Effects of navigation systems errors in the accuracy of AUVs trajectory control algorithms during a recovery manoeuver.

Pedro Martínez[*], **José Luis Aguirre**[*], **Mariano Saura**[*], **Pablo Segado**[*], **Gregorio Munuera**[*]

[*] Department of Mechanical Engineering
Universidad Politécnica de Cartagena
Doctor Fleming, s/n, 30202 Cartagena,Spain
[joseluis.aguirre,msaura.sanchez,
gregorio.munuera]@upct.es
[pmi,psc1]@alu.upct.es

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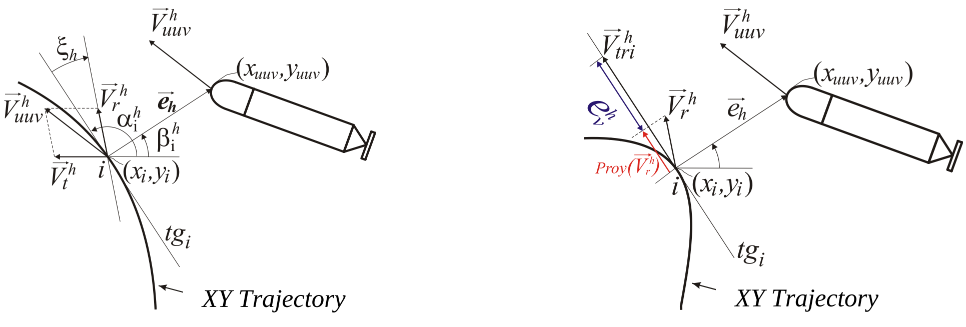
Nowadays, control systems have assumed an increasingly important role in the development and advancement of modern civilisation and technology. In this sense, Autonomous Underwater Vehicles (AUVs) are playing a growing role in the ocean sciences, since they are revolutionising the process of gathering ocean data. This sort of robots has suffered an important evolution in recent years motivated by the advances reached in the field of navigation, guidance and control systems. Their major breakthroughs resulted from successful developments of complementary technologies to overcome the challenges associated with autonomous operation in harsh environments.

By the end of the last century, AUVs have gradually moved from the controlled academic environment into operational scenarios, covering scientific, commercial and military applications.

Nevertheless, the risks associated with the underwater recovery of AUVs are still considerable and there is a great interest in the scientific community in the development of methods and algorithms to increase the accuracy of the autonomous navigation.

The objective of this paper is to present a control algorithm capable of guiding an AUV all along a trajectory to the underwater recovery in a mobile platform and check how the target movement and USBL refresh rate affect. This algorithm controls AUV's government to follow the path with the least possible error in position, orientation and velocity. The operation starts when the vehicle reaches a preset starting zone after finishing its mission and the AUV must to be able to reach a target point placed inside of a recovery station.

The control module is composed of three controllers. The Yaw and Pitch angles use PID controllers to govern the AUV keeping its bow $(x_{uuv}, y_{uuv}, z_{uuv})$ on the calculated trajectory (x_i, y_i, z_i) and its orientation such that the AUV's velocity $(\vec{V_r})$, relative to the moving target, is parallel to a vector $\vec{tg}_i$ tangent to the trajectory (Fig. 2). Position and orientation errors, both in horizontal plane (h) and vertical axis (z) are calculated at each integration point as shown in Equations (1) and (2) respectively.



a) b)

Fig. 2. Vector and variables needed to calculate position and orientation errors (a) and velocity error (b). Only the horizontal plane is shown.

$$\vec{e_h}(t) = [x_{uuv} - x_i, y_{uuv}, -y_i] \ ; \ \vec{e_z}(t) = [0, z_{uuv}, -z_i] \tag{1}$$

$$\xi_h(t) = arg\left(\vec{V_t^h}\right) - \alpha_i^h; \xi_z(t) = arg\left(\vec{V_t^z}\right) - \alpha_i^z \tag{2}$$

The AUV's velocity error is calculated as the difference between its planned relative velocity at each point of the trajectory $\overrightarrow{V_{tri}}$ and the projection of its relative velocity on the vector tg_i tangent to the trajectory at that point. This control is achieved by using a PID controller. It is considered that the AUV can update, at some refresh rate, information enabling it to estimate its actual position and orientation with respect to the recovery point. For that purpose, both Inertial Measurement Unit (IMU) and Ultra Short Base Line (USBL) commercial devices, together with their corresponding measurement errors have been considered in the control algorithm.

The effectiveness of the algorithm has been tested using dynamic simulations of models based on AUVs REMUS100, although it is fully applicable to any other type AUV. Tests have been performed considering variations in the following variables: initial position and orientation of the AUV to the mobile platform, velocity of the platform and refresh rate in USBL measurements. The errors in the AUV's position, orientation and velocity at each point of the trajectory, including the docking point, have been calculated.

The main conclusions drawn by the results analysis carried out in this work shows that the developed algorithm to control of AUV trajectory to underwater recovery in a mobile platform is able to control the vehicle from its initial position to the target point with an error under 0.5m in position and 10º in orientation during the whole trajectory. At the point of capture, the AUV's error does not exceed in any case 0.2m in position or 5 º in orientation.

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