

Mapping Ocean Bathymetry using an AUV Equipped of an Altimeter: A Terrain-Driven Approach

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Abstract: Environment modeling and surveillance can enormously benefit from expedite and cheap means for data acquisition. We present research on the design autonomous underwater mobile systems for coastal ocean observation, with an emphasis on the definition of adaptive intelligent observation strategies, exploiting the mobility of the sensor and its ability to react on-line to the observed data.

Research is presented on the integration of tools and algorithms from automatic control, computational geometry, and statistical signal processing to design autonomous observers of continuous natural spatial fields. In our approach, observation is guided by the intrinsic geometry of the observed field, with advantages - compared to traditional fixed survey designs - in terms of robustness with respect to positioning errors, automatic regulation of the spatial sampling rate, as well as facility of subsequent fusion of partial maps in the context of multi-agent operation. New algorithms are presented that enable guidance of an autonomous sensor along outstanding geometric features of the mapped field: iso-surfaces and lines of steepest variation. A new algorithm is presented that controls the acquisition of these features, gradually building a data structure that completely describes the geometry of observed field. The algorithm switches between periods of passive data-driven behaviour and periods of active search for the singular points of the surface, exploiting their signature in the shape of already acquired iso-level lines to detect their presence, and the fact that they are the attraction points of the guidance laws proposed. Results of the research are illustrated by considering the specific problem of mapping the Belgian sand bank dunes (Kwintebank) with a small autonomous underwater vehicle. The algorithms presented enable autonomous learning of the topography of the sand banks in the form of a tree of contour levels,

that describes the distinct valleys and mountains present, and the corresponding ridges and valleys. At each step, the next feature to be acquired is determined on-line, by analysis of the geometry of the features acquired so far. The advantages of the approach as an alternative of fixed survey designs are discussed and demonstrated using the case study under analysis (mapping of the Kwintebak). The research presented, although applied to the specific case of sand-bank mapping with a small Autonomous Underwater Vehicle A(UV), can be applied to the observation of many other environmental fields, both underwater, terrestrial and atmospheric, and is a step forward in the optimisation of the operation of existing robotic observation tools, which may be unmanned (in the sense that there is no human on-board), but whose behavior is still largely pre-programmed by the user. The approach to the observation of natural fields described can be applied to many priority areas, such as demining, mapping of toxic contamination levels, of oil-spills, etc. As we discuss, the geometry-driven observation strategy proposed presents important advantages in terms of its robustness to failures or degradation of the supporting global positioning system of the mobile platform, by constraining the set of possible platform motion to trajectories that are induced by the observed surface - most in the same manner that noise robustness has been acquired in tele-communications by restricting the actual values of the transmitted signal to be discrete, that is, when switching from analogue to digital communications - enabling, moreover, an easier and more accurate fusion of partial maps in the context of multi-robot operation - by providing a clear representation of the overlapping features. Exploitation of this mapping approach in the context of observation of other environmental phenomena (e.g. plumes) or humanitarian demining, are natural extensions of the work presented.