Lab experiment for simultaneous reconstruction of water surface and bottom with a synchronized camera rig

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Introduction: In photo bathymetry, the bottom of a water body is observed with cameras in the air through the open and dynamic water surface. When entering water, the image rays are bended at the media boundary according to Snell's law of refraction and blurring occurs due to scattering in the water column. In particular, e.g. Okamoto (1982) has shown that the presence of waves at the water surface causes significant errors. The main limiting factor for obtaining higher accuracy in photo bathymetry is therefore the ability to reconstruct or model the dynamic, wave-induced water surface. Existing work regarding the reconstruction of waves includes techniques based on very diverse approaches. Among them, there is the use of surface markers being deployed on an area of interest and their subsequent tracking (e.g. Chandler et al., 2008), which is not easily implementable in large-scale applications. Other examples use optical properties of the water surface, namely the specular reflection (e.g. Rupnik et al., 2015) or the refraction of the optical rays (e.g. Murase, 1992; Morris & Kutulakos, 2011). However, these contributions rely on assumptions such as knowledge of the mean water height or the topography, which is not applicable to our case of study since we aim to reconstruct both the topography and the water surface of an unknown water body. One option to approach the problem is using a camera rig for capturing both the water surface and bottom strictly at the same time with synchronized oblique and nadir images. In this contribution, we present the setup and first results of a feasibility study carried out in the measurement lab of TU Wien.

Camera rig: We have borrowed a complete camera rig from IPF Stuttgart. This setup is composed of four cameras and lenses, an Arduino Leonardo and the associated cabling. The Arduino serves as controller and synchronizes the cameras by sending a trigger signal in user-definable intervals via a cabled USB connection. Two cameras are used to capture the water surface, looking obliquely from the side, and the other two to capture the water bottom, looking nadir from above.

Lab experiment: For testing the idea of simultaneous image acquisition, we designed and conducted an experiment at the 4D measurement lab of TU Wien. As a prerequisite, we first installed an array of coded photogrammetric targets on the floor, walls, and measurement pillars in the corner of the lab and measured the 3D coordinates with sub-mm precision with a total station. These targets served as control and check points in the bundle block adjustment. In a second step, we installed a 200L mortar bucket and covered the bottom with gravel stones. Then we measured the topography of the stones with a conventional image block using a Structure-from-Motion and Dense Image Matching approach. After that, we filled the bucket with clear water, and installed and measured additional coded targets on the top and side of the bucket. Finally, we arranged the four cameras as explained above around the bucket. After these preparation steps, we took a series of synchronized images while creating moderate waves. The entire setup is shown in (Fig. 1).

First results: The entire image block can be oriented and georeferenced in high accuracy via the photogrammetric targets. Only the bottom is visible in the nadir images but not the water surface. From the nadir image pairs we repeatedly derived the bottom topography both for still or wave-induced water surfaces. For the undulated water surfaces, this resulted in the expected drop of accuracy. At the time of writing this abstract, data processing to reconstruct the water surface in 3D from the oblique images is in progress and additional leads are tested, like adding dust in the water to create turbidity. Depending on the final success of the lab experiment, we further plan to use a drone squadron for capturing real world scenes with the same concept.

***Figure 1**: Setup of the lab experiment. Water and stone filled 200L bucket, coded targets serving as control and check points, synchronized camera rig consisting of 2 oblique cameras (left) and 2 nadir looking cameras (top)*

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