ΕΘΝΙΚΟ
ΜΕΤΣΟΒΙΟ
ΠΟΛΥΤΕΧΝΕΙΟ
ΣΧΟΛΗ ΜΗΧΑΝΟΛΟΓΩΝ ΜΗΧΑΝΙΚΩΝ

Α.Π. : 73393
Αθήνα, 11/12/2018

ΚΟΣΜΗΤΟΡΑΣ

Προς τα Μέλη ΔΕΠ της
Σχολής Μηχ/γων
Μηχ/κών

<u>ΠΡΟΣΚΛΗΣΗ</u>

Σας προσκαλούμε στην παρουσίαση της Διδακτορικής Διατριβής του Υ.Δ., κ. **Shahabodin Heshmati Alamdari** του Abbas, την οποία εκπόνησε στον Τομέα Μηχανολογικών Κατασκευών και Αυτομάτου Ελέγχου, η οποία θα πραγματοποιηθεί την **Παρασκευή 21 Δεκεμβρίου 2018** και ώρα **14:00,** στην Αίθουσα Τηλεκπαίδευσης (Πολυμέσων) στο Κτίριο της Βιβλιοθήκης του ΕΜΠ στην Πολυτεχνειούπολη Ζωγράφου.

Ο τίτλος της Διδακτορικής Διατριβής είναι:

«Μεθοδολογίες Ελέγχου Συνεργασίας και Αλληλεπίδρασης για Υποβρύχια Ρομποτικά Οχήματα»

στην δε Αγγλική:

« Cooperative and Interaction Control for Underwater Robotic Vehicles»

Ο Κοσμήτορας της Σχολής

Ν. Μαρμαράς
Καθηγητής Ε.Μ.Π

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National Technical University of Athens
School of Mechanical Engineering
Control Systems Laboratory

Cooperative and Interaction Control for Underwater Robotic Vehicles

Μεθοδολογίες Ελέγχου Συνεργασίας και Αλληλεπίδρασης για Υποβρύχια Ρομποτικά Οχήματα

Shahab Heshmati-alamdari

Advisor: Kostas J. Kyriakopoulos, Professor NTUA

PhD Thesis Abstract

In this dissertation we address the problem of robust control for underwater robotic vehicles under resource constraints and inspired by practical applications in the field of marine robotics. By the term "resource constraints" we refer to systems with constraints on communication, sensing and energy resources. Within this context, the ultimate objective of this dissertation lies in the development and implementation of efficient control strategies for autonomous single and multiple underwater robotic systems considering significant issues such as: external disturbances, limited power resources, strict communication constraints along with underwater sensing and localization issues. Specifically, we focused on cooperative and interaction control methodologies for single and multiple Underwater Vehicle Manipulator Systems (UVMSs) considering the aforementioned issues and limitations, a topic of utmost challenging area of marine robotics. More precisely, the contributions of this thesis lie in the scope of three topics: i) Motion Control, ii) Visual servoing and iii) Interaction & Cooperative Transportation. In the first part, we formulated in a generic way the problem of Autonomous Underwater Vehicle (AUV) motion operating in a constrained environment including obstacles. Various constraints such as: obstacles, workspace boundaries, thruster saturation, system`s sensing range and predefined

upper bound of the vehicle velocity are considered during the control design. Moreover, the controller has been designed in a way that the vehicle exploits the ocean currents, which results in reduced energy consumption by the thrusters and consequently increases significantly the autonomy of the system. In the second part of the thesis, we have formulated a number of novel visual servoing control strategies in order to stabilize the robot (or robot's end-effector) close to the point of interest considering significant issues such as: camera Field of View (FoV), Camera Calibration uncertainties and the resolution of visual tracking algorithm. In the third part of the thesis, regarding the interaction task, we present a robust interaction control scheme for a UVMS in contact with the environment, with great applications in underwater robotics (e.g. sampling of the sea organisms, underwater welding, object handling). The proposed control scheme does not required any a priori knowledge of the UVMS dynamical parameters or the stiffness model. It guarantees a predefined behavior in terms of desired overshoot, transient and steady state response and it is robust with respect to external disturbances and measurement noises. Moreover, we have addressed the problem of cooperative object transportation for a team of UVMSs in a constrained workspace involving static obstacles. First, for case when the robots are equipped with appropriate force/torque sensors at its end effector we have proposed a decentralized impedance control scheme with the coordination relying solely on implicit communication arising from the physical interaction of the robots with the commonly grasped object. Second, for case when the robots are not equipped with force/torque sensor at it end effector, we have proposed a decentralized predictive control approach which takes into account constraints that emanate from control input saturation as well kinematic and representation singularities. Finally, numerical simulations performed in MATLAB and ROS environments, along with extensive real-time experiments conducted with available Control Systems Lab (CSL) robotic equipment, demonstrate and verify the effectiveness of the claimed results.