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INVESTIGATIONS ON THE DYNAMIC STATION KEEPING OF AN UNDERACTUATED AUTONOMOUS UNDERWATER ROBOT

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Abstract

In this paper, a new method for station keeping of underactuated underwater robots in the presence of underwater currents and external disturbances is proposed. Three small additional thrusters are introduced for station keeping purpose which are less power consuming and are actuated only during the station keeping mode. These thrusters are located in such a way that the generated forces and torque are enough to compensate the underwater currents and disturbances. Station keeping thrusters' locations and directions are nearly optimized using Taguchi's robust design method. The effect of additional thrusters on robot tracking control performance is investigated and the results are presented. The effectiveness of the proposed configuration is demonstrated with the help of hardware-in-the-loop (HIL) simulations using an experimental autonomous underwater robot. The underwater current effect on the corresponding motions of the underwater robot is investigated and some interesting phenomena with respect to different underwater current amplitudes and directions are observed. Robustness of the proposed configuration is also investigated.

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Key Words: Station Keeping, Underwater Robot, Underwater Current, Tracking Control, Underactuated Control

1. INTRODUCTION

In the modern years, a great amount of research has been accomplished regarding the operation of autonomous underwater robots (AURs) and they are playing a crucial role in exploration and utilization of resources located at deep oceanic environments. They are found to be very essential to many underwater missions (which are risky in general) such as oceanographic observations, bathymetric surveys, ocean floor analysis, military applications, recovery of lost man-made objects, etc. [1, 2]. The ability of an underwater robot to remain in its position / station is critical for the success of many underwater missions. The robot needs to maintain or keep its geometric body centre at a given coordinate position. This is slightly complex and difficult due to coupled, nonlinear robot dynamics with uncertain hydrodynamic parameters [3, 4]. Moreover, AURs present a challenging control problem since most of them are underactuated, i.e., they have fewer actuated inputs than degrees of freedom (DOF), imposing non-integrable acceleration constraints making control design a hard task [2, 5]. Underwater robot control is mainly divided into two major categories such as tracking and set-point control. Many researchers have approached the first one (tracking) and many solutions have been proposed in the literature, with varying degrees of success, which are summarized in [5-7]. Tracking control techniques proposed in literature can be broadly classified into two major categories: adaptive control and robust control [2, 8]. In adaptive control the controller parameters are automatically varied to maintain a satisfactory level of

[12] Perrier, M.; Canudas-De-Wit, C. (1996). Experimental Comparison of PID vs. PID plus Nonlinear Controller for Subsea Robots, *Autonomous Robots*, Vol. 3, No. 2-3, 195-212, doi:10.1007/BF00141155
[13] Brutzman, D.; Doucy, O.; Healy, A. (2000). Near surface manoeuvring and station-keeping for an autonomous underwater vehicle, *Proceedings of the NATO symposium on Applied Vehicle Technology*, 1-10
[14] Koh, T. H.; Lau, M. W. S.; Seet, G.; Low, E. (2006). A control module scheme for an underactuated underwater robotic vehicle, *Journal of Intelligent and Robotic Systems*, Vol. 46, No. 1, 43-58, doi:10.1007/s10846-006-9052-6
[15] Liu, S.; Wang, D.; Poh, E. (2008). Output feedback control design for station keeping of AUVs under shallow water wave disturbances, *International Journal of Robust and Nonlinear Control*, Vol. 19, No. 13, 1447-1470, doi:10.1002/rnc.1387
[16] Lots, J. F.; Lane, D. M.; Trucco, E.; Chaumette, F. (2001). A 2D visual servoing for underwater vehicle station keeping, *Proceedings of the IEEE International Conference on Robotics and Automation*, 2767-2772
[17] Riedel, J. S. (2000). Shallow water station keeping of an autonomous underwater vehicle: The experimental results of a disturbance compensation controller, *Proceedings of the MTS/IEEE Conference on OCEANS*, 1017-1024
[18] Zwaan, S. V.; Bernardino, A.; Santos-Victor, J. (2002). Visual station keeping for floating robots in unstructured environments, *Robotics and Autonomous Systems*, Vol. 39, 145-155, doi:10.1016/S0921-8890(02)00200-2
[19] Marks, R. L.; Wang, H. H.; Lee, M. J.; Rock, S. M. (1994). Automatic visual station keeping of an underwater robot, *Proceedings of the MTS/IEEE Conference on OCEANS*, Vol. 2, 137-142
[20] Negahdaripour, S.; Fox, J. (1991). Underwater optical station-keeping: improved methods, *Journal of Robotic Systems*, Vol. 8, No. 3, 319-338, doi:10.1002/rob.4620080304
[21] Jin, L.; Xu, X.; Negahdaripour, S. (1996). A real-time vision-based stationkeeping system for underwater robotics applications, *Proceedings of the MTS/IEEE Conference on OCEANS*, Vol. 3, 1076-1081
[22] Santhakumar, M.; Asokan, T. (2010). Planar dynamic station keeping of underactuated autonomous underwater robot in the presence of underwater currents, *Proceedings of the International Symposium on Robotics and Intelligent Sensors*, 84-89
[23] Alvarez, A.; Caffaz, A.; Caiti, A.; Casalino, G.; Gualdesi, L.; Turetta, A.; Viviani, R. (2009). Folaga: A low-cost autonomous underwater vehicle combining glider and AUV capabilities, *Ocean Engineering*, Vol. 36, No. 1, 24-38, doi:10.1016/j.oceaneng.2008.08.014
[24] Chyba, M.; Haberkorn, T.; Singh, S.B.; Smith, R. N.; Choi, S. K. (2009). Increasing underwater vehicle autonomy by reducing energy consumption, *Ocean Engineering*, Vol. 36, No. 1, 62-73, doi:10.1016/j.oceaneng.2008.07.012
[25] Fang, M. C.; Chang, P. E.; Luo, J. H. (2006). Wave effects on ascending and descending motions of the autonomous underwater vehicle, *Ocean Engineering*, Vol. 33, 1972-1999, doi:10.1016/j.oceaneng.2005.09.009
[26] Santhakumar, M.; Asokan, T. (2009). Application of robust design techniques for underwater vehicle control, *Proceedings of ISOPE Ocean Mining Symposium*, 285-289
[27] Slotine, J. E.; Li, W. (1991). *Applied Nonlinear Control*, Prentice Hall, Inc., Englewood Cliffs
[28] Santhakumar, M.; Asokan T. (2010). Investigations on the hybrid tracking control of an underactuated autonomous underwater robot, *Advanced Robotics*, Vol. 24, No. 11, 1529-1556, doi:10.1163/016918610X512587