An Approach to Multiple Cooperative AUV-ASV in Twinned Guided Schema for Coordinated Navigation

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Abstract*—This paper proposes a dual navigation configuration consisting in an Autonomous Surface Vehicle (ASV) and an Autonomous Underwater Vehicle (AUV) in mutual supported guided navigation for long term, high persistence remote deployment. Research and experimentation has already been made by some authors [11], providing interesting results related to cooperative surface-underwater common navigation schema. Nevertheless some aspects have not been thoroughly considered, as long term high persistence deployments based in environmental energy gathering. Based on previous work of some of the author of this paper [1], focused in the study of the feasibility of conducting long term remote operation in tandem navigation, this paper shows the advances that have been made in terms of a navigation scheme based on a meeting-points strategy. To achieve these goals, a collaborative configuration considering a solar powered/wind-sailing ASV in combination with a low cost AUV is proposed. With both vehicles adopting a common referenced guided surface-underwater navigation as it is projected, this combination is expected to be able to face missions when unexpected environmental conditions will be present on the area of operation. Underwater hydro-acoustic communications and positioning referencing is considered for mutual guided navigation. The final goal is to obtain a robust, stable, fail-proof and practical set of vehicles with the additional advantage of being low cost.*

Keywords—AUV, ASV, twinned autonomous vehicles, Marine robotics, autonomous sailing vehicle.

I.INTRODUCTION

In this paper an approach for dual unmanned vehicles navigation schema for long term survey is proposed. This paper continues previous work of the authors related to cooperative navigation strategies that are able to provide a robust distributed platform for long term and high resolution oceanographic surveys as a complementary platform to the efficient and proven glider vehicles [7]. Environmental energy harvesting and robust communication system are important consideration for this schema [10]. The proposed twinned configuration provides a solution when continuous underwater operation and long term missions with remote deployment are required.

Because of the nature of both systems, ASV and AUV, a solution for keeping them close enough to ensure communications has been proposed. Related with the previously mentioned requirement, there are several problems to deal with:

- The ASV is exposed to different environmental disturbances (e.g. wind and waves) than the AUV.[4]
- Different propulsion systems: The ASV is propelled by its sail most of time, subjected to wind speed and direction and water conditions together with a solar-electric powered propulsion system. The AUV in the other hand, are propelled by an electric motor with limited time of energy reservoir.
- The AUV cannot trust in accurate self-positioning based on GNSS below the water surface.

II COLABORATIVE NAVIGATION

An important problem to consider related to coordinated navigation conducted by heterogeneous vehicles is the different environmental disturbances that can affect each of them. Wind and waves are important for an ASV Currents have less effect and are more predictable. In the other hand, currents are the main disturbances that can affect the AUV trajectory. In addition the fact of considering wind based sailing autonomous navigation for the surface vehicle limits the possibilities of tracking path-following strategies [10]. A prearranged rendezvous control waypoints path for the AUV underwater positioning validation and mission replanning instructions will be performed.

III SURFACE VEHICLE

Regarding the ASV, one of the main goals is to provide this vehicle with enough elements for guarantying the possibility of reaching any prearranged meeting point in the expected time, by using different complementary propulsion systems. Wind based propulsion system is considered as a primary power source. This kind of propulsion has special requirements for being automatized on an autonomous vehicle [6]. Electric power with solar cells rechargeable batteries based system is proposed as a complement for approaching and maneuvering operations, and for managing when harsh environmental disturbances or absence of wind are present [4].

A. ASV AUV acoustic communication system

A coordination guiding control based on underwater acoustic signals is proposed (Fig. 1). This strategy can be useful for minimizing problems associated with low cost instrumentation [9] present onboard this kind of vehicles. A set of acoustic transducers will be used in the surface vehicle to provide an equivalence to Short Base Line underwater positioning system. An acoustic array as passive sonar will provide the AUV acoustic bearing and range sound source identification capability.

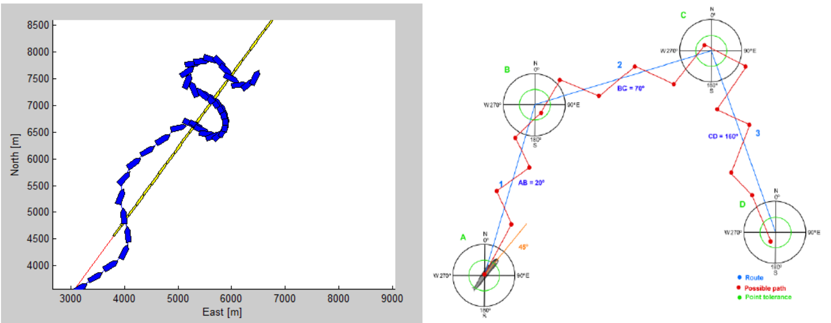

Fig.1. Example of navigation trajectories effective course for both vehicles (blue) and wind-sailing path for the ASV (red). Meeting points are the intersection between blue and red legs. Waypoints as items for navigation planning and reference are indicated by circles [5]

In addition, there are some considerations that should be taken into account. Wind sailing boats have special demands, a pseudo station keeping [10] carried out by the ASV in the vicinity of the meeting point in some cases will be necessary (Fig. 1). Motorized vehicles can perform this task by an adequate control based on observers, thrust allocation and controller systems, providing Dynamical Positioning Control System (DP) [8] capabilities. In our case, flexible course planning is necessary to be considered, according to the ASV special wind propulsion requirements. The most important constraint as it has been mentioned, will be the capacity of reaching the pre-programmed waypoint/meeting point in the prearranged time. This strategy will be of interest in cases when the surface vehicle will be able to sail faster and safely (considering that for wind-sailing craft not always slower is safer). In these cases it could be more convenient for the SAV reaching the meeting point even earlier and waiting for the arrival of the AUV. Is in this situation when the pseudo DP will be performed, keeping in the meeting point surroundings area waiting for the AUV arrival (Fig. 1).

IV. ASV-AUV COORDINATED OPERATION

The main objective is to provide the two twinned vehicles with some capabilities to guarantee surface-underwater coordination as proposed in [11], vehicle location and some basic commands and instructions to allow the AUV of being controlled in remote mode interfacing through the surface vehicle and with the command center station inshore [11]. Nevertheless a sailing based surface navigation has to deal with different problems than standard propulsion based vehicles. SAV and AUV cooperative navigation as it is proposed in this paper, will require a hybrid based control system for adapting long term deployment to the different expected navigation and environmental conditions in the area of operation [10].

Typical scientific missions for oceanographic research and suitable for twinned navigation schema based on wind propulsion can be: upwelling front detection and tracking, thermocline halocline characterization [3], and Harmful Algae Bloom (HAB) detection among others. The possibility of using a combination of two vehicles will provide a tool to track the phenomenon of interest with near real-time data transfer from underwater environment [10]. This fact will help to take decisions for adapting more quickly the survey planning according to the retrieved data [2]. With this schema, interruptions in the survey procedure by the AUV for surfacing, send data and receive new instructions will minimized.

V. COMMUNICATIONS

Multiple wireless acoustic communication system is performed both in the ASV and the AUV for data delivering and control. Adaptive control involving AUVs and ASVs using remote human supervision complementary with autonomous self-decision provides a robust combination for achieving the expected goals. Underwater communications are relied to ultrasound transducers and hydrophones, in addition to dedicated software. In the case of the SAV, a set of four transducers, each placed on one extreme of the hull is expected to provide Short Base Line (SBL) positioning bearing capabilities for AUV bearing control. In addition, the AUV vehicle is equipped with short range wireless communication for ASV-AUV data transmission and control instruction delivering.

VI. CONCLUSIONS

Path following and trajectory tracking navigation in twinned vehicle configuration seems to be a good schema for conducting long term missions, specially when continuous underwater operation is one of the goals. Twinned navigation strategies can avoid problems related to space-temporal underwater vehicles, self-positioning in long term and persistent AUV underwater operations. A Twinned Unmanned Vehicle in simultaneous surface and underwater operation based on environmental sources of energy for sailing and maneuvering has been proposed as a solution for persistent underwater vehicle operation. Remote supervision and long term long persistence cooperative navigation will be also performed.

VII. FUTURE WORK

Future work will involve new scenarios and different navigational schemas. Additional procedures and algorithms for solving different situations will be developed. Real field test with vehicles, instruments and algorithms validation will be performed along this year.

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