On Autonomous Cooperative Underwater Floating Manipulation Systems

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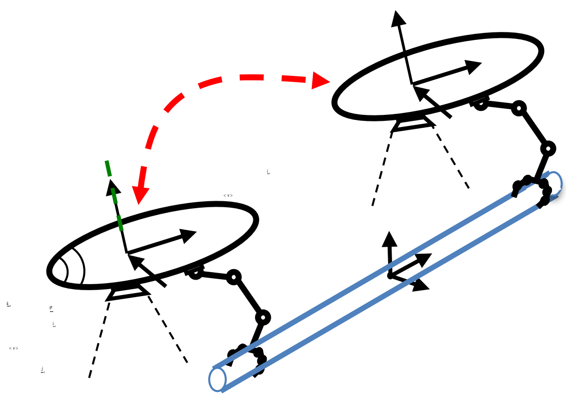
Abstract

Main research activities on underwater autonomous manipulation and transportation can be dated back to the end of the nineties, when within the EU-funded pioneering project AMADEUS [1] the ability of performing autonomous bi-manual operations by part the homonymous fixed-base underwater dual-arm wok cell were achieved. Underwater autonomous manipulation capabilities were also exhibited within the EU funded project ALIVE [2] project, by part of a single manipulator operating from an autonomous vehicle that was preliminary grabbing a submerged structure to be inspected. Successively, advances toward autonomous manipulative operations, to be performed by floating vehicle-manipulator systems, were for the first time achieved within the SAUVIM project [3] at University of Hawaii, by employing a large vehicle endowing a much smaller arm. Then, within the recently concluded EU-funded project TRIDENT [4], more enhanced control capabilities for autonomous floating vehicle-arm systems, also including operational effectiveness aspects to be exhibited in terms of "agility" of the overall system, were finally achieved for vehicles and arms of comparable masses and inertias; and within a unifying, functional and algorithmic, control and coordination framework [5]. Moreover, at present time the EU-funded running project PANDORA [6] is pursuing the ambitious objective of assigning, to a single floating vehicle-manipulator system "persistent autonomy" capabilities, to be mainly expressed in terms of learning abilities from accumulated experience during operations, as well as in terms of abilities in effectively adapting to changeable underwater environmental conditions.

In force of the above outlined advances on control of individual autonomous underwater vehicle-manipulator systems, the idea of proceeding further-on by the investigating the possibility of now having a team of underwater vehicle-manipulator systems, cooperatively acting to the accomplishment of a common manipulation and transportation underwater mission, quite obviously arises, with motivation strictly similar to those driving the employment of networked robots within ground, as well as space, applications. And in this perspective the currently running Italian national project MARIS [7] has been recently launched, just aiming to provide methodological, technological, as well as experimental proof-of-concept trials, evidencing the possibility of effectively implementing team-cooperative intervention activities within underwater environments.
In particular, within MARIS, the paradigmatic primary problem to be tackled corresponds to the one roughly sketched in the figure, where two floating manipulators have to cooperatively act in such a way to ultimately transport a firmly grasped common object toward an final destination, with this last expressed in terms of a final position and attitude to be achieved by the object.



Moreover the transportation mission must be accomplished by also requiring each floating manipulator to operate in a way to always avoid mutual collisions; while also guaranteeing the maintenance of all a set of its own inequality objectives, regarding its safety and/or operation-enabling conditions (that is, for instance, the joints and manipulability of each arm must stay within its own suitable ranges; each supporting vehicle must maintain an almost horizontal attitude for energy saving reasons, etc.); while further acting in such a way to allow the companion system doing the same; other than acting for ultimately accomplishing the assigned cooperative transportation and positioning task.

Since the cooperation between individual agents always benefits from some information exchange among them, we can see how the considered control problem consequently configures as a networked multi-objective one, also subjected to the equality constraints deriving from the firm grabbing of the shared object to be transported.

To this respect, however, since within underwater environments any explicit information exchange generally requires the employment of very low bandwidth acoustic communication devices, it is then clear that, in order to be practically feasible, the cooperative control strategy should also obey to the requirement of a minimal use of explicit underwater data exchanges between the agents; being this last a requirement sensibly driving each development step of the cooperative control policy design.

Thus, as a complement the limited explicit information exchanges, the contemporary employment of the so-called *implicit* information exchanges, for instance provided by the separate measurements of the interactions occurring with the transported object; or the distance between the agent supporting vehicles (to be maintained higher than a certain threshold for avoiding collisions) separately measured by acoustic pingers, lasers, or sonars; and even the use of mutual vision between the agents, must be consequently exploited as much as possible, whenever possible.

Within the above outlined framework, the talk will consequently provide an adequately detailed presentation of the results till now achieved, while also indicating the currently pursued directions for achieving smart and full cooperation capabilities within the underwater environment.

Currently performed encouraging simulation experiments will also be provided, with reference to the previously mentioned active national project MARIS.

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