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Shared Autonomy for Mapping and Exploration of underwater environments using an HROV

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***Abstract* – One of the main goals in robotics is to achieve full autonomy. However, for certain tasks, robots still lack the level of abstract reasoning that gives the ability to make decisions, plan ahead, and change actions during the execution of a process, these abilities are acquired at its best degree only by humans. In terms of unknown underwater environments, the combination of specialized robotics that can withstand harsh environments and the reasoning of a human operator can give effective results on exploration, inspection, and subsequent tasks. Standard solutions propose to use fully teleoperated Remotely Operated Vehicles (ROV)s or fully Autonomous Underwater Vehicles (AUV). Still, both solutions have their drawbacks: high operation costs and limitations due to the need of a physical connection in the case of ROVs, and limitations in the communications or problems while facing complex decision making in case of AUVs. These limitations can be overcome with the concept of shared autonomy applied to a Hybrid ROV (HROV). In this new paradigm, an operator leads the mission by selecting objectives at a high level, and a HROV executes them taking all the low level decisions. This paper explores the shared autonomy concept applied to an underwater exploration task, leading the first steps towards intervention missions.**

***Keywords* –** *Exploration, Frontier, Shared Autonomy, HROV, Clustering.*

I. INTRODUCTION

Technology has always helped us tackle challenging tasks, from complex calculations to working in hard-to-reach places like underwater environments. Diving into this context, underwater robotics, such as Remotely Operated Vehicles (ROVs) and Autonomous Underwater Vehicles (AUVs), have emerged as a solution for exploring these harsh environments. Both of these offer good results depending on the task to achieve, but also account for different challenges. While ROVs provide continuous control and real-time feedback to operators, they need to be tethered to expensive vessels to achieve these capabilities. In contrast, AUVs can operate autonomously without constant supervision, but their level of autonomy is limited, normally, to basic survey tasks.

Joining both approaches (ROVs and AUVs), can settle a middle ground solution to ease these challenges. This can be established with the concept of Shared autonomy [1], where the high level thinking of a human operator can be combined with the autonomous execution of low level tasks by an HROV to achieve a complex goal.

II. METHODOLOGY

Although our end goal is to perform partially supervised intervention in underwater scenarios, the first task to achieve is to understand the environment by means of exploring it, to generate a map that can be used to navigate and perform further tasks. The approach in this paper is covered in three main pivots: the gathering of mapping data with on-board sensors, propose new locations to be mapped to an user using an utility metric, and then navigate to them using motion planning techniques. While basic tasks will be directly carried out by the robot, others will be validated by a human operator in the shared autonomy strategy trying to maximize safety and effectiveness.

This proposal uses the Octomap [2] framework as a mapping tool. From a point cloud obtained by a 3D laser sensor [3] or a stereo camera placed in the robot, an occupancy grid map is generated, giving a three dimensional representation of the environment using voxels. The map is structured as an octree, which is processed to locate frontier voxels, found on the boundaries between free space, and unknown space [4].

The frontier voxels are grouped by means of a clustering algorithm [5], which takes the position of said voxels as an input, and outputs a centroid position for each cluster of voxels in close proximity. These centroids are marked as suggested points to the user, allowing them to choose the next position of interest.

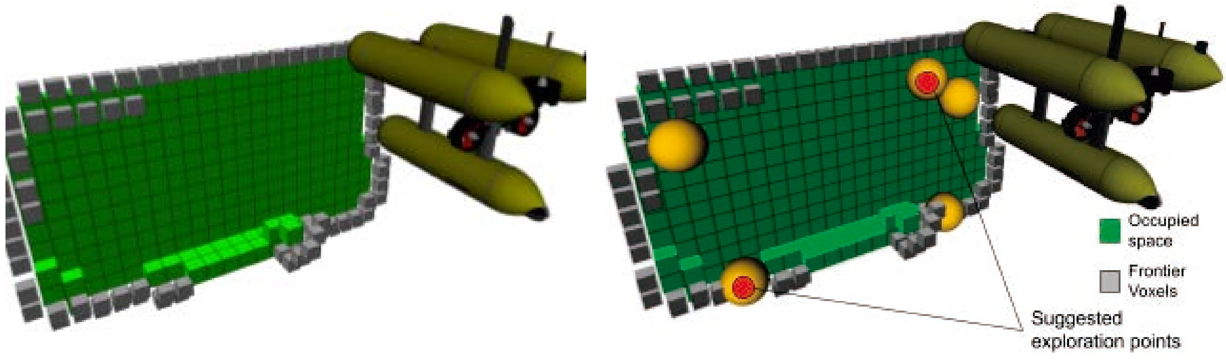

Fig 1. Suggested exploration points obtained by clustering frontier regions.

Once a suggested point is selected by the user, the robot will employ a motion planning algorithm to suggest a path, which the user can also validate, or, request another path to be proposed.

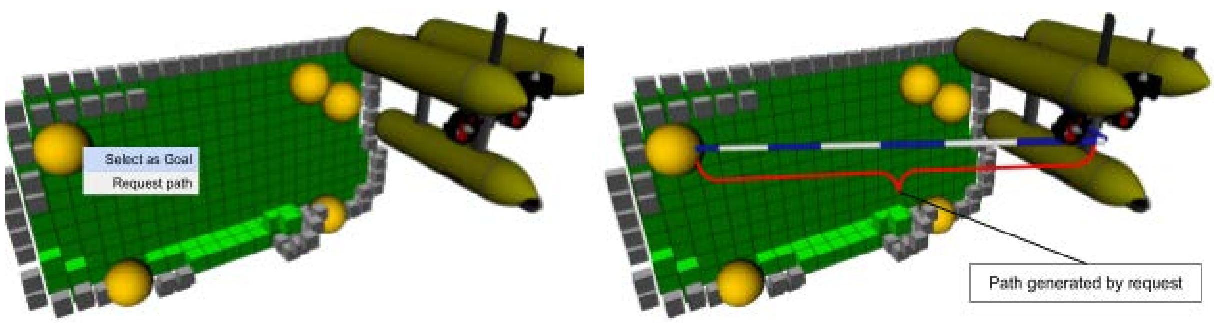

Fig 2. Path generation to selected cluster centroid as a goal.

As the robot navigates to these points, the map will keep growing, accomplishing the exploration task around the area of interest to the user through the shared autonomy technique. The robot will check that the path the robot is following is still valid, and in case it is no longer valid prompts the user how to proceed.

Communication between the HROV and the user can be performed over a low bandwidth channel and withstand significant delays as the robot performs all low-level actions. For the proposed application, we propose to use an optical modem with a velocity of about 10 Mb/s but with a limited field of view that introduces additional constraints to both the exploration and the motion planning.

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