UNDERWATER SCENE RECONSTRUCTION

N. Hurtós, X.Cufí, J.Salvi
Department of Computer Engineering, Universitat de Girona –17001 Girona, Spain
{nhurtos,xcuf,qsalvi}@eia.udg.es

Abstract- Combination of optical and acoustic sensors to overcome the shortcomings presented by optical systems in underwater 3D acquisition is an emerging field of research. In this work, an opti-acoustic system composed by a single camera and a multibeam sonar is proposed, providing a simulation environment to validate its potential use in 3D reconstruction. Since extrinsic calibration is a prerequisite for this kind of feature-level sensor fusion, an effective approach to address the calibration problem between a multibeam and a camera system is presented.

Keywords - optical and acoustic fusion, multibeam sonar, underwater 3D reconstruction, calibration

I. INTRODUCTION

Three-dimensional underwater reconstructions allow the analysis of the temporary evolution of marine ecosystems, as well as the morphology of the underwater seafloor. In order to obtain 3D information, scene key points from multiple underwater views (either supplied by multiple cameras or by a single moving camera) can be used to extract 3D estimates. However, while optical approaches provide high resolution and target details, they are constrained by limited visibility range. Underwater sonars can operate in larger visibility ranges and provide 3D information even in presence of water turbidity conditions though at expense of a coarse resolution and harder data extraction. Hence, a promising emerging area of underwater 3D reconstruction has started to study the combination of data exploiting the complementary nature of optical and acoustic sensors. Despite the difficulty of combining two modalities that operate at different resolutions, technology innovations and advances in acoustic sensors have progressively allowed the generation of good-quality high-resolution data suitable for integration and consequently the related design of new techniques for underwater scene reconstruction. The main works combining some type of sonar (acoustic camera, single beam sounder, multibeam…) and vision data [1,2,3,4,5] have been reviewed showing that data integration is performed at a feature level, basically through geometrical correspondences and registration. In this way, a crucial problem becomes the data alignment (or sensor calibration) problem which allows data from one sensor to be associated with the corresponding data of the other sensor.

II. PROPOSAL OF OPTI-ACOUSTIC SYSTEM

The proposed system is constituted by a camera and a multibeam sonar that will be attached to the vehicle rigid frame in order to acquire images and profiles of the vehicle's underlying seafloor. Hence, we want to take profit of the acoustic sensor to obtain seabed range information, while the camera is used to gather other features such as color or texture. In order to later combine information from both sensors its configuration must be such that part of the swath from the multibeam sonar intersects the projection area of the image.

A simulation environment has been created in order to perform tests using simulated camera and multibeam data. System sensors have been geometrically modeled using the standard pinhole camera model and a multibeam simplified model reduced to a number of beams equally distributed along the total aperture of the sonar. These models have been parameterized with the values of the real sensors mounted in our AUV, a Tritech Super SeaSpy camera and a DeltaT multibeam sonar from Imagenex. Within simulation environment, the mapping between acoustic profiles and optical images can be established applying the rigid transformation matrix that relates the two sensors. Thus, given an acoustic profile, composed by a set of target points, each with a certain 3D position, we can project it onto the optical image plane, obtaining the depth (and eventually also the reflectivity value) with reference to the image plane. The potential use of this mapping to robustly characterize features becomes evident since a feature could be described by an interest point descriptor from the image but also by a particular depth and a specific acoustic reflectivity.

Besides, a straightforward approach considering ideal calibration and navigation data has been implemented to demonstrate that a calibrated camera-sonar system can be used to obtain a 3D reconstruction of the seafloor. Supposing the camera center of projection at the each of the corresponding locations with respect to the multibeam, the images can be reprojected over the bathymetry thus giving a 3D reconstruction of the terrain which comprises both range and visual information. However, this approach would rarely have a good performance in real conditions since data accuracy of typical navigation systems far exceeds the intrinsic accuracy of the sonar. Then, an appropriate SLAM algorithm should be designed in order to enforce local and global consistency within navigation data and sensor measurements to yield superior mapping results.

III. EXTRINSIC CALIBRATION BETWEEN A CAMERA AND A MULTIBEAM SONAR

In order to obtain the relative position and orientation of the multibeam and camera coordinate systems we sought for a calibration method that does not rely on explicit opti-acoustic matches, since we experimentally tested that the establishment of these correspondences is a nearly impossible task due to the different resolution of both sensors and the noise of the acoustic data. Since we assume a simplified multibeam model, our problem might be considered similar to a calibration of a camera-laser system, so we tried to adapt a calibration procedure presented by Zhang and Pless [6] to calibrate a camera and an invisible laser range finder. Some simulations have been performed to evaluate the suitability of the method using the geometrical modeling of the sensors previously described. Gaussian and uniform noise has been added to the multibeam points simulating the accuracy of our real multibeam, showing that the method can effectively perform the extrinsic calibration of the sensors.

IV. CONCLUSIONS

In this work, we have presented a first step towards the integration of optic and acoustic information for the three-dimensional reconstruction of underwater scenes. An opti-acoustic system composed of a camera and a multibeam sonar has been proposed, providing simulations to validate its potential use both in the establishment of robust features and the 3D reconstruction of environments. In order to calibrate the system an approach originally developed for a calibration of a laser range finder and a camera has been considered.

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