Abstract

Underwater robots are well-known for different marine applications, such as oceanographic surveys, marine life exploration, underwater defense technology, underwater maintenance, and manipulations. Dynamic analyses of underwater vehicle, underwater vehicle-manipulator system (UVMS), and tethered underwater vehicle-manipulator system are presented in this thesis. The finite segment method (FSM) has been used to model the flexible nature of the tether as well as a flexible underwater manipulator. The equations of motion (EoM) for dynamic simulation were derived from the Newton-Euler form of Kirchhoff's equations and the decoupled natural orthogonal complement (DeNOC) matrices. The use of the DeNOC helped to obtain the elements of the generalized inertia matrix (GIM) associated with the EoM recursively. Besides, the DeNOC-based formulation allowed to write the elements of the associated matrices and vectors analytically leading to a better understanding of the dynamics and the effects of various parameters on the system's behaviour. A major contribution of the thesis is a simplified drag model, which is basically the analytical form of the well-known drag model based on strip theory. Due to the uncertainties in hydrodynamic parameters, the drag coefficient was first identified for a two-link manipulator and validated experimentally. The thesis revolved around four important aspects of multi-body dynamics, namely, hydrodynamic simulations, identification of dynamic and hydrodynamic parameters, rigid-flexible tree-type system, and design of experiments for validation of hydrodynamic simulations. The semi-analytical solution for static analysis of inextensible and extensible underwater cables have also been proposed to get an initial state for dynamic simulation of variable length underwater vehicle-cable system. Different applications of the proposed drag model are presented in this thesis for hydrodynamic as well as aerodynamic systems. Several numerical simulation results are also reported for applicability of the various modeling approaches and better clarity.

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