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Underwater SLAM with ICP Localization and Neural Network Objects Classification

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ABSTRACT

The aim of this paper is to propose a technique for Simultaneous Localization and Mapping in underwater environments by means of acoustic sensors. The proposed procedure consists in the application of suitable Neural Network and Iterative Closest Point algorithms for objects detection, agent localization and map construction. General Regression Neural Network and improved ICP algorithms are implemented in order to process sonar data, to minimize the computational time and to maximize efficiency in localization tasks without using dynamical models of the agent. Experimental tests have been performed in a simple, structured static environment collecting data by means of a single-beam, mechanically scanning sonar. Results show good performances of the procedures in simple but meaningful situations.

KEY WORDS: sonar, Unmanned Underwater Vehicles, SLAM, ICP, GRNN.

INTRODUCTION

To localize oneself and to map the surrounding environment are important activities that an agent, especially an unmanned underwater vehicle, should be able to execute in order to operate safely and to perform general tasks. In this paper, we propose a Simultaneous Localization and Mapping (SLAM) technique, which can be employed by unmanned underwater vehicles equipped with single-beam mechanically scanning sonar in structured environments. The technique is based on the use of an Iterative Closest Point (ICP) algorithm in order to estimate the vehicle displacement and to localize it in the environment, while map building and updating is performed by a Kalman filter. The standard ICP algorithm has been improved by adding specific procedures for object detection and for optimizing the computation of optimal transformations. The optimization step increases the computational burden, but the object detection capabilities help in speeding up the process. The paper is divided in three Sections. The first one gives a short description of the SLAM Problem and of the state of the art of the related methodologies, including ICP algorithms. The second Section presents the proposed approach and the last Section discusses some experimental results.

SLAM: SIMULTANEOUS LOCALIZATION AND MAPPING

The problem of estimating the motion of an agent in an unknown environment, without any a priori information, is a well known and challenging one. Basically, it consists in constructing a map of the environment and, in the meantime, in estimating the position of the agent by exploiting the information collected, during the motion, by means of various sensors. In the literature this problem is known with the acronym SLAM (Simultaneous Localization and Mapping) and, since it was formally introduced in Smith, Self, and Cheeseman (1987), many different applications and solutions have been proposed. Actually, the possibility of giving a satisfactory solution to a SLAM Problem depends on several heterogeneous factors, which can be grouped into three categories: the environment's configuration (notably the presence of structure), the degree of knowledge about the agent's characteristics (notably about its dynamical model) and the kind and quality of its sensory equipment (which may include external and internal sensors, like e.g. cameras, sonar, laser, inertial measurement units, encoders, compasses, and so on).

Methodologies

In order to solve SLAM Problems, statistical approaches such as Bayesian Filters have found widespread acceptance in robotic. In the first approach proposed in Smith, Self and Cheeseman (1987), the authors use an Extended Kalman Filter (EKF). A similar methodology has been used in Williams, Newman, Dissanayake and Durrant-Whyte (2000); Newman and Leonard (2003); Newman, Leonard and Rikoski (2003); Newman (1999) and Leonard, Moran, Cox and Miller (1995). In these approaches, geometric objects (like points, lines, and circles chosen in order to match the environment's features or landmarks) are used to represent and to map the environment. A different approach was developed in Elfes (1987), where a statistical representation of the environment by means of cells and grid is proposed. This method has been used in many other situations by a number of authors (Conte, Gambella, Scaradozzi and Zanoli, 2006; Elfes, 1989; Gutmann, and Schlegel, 1996; Martin, and Moravec, 1996; Moravec, and Elfes, 1984; Schiele, and Crowley, 1994; Schultz, and Adams, 1998).
In general, all the mentioned approaches may show drawbacks that can compromise the convergence and the stability of the algorithms used