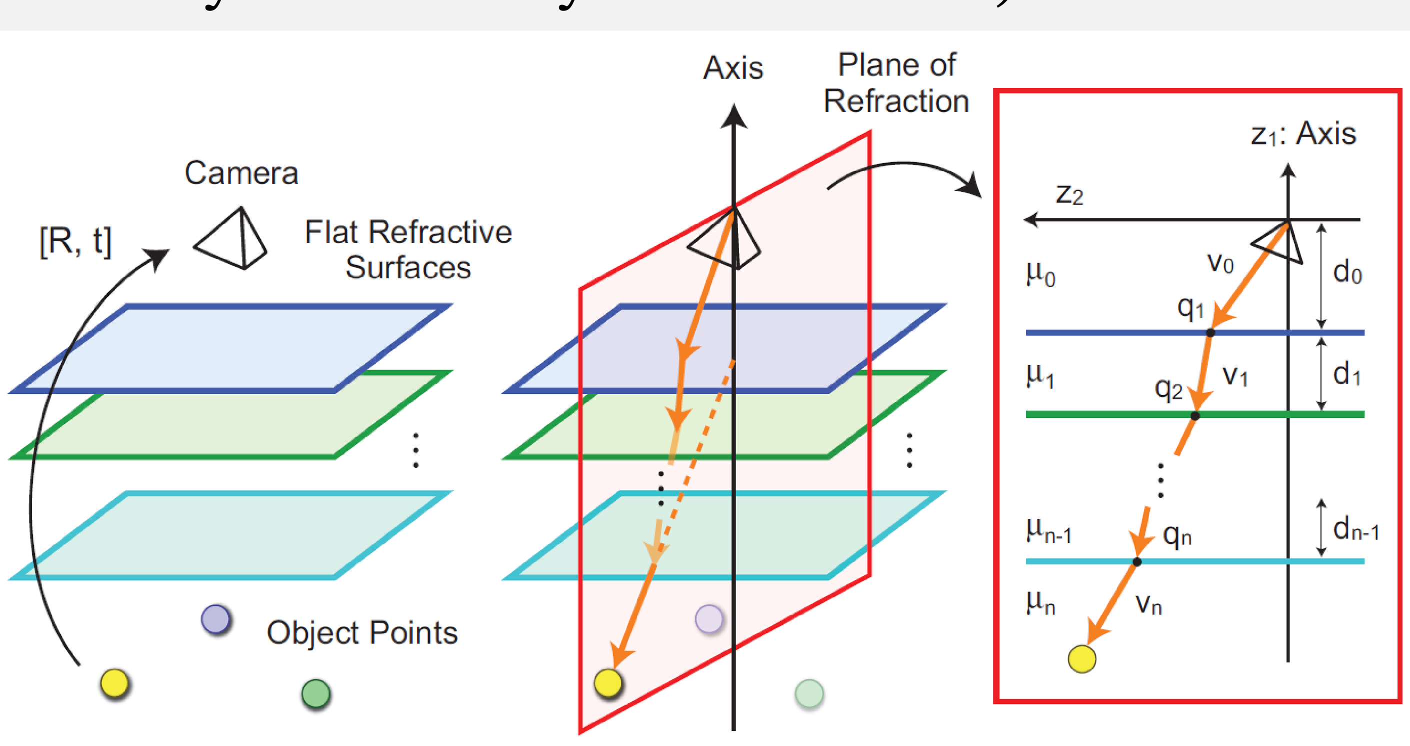
Underwater scanning is simulated in a lab using a water tank where the camera captures the submerged object through a flat refractive glass interface.

Scanning system (a projector and a pair of cameras)

Water tank (empty)

3. Camera calibration

A calibration object is scanned through *n* parallel flat refractive layers. The plane of refraction (POR) is spanned by camera's axis **A** and the layers normal **n** and contains the whole light path of any point on the object's surface (all refracted rays across *n* layers are on POR).

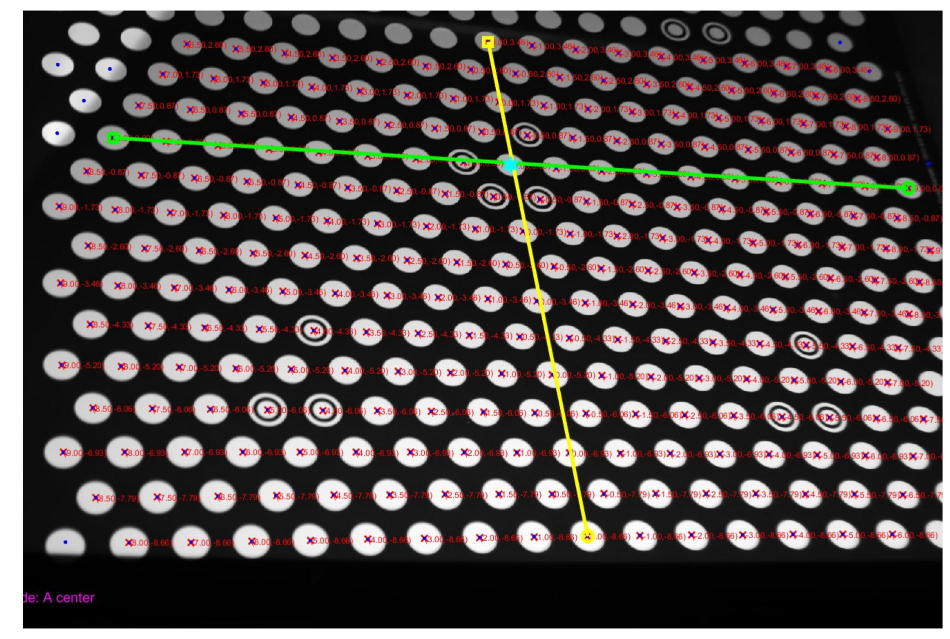


Refractive geometry across n-layer system

The calibration process consists of the following steps:

1. A standard camera calibration in the air
2. Imaging of the submerged calibration board in many poses
3. Estimation of camera's pose and axis
4. Estimation of layers' thicknesses
5. Visualization of the recovered refraction geometry

Underwater scanning

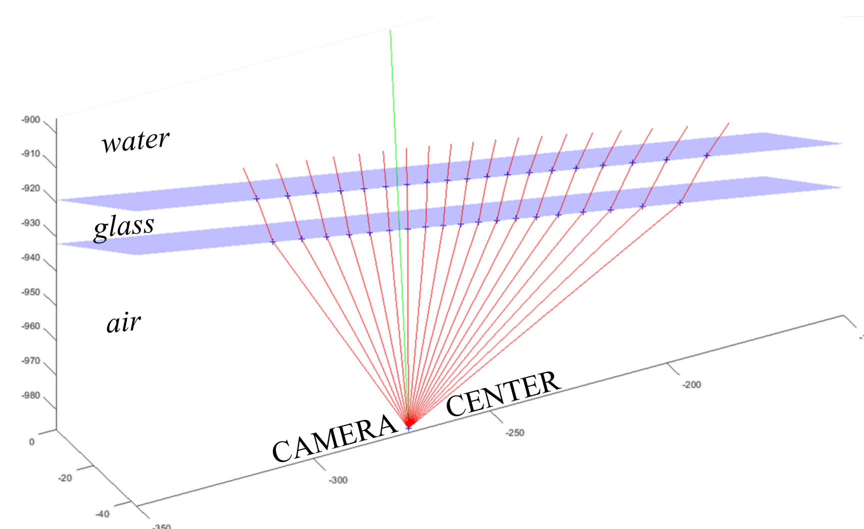


Circle detection on the submerged calibration board

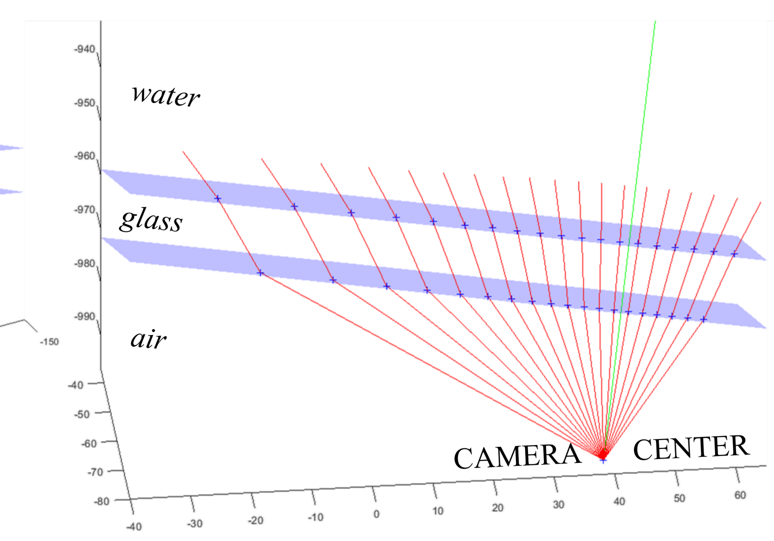
4. Results

Uniformly spaced rays for one row of pixels illustrate refractions on both the air-glass and the glass-water boundaries.

Refraction on both interfaces causes a decrease in the field of view (FoV).

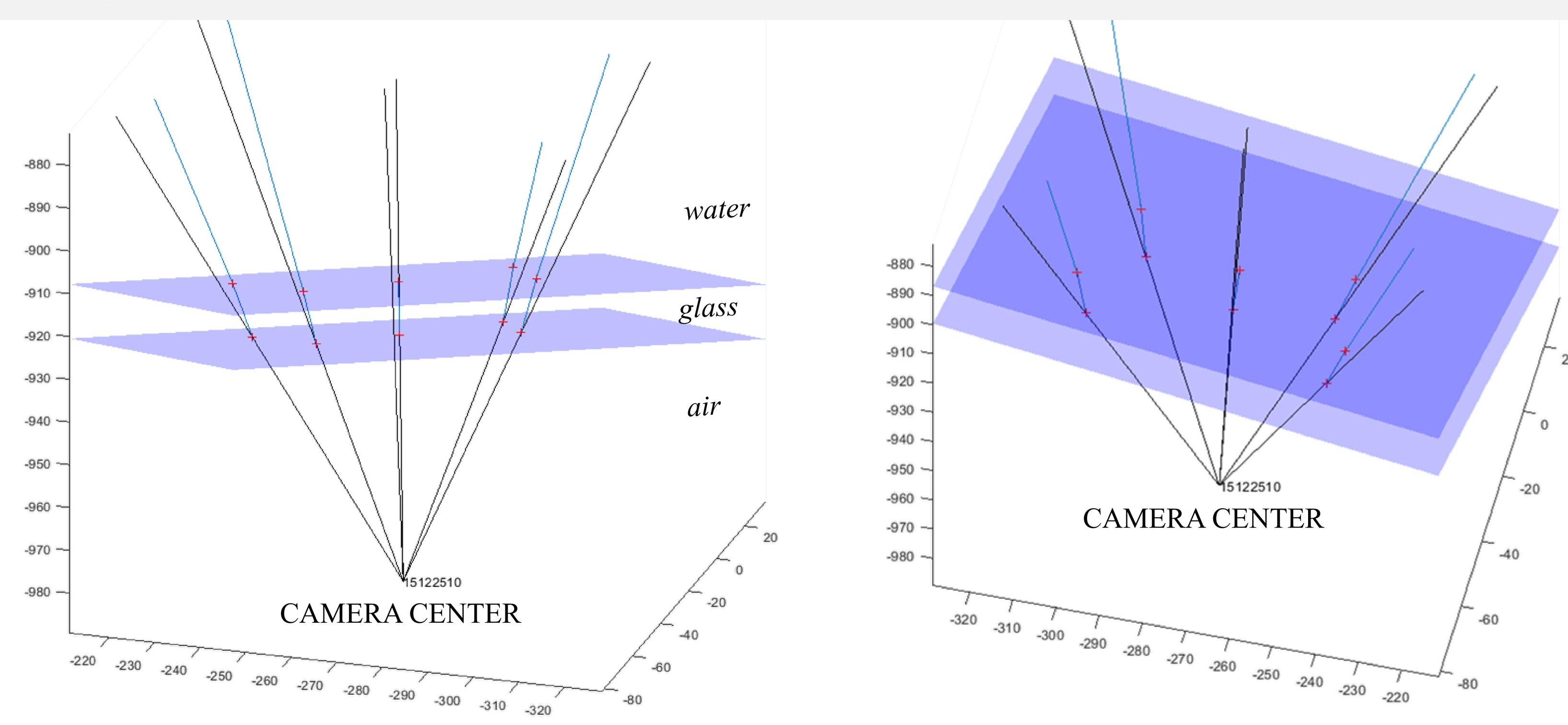


First camera view



Second camera view

The visualization of the camera's image corner rays clearly shows the reduction in underwater camera's field of view compared to the in-the-air camera's field of view.



Refraction of the corner rays defining the camera's field of view (FoV)

The solution of the analytical calibration procedure is a good starting point for the subsequent numerical optimization.

5. Conclusion

Underwater camera calibration was implemented for the case where the camera scans the object across the protective glass surface.

The calibration results include the known camera pose and the pose of the protective glass surface.

Calibration process was implemented using MATLAB.

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