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Dynamic Simulation of Autonomous Manipulation Task for UVMS with Fusing Vision and Inertial Measurements

Qiang Li[1,2] *Qifeng Zhang*[1] *Xiaohui Wang*[1]
[1] State Key Laboratory of Robotics, Shenyang Institute of Automation, Chinese Academy of Sciences
Shenyang, LiaoNing, China
[2]Graduate School of the Chiese Academy of Sciences
Beijing, China

ABSTRACT

In this paper, a simulator based on the Matlab is proposed to simulate the manipulation action of UVMS(Underwater Vehicle-Manipulator Systems).In the simulator a fuzzy adaptive PID controller and a relative position observer are presented. The observer can estimate the relative position between the vehicle and the target to be manipulated by fusing vision and inertial measurements. Simulation results indicate that the compounded control strategy can complete the manipulation task and manipulation error can reach the centimeter level.

KEY WORDS: UVMS; dynamic simulation; relative position estimator; UKF; fuzzy adaptive PID; Autonomous Underwater Manipulation

INTRODUCTION

UVMS(Underwater Vehicle-Manipulator Systems) is an underwater vehicle system mounted one or more manipulators to complete certain underwater task. With the increased interest in the development of undersea intervention technology in the fields of offshore oil, military, and ocean scientific investigation, many approaches have been presented to improve undersea intervention capability of UVMS. Professor Antonelli investigated many aspects about UVMS, which included inverse kinematics resolution to find suitable vehicle/joints trajectory corresponding to a desired end effector (Antonelli and Chiaverini, 1998), adaptive tracking control(Antonelli and Caccavale, 2004) and interaction control of UVMS(Antonelli,2003). Mclain(1995) developed the hydrodynamic model of underwater manipulator in Standford. Professor J.Yhu(1998) introduced the development of SAUVIM(semi-Autonomous Underwater Vehicle for Intervention Mission)in the University of Hawaii.

In the literature about UVMS, few papers have addressed a integrated simulator which includes the inverse kinematics and dynamics control as a whole. However, this work can be very helpful in following aspects: (1)tesing multiple motion trajectories under dynamic control and selecting the best one,(2)selecting the sensors to be used in UVMS and analyzing the influence of sensor's performance to UVMS's manipulating task, (3)providing great insight into the control method because the parameters of modeling can be varied easily and all measurements are immediately available.

This paper mainly addresses a simulator whose main issues are localization and manipulation. The remainder of the paper is organized as follows. In problem statement section, the simulation scene is described and a fuzzy controller & nonlinear relative position observer strategy is presented. In vehicle motion and controller section, a fuzzy adaptive PID controller is proposed which will be used to control the vehicle's motion. Also the motion is necessary for estimating the relative position by fusing vision and inertial measurements. In relative position estimation section, a relative position's estimating algorithm is proposed. In end-effector planning section, inverse kinematics is used to make the manipulator approach the target while the vehicle is moving. At last, a series of simulation cases are carried out to show: (1)the robustness of the fuzzy controller (2) the effectiveness of the proposed observer (3) a successful manipulation by using the control strategy and the accuracy of manipulation is up to the centimeter level.

PROBLEM STATEMENT

In this paper we assume that the UVMS will approach a fixed button which is equal to making the manipulator end effector reach a certain point. The UVMS is composed of an autonomous underwater vehicle and a 2 joints(3 DOF, a gripper is included) manipulator, and the manipulator can work in horizontal plane. There are two steps to complete autonomous manipulation of UVMS by fusing vision and inertial measurements. Step 1: when the target point is in the view field of camera, the vehicle begins to fly according to the predesigned trajectory, and the observer routine starts to compute the relative position between the gravity center of vehicle and the target point. The observer depends on the measured values of the feature point on image plane, the rotational velocity and the linear acceleration of vehicle. Step 2: the manipulator is driven to approach the target point according to the estimated relative position while the vehicle is moving. The localization and manipulation action are shown in Fig 1.