Introduction

- Autonomous Underwater Vehicles (AUVs) open great possibilities to address some critical problems for dangerous operations at depths of sea, with available and cost-affordable technology.
- MDM Lab, the Laboratory of Mechatronics and Dynamic Modelling of the University of Florence, is partner of the Thesaurus project, funded by Regione Toscana, with the aim of designing a moderate-cost AUV, called Tifone, to be used, in swarm, for research and monitoring of archaeological sites.
- The absolute localization of a fleet of AUVs is a challenging problem due to the unavailability of Global Positioning System (GPS), [1,2].

Swarm configuration

- The system we refer to is composed of three underwater vehicles and a surface support ship.
- Each AUV is equipped with low-cost inertial sensors, a compass, a depth sensor and an acoustic modem.
- Only the master AUV has a high accuracy navigation sensor such as the Doppler Velocity Log (DVL).
- The surface boat locates itself through GPS.
- By the means of the acoustic modems, each vehicle can calculate its distance from the other vehicles of the fleet, while it receives data, with an update period considered around 10 s [1].
- The master AUV performs a geometric algorithm based on a tetrahedral configuration, Tetrahedron Based Position Estimator, with the aim to extend the advantages of the use of DVL to vehicles not equipped with it.
- Some strategies of propagation of the estimates have been implemented in the master AUV in order to limit the lack of information due to communication.
- The estimate of the orientation is implemented through a non linear attitude observer called Non linear Complementary Filter [3].

Tetrahedron Based Position Estimator

Through range measurements \((d_{ij})\) provided by acoustic modems, a geometric method based on a tetrahedral configuration allows a deterministic fix for position, avoiding unbounded error growth in the position estimate of each AUV.

\[
\begin{align*}
AUVs \text{ coordinates (A Frame):} \\
& z_1^i = d_{11} \\
& y_1^i = 0 \\
& x_1^i = \frac{d_{12} - d_{13} - d_{14}}{2d_{11}} \\
& \sqrt{y_1^2 + z_1^2} = \frac{d_{21}}{d_{11}} \\
& z_1^f = 0 \\
& x_1^f = \frac{d_{23} - d_{24} - d_{21}}{2d_{22}} \\
& \sqrt{y_1^2 + z_1^2} = \frac{d_{31}}{d_{22}} \\
\end{align*}
\]

\[
\begin{align*}
AUVs \text{ coordinates (Fixed-frame n):} \\
& R_1^n = \begin{bmatrix} z_1^n & y_1^n & x_1^n \end{bmatrix} \\
& R_2^n \text{ to be determined by means of depths:} \\
& R_3^n = \frac{R_1^n - R_2^n}{R_4^n} \\
& R_5^n = r_5 \\
& \text{And by means of AUV}_i \text{ (with DVL) estimated position:} \\
& \begin{bmatrix} x_i^n & y_i^n & z_i^n \end{bmatrix} = \begin{bmatrix} R_1^n & R_2^n & R_3^n \end{bmatrix} \\
& 5 \text{ elements are sufficient to calculate the whole } R_1^n \text{ matrix. Thus positions } P_1^n \text{ as the fixed frame can be determined.}
\end{align*}
\]

Simulations and Results

- A dynamical model of an AUV has been implemented, using Matlab-Simulink, with reference to [4].
- A sensor mask has been applied to each measurement to model error sources.
- The trajectories, chosen for the simulations, provide that the support ship remains stationary, whereas the three AUVs follow the paths shown in Figure 3.
- Statistical simulations based on 100-simulations-Monte Carlo method, in Figure 4, represent the evolution of RMS estimate error of position for the three AUVs as to the time.

Conclusions

- Preliminary results, based on Matlab-Simulink simulations, point out the advantages of using the strategy proposed.
- Further activities will be carried out to test the algorithm through realistic experiments.

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References


Fig. 1. CAD model of Tifone

Fig. 2. A Frame

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A \text{ frame:} \\
x^A \text{ axis so that AUV}_i \text{ belongs to it} \\
y^A \text{ axis so that AUV}_2 \text{ belongs to } x^A y^A \text{ plane } (y^A > 0) \\
z^A \text{ consequently}
\]

Fig. 3. Followed paths

Fig. 4. Time evolution of RMS estimate error