ID25 AN OPEN-SOURCE CONTROL ARCHITECTURE FOR TELEOPERATED UNDERWATER LEGGED ROBOTS

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Abstract

Legged robots have achieved unprecedented performance in the terrestrial environment. The capability of legged agents to harness the contacts with the ground for locomotion, adapt their gait to negotiate regular terrains, avoid obstacles, and interact gently with the environment are currently unmatched in the underwater domain. This would represent a valuable asset for both scientific and industrial marine applications. Notwithstanding this, the development of Underwater Legged Robots (ULRs) has not progressed at the same pace as their terrestrial counterparts due to the high costs and risks associated with marine field robotics. In this contribution, we will present the control architecture for the teleoperated ULR SILVER2 enabling the core functionalities of locomotion, manipulation, proprioception, and vehicle monitoring. The control architecture design, including software, will be available under a Creative Common license to simplify access to this emerging field and promote the exchange of knowledge between the communities of legged and underwater robotics. The presentation of the control architecture will allow us to focus on the several research opportunities connected with the novel categories of ULRs which span from bio-inspiration and control to field applications. The application of ULRs to marine ecological monitoring in the framework of the Marie Curie Action BluE will be thoroughly discussed as a case study.

Keywords - underwater robot, legged robot, open-source, control electronics, bio-inspired robot and bio-mimetic robot.

INTRODUCTION

This work presents the development of an open-source control electronic for teleoperated Underwater Legged Robots (ULRs).

Legged robots have reached an unprecedented level of performance in terrestrial environments. They can adapt their gaits to negotiate irregular terrains, avoid obstacles, and interact gently with the environment using their legs or additional manipulators. Terrestrial legged robots are now commercially available as research platforms and can be equipped with high-resolution sensors for autonomous inspection of industrial plants or hostile environments such as caves or disaster sites [1].

Similar capabilities cannot be found in mainstream underwater vehicles. On one hand, propeller-driven vehicles, such as Remotely Operated Vehicles (ROVs) or Autonomous Underwater Vehicles (AUVs), are better suited for surveying wide areas but struggle in intervention tasks due to their floating nature. On the other hand, benthic crawlers are very stable platforms, but require a continuous seafloor for locomotion and may damage sessile fauna with their tracks. Consequently, the capabilities of legged robots could be invaluable in the marine sector, for both industrial and scientific applications. ULRs were first proposed in the late 1990s, and their development has followed various approaches, resulting in a diverse range of morphologies, actuation strategies, sizes, and envisioned applications. Notwithstanding this, their development has not progressed at the same pace as their terrestrial counterparts, both in terms of control algorithms and hardware. The reasons for this disparity can be attributed to the traditionally high costs and risks associated with marine field robotics which have deterred several research groups from venturing into this emerging field [2].

Providing the robotics community with affordable, standardized, and reliable hardware would significantly simplify the access to this novel research area and promote the exchange of knowledge between the legged robotics and the underwater robotics communities. With this spirit, we would like to introduce the design, development, and testing of the new control electronics of the ULR SILVER2 (Fig. 1) [3], whose code and design will be available under a Creative Commons license.

CONTROL ELECTRONICS FOR SILVER2

The herein presented SILVER2 control electronics is the culmination of several years of experience in deploying ULRs and its design was guided by the following principles:

1. Enable the core functionalities of a ULR including locomotion/manipulation, proprioception, and monitoring of power consumption and leakages;

2. Ensuring wide accessibility by using components with available free software and open-source libraries.

The result is a system architecture based on ROS2 running on a Raspberry Pi4. The presented board supports the use of all RS485-based Dynamixel Smart Servomotors, allowing users to choose from position, velocity, and current control modes, and providing great versatility for research projects involving both locomotion and manipulation tasks. Proprioception encompasses the state of individual motors (angle, velocity, and torque), accelerations, angular velocities, orientation of the vehicle, and external pressure. The board is completed with a power management system that provides a stable 12V, 5V, and 3.3V supply, consumption monitoring, and an array of humidity sensors for the early leakage detection at each different ULR cylinder.

ULRs IN MARINE ECOLOGICAL MONITORING AND OTHER APPLICATIONS

In the field of marine ecology, monitoring an environment for extended periods without perturbing it is crucial. Underwater cabled observatories have been developed for this very reason and they are a source of valuable time series dating back to more than 10 years. Naturally, they lack a significant spatial coverage which can be overcome through the integration of mobile platforms. In the framework of the Marie Curie Action BluE (Bioinspired Legged robotics for Ecological monitoring and Exploration), the ULR SILVER2 will be integrated with the OBSEA cabled observatory to extend its monitoring radius in visual census applications. At the same time, the disturbance introduced in the environment in comparison with other mobile platforms such as propeller-driven vehicles or benthic crawlers will be experimentally assessed. During the workshop, the up-to-date status of the integration of SILVER2 with the OBSEA will be presented, together with other applications of ULRs.

CONCLUSIONS

This work represents a step towards establishing a standardized control architecture for this innovative category of underwater robots. It is expected to enable more researchers to contribute to the development of ULRs, enhancing the operational capabilities for end-users and serving as research platforms to address fundamental questions about aquatic and extra-terrestrial pedestrian locomotion.

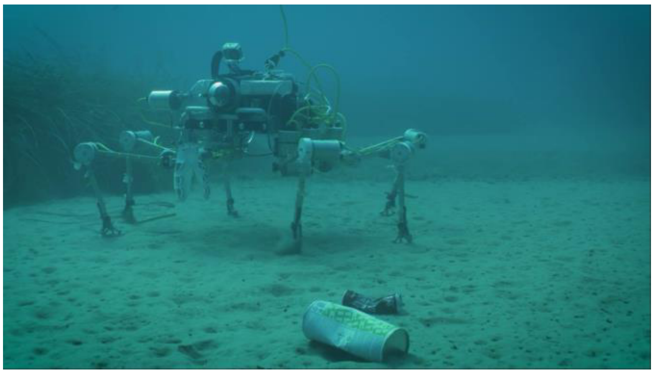

Fig 1. The ULR SILVER2 equipped with a sediment sampling device during field trials in Livorno, Italy

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ID26 SLAGREEF, SLAG BASED ARTIFICIAL REEFS DESIGN PRELIMINARY RESULTS

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Abstract

Climate change exerts a profound impact on coastal regions, with severe environmental consequences. Coastal areas bear the brunt of intense storms that adversely affect both beaches and urban infrastructures situated along the coastlines, resulting in substantial harm to marine ecosystems. Furthermore, proximate urban areas contribute to the contamination of seawater, leading to significant adverse effects on marine life. Conversely, industries such as steel and aggregates generate substantial quantities of slag furnace and inert waste residues, respectively. Although there is often some utilization of these by-products, a considerable volume ultimately finds its way into landfills or serves as backfill. Consequently, the global challenge lies in effectively repurposing these waste residues. This abstract presents a preliminary slag based artificial reefs (AR) design focused on the exploration and advancement of novel materials derived from slag furnace residues and inert waste from. The construction employed a 3D slag-concrete printer to craft artificial reefs. First design is being tested since summer 2023 at Obsea underwater observatory, where a dedicated 24/7 monitoring system was designed and deployed to study how the artificial reef serves a dual purpose by safeguarding coastal areas and contributing to the restoration of damaged ecosystems. Keywords - Recycling, construction technologies, 3D printing, metallurgical slag, mining slag, artificial reef, underwater monitoring, underwater life, Artificial Intelligence (AI) and image processing.

INTRODUCTION

In recent years, the popularity of artificial reefs (AR) has surged, driven by the aim to increase marine biodiversity and advocate for sustainable fishing practices. These structures, crafted by human intervention, are specifically formulated to replicate the natural habitats of marine organisms. Composed predominantly of materials like concrete, steel, or stone, these artificial reefs are strategically positioned in locations characterized by a dearth of marine life or ecological impairment. The primary objective of deploying artificial reefs is to establish novel habitats capable of sustaining a varied spectrum of marine species, thereby fostering the principles of sustainable fishing practices [1]. The first prototype design was based on Carral's et al. analysis [2], where a list of requirements were introduced as listed in table 1:

Nr	Requirement	Observation
1	Concrete printed design	Presentation
2	Modular	Presentation
3	Adaptable to the environment	Presentation
4	1-meter diameter	Presentation
5	Environmentally safe	Presentation
6	Reef's lifetime as long as possible	Dimensions
7	Pieces must be able to gather	Dimensions
8	Outstanding design	Dimensions