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# Experimental Study on Autonomous Manipulation for Underwater Intervention Vehicles

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## ABSTRACT

Autonomous manipulation refers to the capability of a robot system that performs intervention tasks requiring physical contacts with unstructured environments without continuous human supervision. Today, few Autonomous Underwater Vehicles (AUVs) are equipped with autonomous manipulators. SAUVIM (Semi Autonomous Underwater Vehicle for Intervention Mission, University of Hawaii) is one of the first AUVs capable of autonomous manipulation. This paper presents one of the first successful underwater intervention mission of SAUVIM, consisting in a recovery operation of a submerged target. The focus of this manuscript is mainly on the manipulation aspect, introducing the solution adopted in order to achieve the goal.

KEY WORDS: AUV, Autonomous manipulation; underwater intervention; computer vision; image processing; target tracking.

## INTRODUCTION

Most of today's underwater intervention tasks are performed by manned submersibles or remotely operated vehicles (ROVs). In autonomous underwater vehicles, the low bandwidth and significant time delay inherent in acoustic underwater communications are considerable obstacles in remotely operating a manipulation system and reacting to unexpected situations in a timely manner.

However, autonomous vehicles with no physical link to the human operator could permit operating in the areas where humans cannot go, such as under ice, in militarily denied areas, or in missions to retrieve hazardous objects.

The key element in improving underwater intervention capability in AUVs is autonomous manipulation. It is a challenging technology milestone, which refers to the capability of a robot system that performs intervention tasks requiring physical contacts with unstructured environments without continuous human supervision. Today, few AUVs are equipped with autonomous manipulators. SAUVIM (Semi Autonomous Underwater Vehicle for Intervention Mission, University of Hawaii, Fig. 1) is one of the first AUVs capable of autonomous intervention.

Autonomous manipulation systems, unlike teleoperated manipulation systems that are controlled by human operators with the aid of visual and other sensory feedback, must be capable of assessing a situation, including self-calibration based on sensory information, and executing or revising a course of manipulating action without continuous human intervention. It is sensible to consider the development of autonomous manipulation as a gradual passage from human teleoperated manipulation. Within this passage, the most noticeable aspect is the increase of the level of information exchanged between the system and the human supervisor. In teleoperation mode, the user sends and receives low-level information in order to set the position of the manipulator with the aid of visual and other sensory feedback. As the system becomes more autonomous, the user may provide only a few higher-level decisional commands; the management of lower level functions (i.e. driving the motors to achieve a particular task) is left to the onboard system. The level of autonomy is related to the level of information needed by the system in performing the particular intervention. At the task execution level, the system must be capable of acting and reacting to the environment with the extensive use of sensor data processing.

This paper presents experimental results of the first attempt of underwater autonomous manipulation. For the best knowledge of the authors, no result in underwater autonomous manipulation has been presented in the literature. The presented recovery operation consists in a sequence of autonomous tasks finalized to search for the target, to hook an underwater inflatable lift bag on it and finally to deploy the lifting mechanism in order to bring the target to the surface.

## TELEPROGRAMMING AND AUTONOMOUS MANIPULATION

The principal obstacle in exchanging data with a generic AUV during a mission is the low bandwidth and a significant time delay inherent in acoustic subsea communication. This aspect makes very difficult operating the manipulator remotely.

Robot teleprogramming was proposed as an intermediate solution between supervised control systems and direct teleoperation when a significant time delay appears in the communication (Funda-Linsday and Paul, 1992, Paul-Sayers and Stein, 1993, Sayers-Paul-Catipovic-Whitcomb and Yoerger, 1998). The main idea is to make the operator feeling the system as a common teleoperation where the communication delay has disappeared. The concept consists in decoupling the local and remote zones by limiting the data exchange to a few symbolic information, in opposition to the common robot teleoperation system that use low level information (e.g. the joint position, motor velocity reference, etc.).

Usually, in teleprogramming systems, a partial copy of the remote