UAV multispectral images for bathymetry estimation

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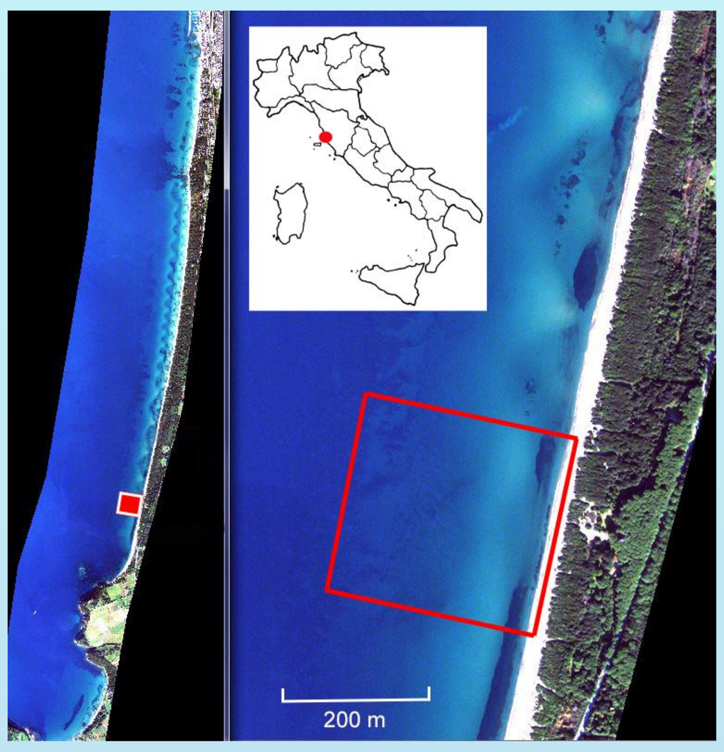
Abstract

Remote sensing derived bathymetric mapping using high-resolution multispectral satellite imagery are increasingly used. The present study shows the results of an Unmanned Aerial Vehicle (UAV), also known as drone, derived bathymetry (UDB) equipped with a multispectral camera acquiring in the same WorldView-2 sensors spectral bands.
Results show the possibility to obtain accurate UDB in shallow waters with low operational costs.

Location

The study area is located on the Central Tuscany coast (San Vincenzo, Italy). The test area is approximately 300x400 m and characterized by a sandy beach and very shallow water, were some near shore sandbars are present. Investigated depth was from the shoreline down to the Posidonia oceanica inner edge, about 10 m depth.



Methodology

Bathymetry was derived by the use of AUV multispectral images computed with widely used Lyzenga and Stumpf methods. The results where compared with bathymetric data survey.

The UAV (Unmanned Aerial Vehicle) used for this study was equipped with MAIA WV; a multispectral camera acquiring in the same wavelength intervals of WorldView-2™ satellite sensor. Sensors present excellent characteristics in terms of sensitivity. Each sensor is global shutter and shoot simultaneous.

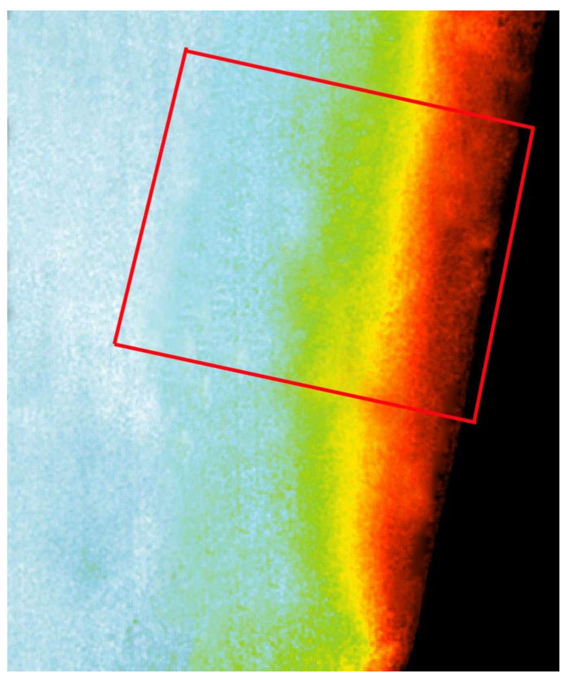
Nine images were acquired on April 2018 at 150 m flight height. Images were georeferenced using the flight parameter as GPS position, heading, picth/roll and knowing the camera ground footprint for that elevation (96x72 m), also verified with a RTK GPS survey. Furthermore, two buoys equipped with a GPS, recording in real time the position, have been used as sea control points. Finally, a GeoTIFF image mosaic has been produced.

UAV and multispectral camera

A singlebeam and multibeam bathymetric survey was carried in the some on the study area. These measurements have been converted into elevations relative to national datum and averaged at 3x3 m grid for noise reduction.
A certain number of SBCPs (Sea Bottom Control Points) have been used for UDB output calibration (50, 200, 500 Pts). The remaining for method validation.

Images processing:

- Ortho-rectification and mosaic;
- Radiance and reflectance conversion;
- Land mask;
- Sun glint correction;
- Stumpf and Lyzenga models testing different bands;
- Density slice at spectral reflectance intervals;
- Density slice calibration, with real survey depths, testing different number of SBCPs;
- Bathymetric map and DTM (Digital Terrain Model) at different scale resolution.

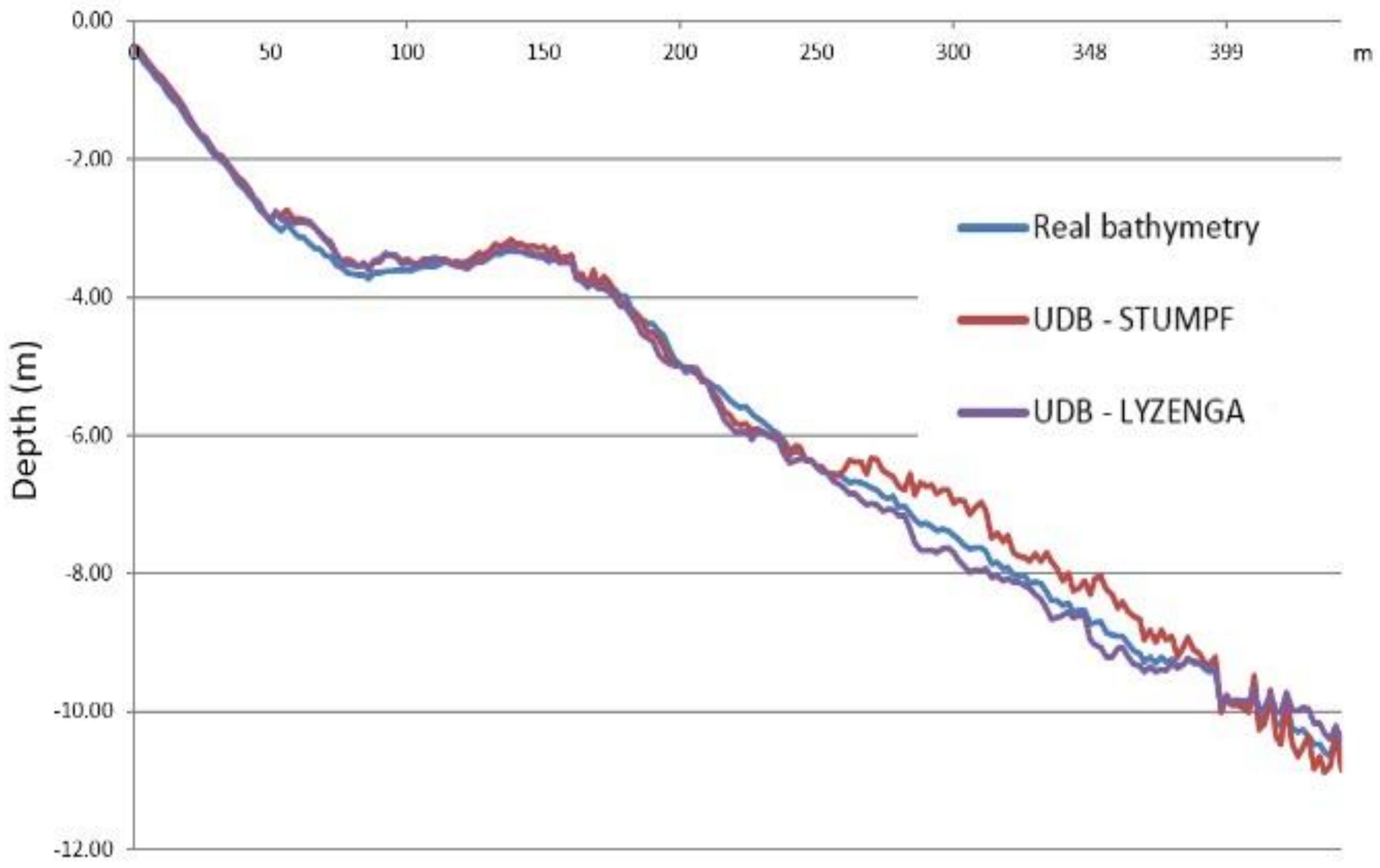


*UAV Derived Bathymetry (**UDB**)*

Results

Both models produced encouraging results and show a points dispersion growing with the depth. Stumpf processing is simpler compared to Lyzenga, that requires multiple regression methods, but delivers slightly rough results.

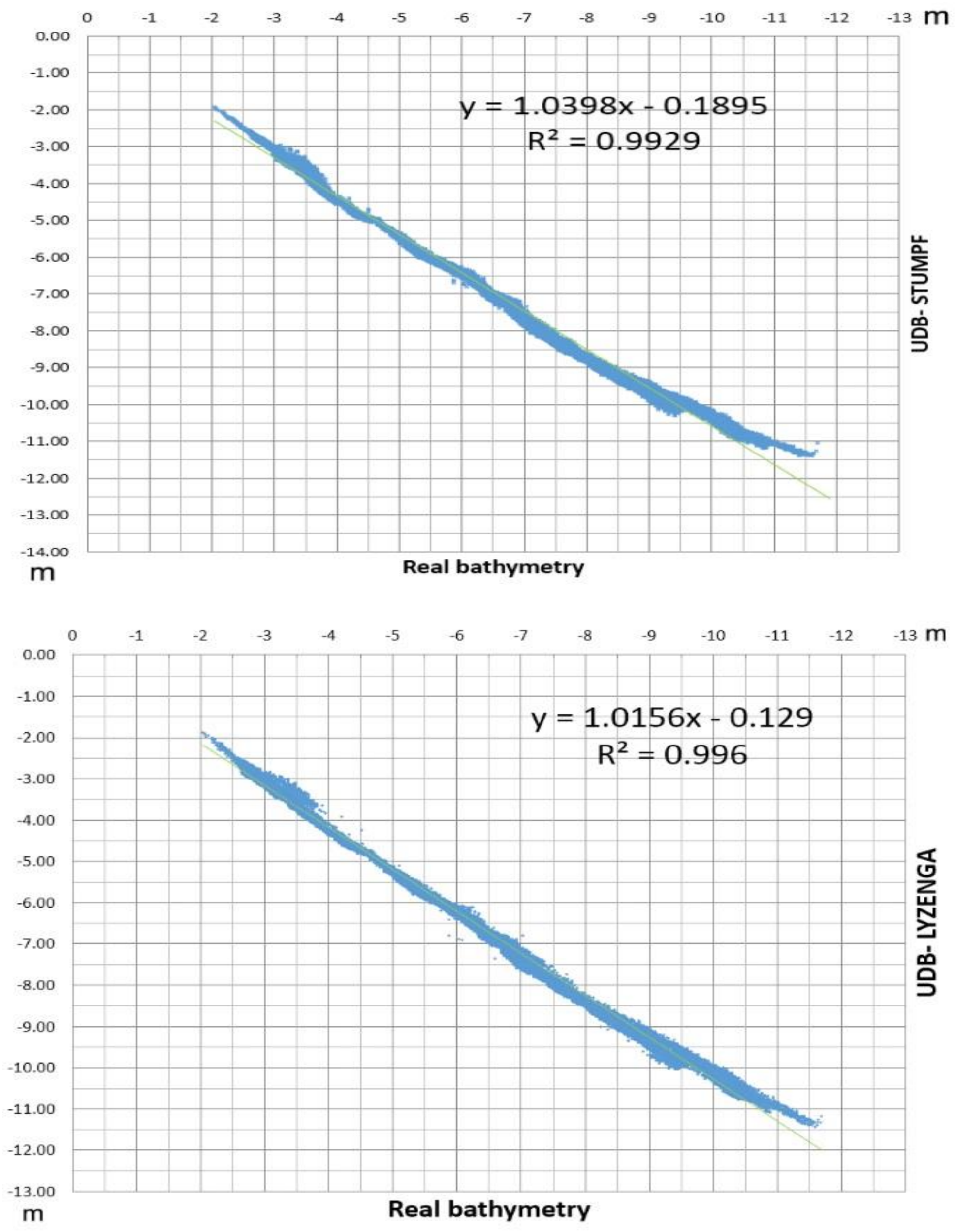
Comparison between surveyed and estimated bathymetric profiles located at the center of the study area.



Mean Absolute Deviation (MAD) was also used to verify the results between measured and estimated values (m) for both methods at different depth ranges for the considered full dataset points.

Depth	Lyzenga	Stumpf
0-5	0.19	0.21
0-11	0.41	0.47

Depth values retrieved from Lyzenga and Stumpf methods have been compared with 28.000 measured depth points derived from the bathymetric survey.
Computed coefficients of determination (R^2):
Stumpf = 0.992, Lyzenga= 0.996



Scatter plot of Surveyed bathymetry vs. Stumpf and Lyzenga UDB

Discussion

The possibility to derive bathymetry from satellite remotely acquired images has been largely studied in the letterature, expecially for shallow water. Accuracy of approximately +/- 50 cm allows its use mainly for monitoring regional geomorphological variations.
In our study UAV derived bathymetry (UDB) shows higher accuracy than satellite one.

A disadvantage in using satellite images for any beach monitoring is the availability of data acquired in the requested period. Clouds precence and sea conditions can also limit images availability. On the contrary, UAV surveys can guarantee low cost and easily acquired images for coastal monitoring on small to medium size areas. With an accuracy of about 20 cm (inland of the -5 m depth contour) they allow to connect the dry beach topography to the multibeam survey, at depth where the latter cannot operate.

References

Stumpf, Richard P., Holderied, Kristine, and Sinclair, Mark, 2003, Determination of water depth with high-resolution satellite imagery over variable bottom types: Limnology and Oceanography, no. 41(1, part 2), p. 547-556.
D.R.Lyzenga, "Remote sensing of bottom reflectance and water attenuation parameters in shallow water using Aircraft and Landsat data", Int. J. Remote Sens. Vol. 2, 1981, pp.72–82.
L. Rossi, I. Mammi, E. Pranzini (2019) - A comparison between UAV and high-resolution multispectral satellite images for bathymetry estimation - Earth observation advancements in a changing world", Vol. 1, Associazione Italiana Telerilevamento AIT