# Survey planning for coastal areas coupling aerial and marine autonomous vehicles to achieve a seamless DSM

Ali Alakbar Karaki[1[0000-0001-6045-3480]], Marco Bibuli[2[0000-0002-5345-2292]], Massimo Caccia[2[0000-0002-4482-4541]], Bianca Federici[1[0000-0002-4598-4758]], Ilaria Ferrando[1[0000-0002-9121-6821]], Sara Gagliolo[1[0000-0002-6099-1331]], Angelo Odetti[2[0000-0003-0338-0742]], e Domenico Sguerso[1[0000-0001-7683-3306]]

[1] Geomatics Laboratory, Department of Civil, Chemical and Environmental Engineering (DICCA), University of Genoa, Italy; karakialiakbar@gmail.com; bianca.federici@unige.it; ilaria.ferrando@edu.unige.it; sara.gagliolo@edu.unige.it; domenico.sguerso@unige.it
[2] Institute of Marine Engineering, National Research Council of Italy (CNR), Genova, Italy; marco.bibuli@cnr.it; massimo.caccia@cnr.it; angelo.odetti@cnr.it

**Abstract.** Coastal areas are widely investigated and monitored due to their significant influence on marine environment. Many methods have already been proposed for monitoring the seabed evolution, mainly through periodic high-resolution and georeferenced spatial data acquisition and processing [0]. Challenging questions appear when working in this boundary environments: how to integrate different techniques in a unique survey campaign to obtain a seamless continuous Digital Surface Model (DSM) for the emerged and submerged zones? Accordingly, the present work is part of a wider research, focusing on the definition, implementation, development and validation of a methodology to execute integrated aerial and underwater survey campaigns for shallow water areas by working in a smart manner, reducing the costs and extending new standards of safety through an interdisciplinary approach, involving geomatics and robotic fields of knowledge. The difficulties of creating a single coherent DSM for different environments are related to the vertical datum variation and the presence of horizontal gaps beyond merging two datasets [2, 3]. One of the optimal solutions is to rely on the use of GNSS as a technique for georeferencing measurements from different sensors. In this context, the bathymetric measurements performed by SBES/MBES (Single/Multi Beam EchoSounder) are georeferenced directly by the GNSS sensor mounted on the surface vehicle. Conversely, topographic measurements obtained from sensing techniques (photogrammetry, LiDAR and laser scanner) could be georeferenced by relying on the presence of GCPs (Ground Control Points) measured by GNSS. In fact, the use of GNSS in both environments allows combining the two georeferenced data sets, but several common points appropriately distributed and observed are essential in order to improve and evaluate the uncertainty of the merged data sets. To detect observed common points between the two surveys, an integrated approach is needed by collecting data in parallel from UAV photogrammetry and from SWAMP (Shallow Water Autonomous Multipurpose Platform), a prototype of Autonomous Surface Vehicle (ASV) for data collection in shallow water, designed and built in a collaboration between CNR-INM and DITEN UNIGE [4], for the emerged and submerged zones, respectively. Through the joint adjustment process, the achieved measurements of the GCPs imposed in the Bundle Block Adjustment (least squares approach) [2], permit to evaluate the observation positioning and attitude angles of the aerial and marine drone and their accuracy. The final uncertainty for the jointed

block is determined by comparing the observed coordinates with the known values of a set of points not used in the adjustment, called check points (CKPs). The plan is optimized with a cross intersection between the path of UAV and SWAMP. The initial rough information about the two paths and the expected cross intersection point will be coming from the GNSS. The motivation of having the intersection locations is to obtain a photogrammetric recognition for the SWAMP while performing bathymetric survey. In other words, the SWAMP will be a kinematic GCP with respect to the UAV to link both data sets from different environments. The method can be used in complex scenarios, e.g., harbors, and in all the cases were relying on the GNSS support is challenging. Moreover, in inaccessible areas, where it is impossible to place GCPs, the proposal method using a kinematic GCP mounted on ASV and detected from UAV may be an interesting solution to join the bathymetric and aerial surveys.

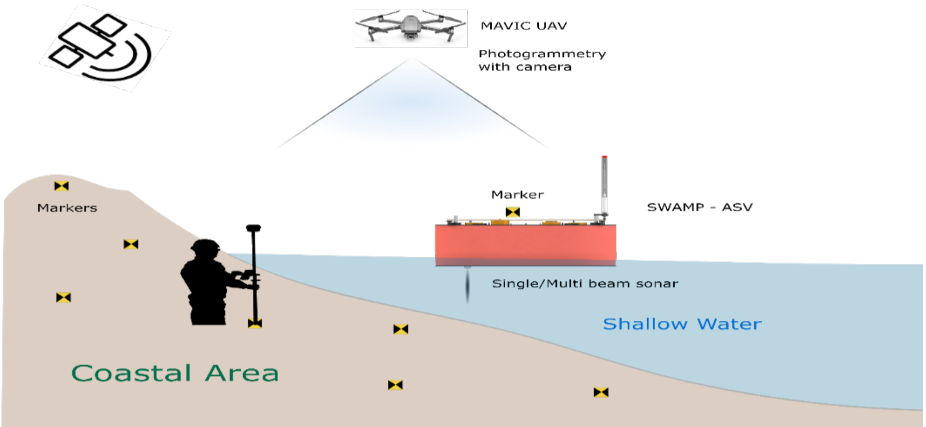


Fig. 1. Represents the interdisciplinary approach by using several techniques to perform integrated survey campaign over different environments (emerged and submerged zones).

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