

Identification of Low-Order Dynamic Models for Deeply Towed Underwater Vehicle Systems

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ABSTRACT

The horizontal dynamics of deeply towed underwater vehicle systems can be effectively modeled by nonlinear partial differential equations. However, high-resolution numerical solutions are of limited use in controller design, where methods for systems of very high or infinite order are not well developed. This paper examines the possibility of finding low-order dynamic models in differential equation form, in order to present a more tractable control problem. A learning model method is used, and the identification process is novel in that a verified high-order model provides the primary data set. This approach allows a priori characterization of system responses in regimes or scenarios for which no experimental data exist. The performances of the reduced-order forms are verified through comparison of model output with actual sea data obtained during recent deepwater tests.

INTRODUCTION

Towed underwater vehicles have many applications in science and industry, in both shallow and deep water. When depths on the order of several thousand meters are involved, the inertial and drag forces on the cable may be very large. Therefore, accurate models of the cable and vehicle are important for tasks in which the vehicle position is controlled by maneuvering the ship.

As an example, we consider the horizontal control of MEDEA/JASON, a deeply towed two-vehicle system developed at the Woods Hole Oceanographic Institution. (See Fig. 1.) MEDEA, a heavy sled hanging from a taut cable terminating at the surface ship, serves as an instrumented clump weight. JASON is a neutrally buoyant ROV that carries thrusters and operates on a 50-m tether attached to MEDEA. This configuration decouples high-frequency heave motions of the ship from JASON, and, at the same time, provides high cable tension to keep the horizontal offset small. This offset is the distance between the ship's vertical projection on the seafloor and MEDEA, and is caused by ship motions or by currents.

Horizontal position control of a vehicle such as MEDEA is not a straightforward task, because the ship motions are mechanically transmitted through a very long flexible structure. Traditionally, changes in vehicle setpoint are executed by simply moving the ship over a new desired work site and waiting for the vehicle and cable to follow. While this procedure requires no knowledge of the system dynamics, it may carry time constants on the order of 20 minutes or more for long cables. By using models of the cable system in these situations, the overall dynamic response could be improved.

It has been shown that cable models using finite-element (Sanders, 1982) and finite-difference (Ablow and Schechter, 1983) schemes, or a spectral decomposition (e.g., Triantafyllou, 1982; Burgess and Triantafyllou, 1987), can provide good simulation of a

towed system, with little parameter guessing. However, distributed system control is a very new topic. The recent surge of interest in the theory of low-dimension controllers for infinite-dimensional systems is promising (e.g., Schumacher, 1983; Curtain, 1989; and Harn and Polak, 1988), but a specific methodology for applications has not yet been developed. Flexible robot arms are an exception: A number of techniques are available for designing stable controllers for such systems (e.g., Balas, 1978; Cannon and Schmitz, 1984; Bayo 1987; and Yeung and Chen, 1989).

Ultimately, any controller for a towed cable system has to be of finite dimension, for computational reasons. In addition, there are practical limits on the number and type of sensors that can be incorporated. Thus, the aim of this paper is to investigate the performance of very low-order approximations of the towed system, with an eye toward the above control developments. We first dis-

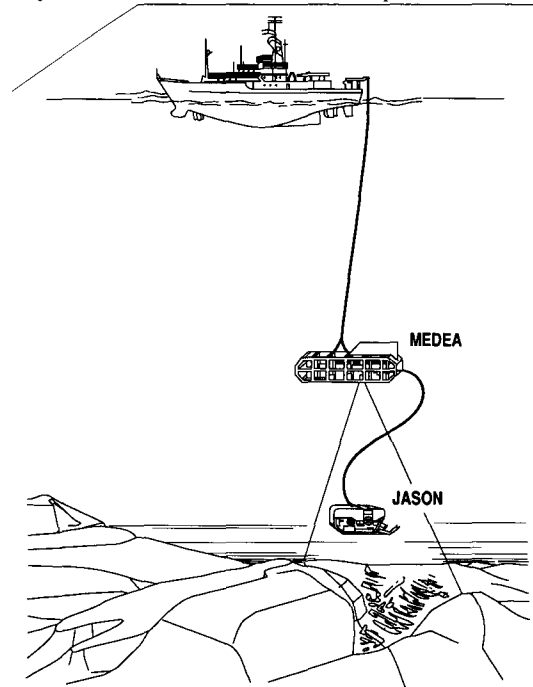


Fig. 1 MEDEA/JASON System consists of two vehicles: heavy towed sled MEDEA and robot JASON.

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