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Map Based Navigation for Autonomous Underwater Vehicles

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ABSTRACT

In this work, a map based navigation algorithm is developed wherein measured geophysical properties are matched to a priori maps. The objective is a complete algorithm applicable to a small, power-limited AUV that performs in real time to a required resolution with bounded position error. Interval B-splines are introduced for the nonlinear representation of two-dimensional geophysical parameters that have measurement uncertainty. Fine-scale position determination involves the solution of a system of nonlinear polynomial equations with interval coefficients. This system represents the complete set of possible vehicle locations and is formulated as the intersection of contours established on each map from the simultaneous measurement of associated geophysical parameters. A standard filter mechanism, based on a bounded interval error model, predicts the position of the vehicle and, therefore, screens extraneous solutions. When multiple solutions are found, a tracking mechanism is applied until a unique vehicle location is determined.

INTRODUCTION

Autonomous underwater vehicles (AUVs) offer the potential for an efficient and cost-effective means of measuring physical properties and performing surveys of the hostile and largely unknown ocean environment. Particular applications that are currently envisioned include surveys of the deep ocean, contaminated coastal waters, and the ice-covered seas of the Arctic and Antarctic. As AUVs become more intelligent and cost-effective, large groups, acting alone or in concert, might one day be able to provide sufficient measurement resolution to permit accurate initialization of climate simulation models. An outstanding problem in permitting such applications of AUV technologies is navigation, the ability of the AUV to determine its global position at any time.

This paper is structured as follows. In the next section, we provide a motivation for map based navigation systems as applied to AUVs and then give a brief survey of current map based navigation systems. We then formulate and outline our navigation algorithm and discuss in detail various aspects of our approach. We provide an example of geophysical navigation and then, finally, offer some closing remarks.

MOTIVATION

Motivation for a map based approach is found in Table 1. Various AUV navigation systems are listed, and the remaining columns

TYPE	A	B	C	D	E
dead reckoning	N	Y	none	none	Y
Doppler velocimeter	Y	Y	near bottom	moderate	Y
INS	N	Y	none	high	Y
GPS	Y	N	near surface	none	Y
LORAN	Y	N	near shore & surface	none	Y
Long Base Line	Y	N	near array	high	N
Ultra Short Base Line	Y	N	near beacon	high	Y
geophysical map	Y	Y	area of survey	initial	N

Table 1 AUV navigation overview. Y and N refer to yes and no, respectively.

refer to:

A - ERROR BOUNDED - if the position error is bounded as time or distance traveled increases.

B - AUTONOMOUS - only data and sensors on board the vehicle are needed to perform navigation.

C - SPATIAL RESTRICTION - whether the use of the navigation system is restricted to a certain spatial region.

D - COST RESTRICTION - whether cost is prohibitive as compared to a platform cost of $50,000 US.

E - EXTRA COST/UNIT - whether the mission cost of navigation for multiple AUVs is a direct multiple of the number of vehicles.

Of particular interest is that an unlimited number of vehicles

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