Proceedings of The Fourteenth (2004) International Offshore and Polar Engineering Conference
Toulon, France, May 23–28, 2004

ISBN 1-880653-62-1 (Set); ISSN 1098-6189 (Set)

Benthic Contour Mapping with a Profiler Sonar

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ABSTRACT

The paper presents work on autonomous mapping of boundaries between distinct benthic regions using an AUV equipped of a mechanically scanning profiler sonar. The robot autonomously tracks the boundary between distinct sea-bed types, using the guidance loop closed around the sonar returns, presented in [1]. The collected data is processed by the mapping algorithm, that iteratively updates the contour representation, and that can be thought of as a *statistical version* of the standard *deformable curves* (or snakes), driven by a measure of the *contrast between the probability distributions associated to the sensed points separated by the contour.*

KEY WORDS: Contour tracking; mapping natural environments; underwater robotics.

INTRODUCTION

The ability to directly map contours between distinct regions at sea is a useful observation tool in the context of several applications. It is not only an efficient observation behavior for many oceanography or biology studies, but it also provides the ability of mapping the macroscopic perceptual features of the workspace, which can be used later by the robot to relocate itself, resetting positioning errors after long periods of dead-reckoning. In this last perspective, it is also an important tool for autonomous -bottom-referred- navigation in unknown extended regions.

The paper presents work on autonomous mapping of boundaries between distinct benthic regions using an AUV equipped of a mechanically scanning profiler sonar. However, the methodology presented is general, enabling its application to signals provided by other oceanographical sensors yielding single point samples, such as, e.g., temperature, turbidity or salinity.

The underwater robot autonomously tracks the boundary between distinct sea-bed types, using a guidance loop directly closed around the exteroceptive sensor (in our case, the profiles returned by the sonar), which generates the appropriate references for the low-level yaw rate controller (Barat and Rendas; 2003a). Depth is held constant during the entire observation, minimizing the impact of varying observation conditions. The control algorithm has been presented in (Barat and Rendas; 2003b)(Rendas and Barat; 2003), and is based on fitting a binary statistical mixture model to the sensor data received during tracking. The mixture coefficient can be seen as a soft classification of the sensed sea bottom region: values close to 0 or 1 indicate pure regions, while values close to 0.5 flag transition regions. Note that each component of the mixture model is associated to one of the adjacent regions that define the contour, and are learned autonomously by the robot upon detection of a transition region.

The collected data is then processed by the mapping algorithm, that updates an internal representation of the geometry of the detected contour. It iteratively updates the contour representation, which initially coincides with the estimated robot trajectory. Note that if the contour's curvature is small, the oscillations of the robot around the contour will also be small, and few iterations will be required to obtain the true contour shape. The proposed algorithm can be thought of as a *statistical version* of the standard *deformable curves* (or snakes) used in computer vision for image segmentation. The gradient at the image pixels, from which is derived the driving term of the equation that gradually deforms the boundary is replaced in our context by a measure of the *contrast between the probability distributions associated to the sensed points separated by the estimated contour.*

The paper is organized as follows. In the first section we formulate the mapping problem. The subsequent section briefly summarizes the approach on which the guidance algorithm used for contour tracking is based, introducing notation and nomenclature necessary for the explanation of the mapping