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Original article

Seafloor analysis and understanding for underwater archeology

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ABSTRACT

Surveying the oceans' floors represents at the same time a demanding and relevant task to operators concerned with marine biology, engineering or sunken cultural heritage preservation.

Scientific researchers and concerned persons combine their effort to pursue optimized solutions aiming at the mapping of underwater areas, the detection of interesting objects and, in case of archeological survey mission, the safeguard of the detected sites.

Among the typical tools exploited to perform the cited operations the Autonomous Underwater Vehicles (AUVs) represent a validated and reliable technology. These vehicles are typically equipped with properly selected sensors that collect data from the surveyed environment. This data can be employed to detect and recognize targets of interest, such as manmade artifacts located on the seabed, both in an online or offline modality. The adopted approach consists in laying emphasis on the amount of regularity contained in the data, referring to the content of geometrical shapes or textural surface patterns.

These features can be used to label the environment in terms of more or less interesting areas, where more interesting refers to higher chances of detecting the sought objects (such as man-made objects) in the surveyed area.

This paper describes the methods developed to fulfill the purposes of mapping and object detection in the underwater scenario and presents some of the experimental results obtained by the implementation of the discussed techniques in the underwater archeology field.

1. Introduction

Mapping the oceans' floors represents an extremely demanding task to the man. The peculiar environmental setting is for the most part out of reach to human operators because of the hard environmental conditions that make the survey complex and dangerous. Nevertheless the sea waters cover approximately the 72% of the planet's surface and mapping the seafloors is still a relevant task of typical concern to many involved operators such as biologists, engineers and archeologists.

On the other hand it is known that the oceans' floors host large amounts of cultural heritage (more than 3 million of wrecks according to the latest UNESCO reports) as a consequence of ship wreckages that took place during the past ages. This fostered the combined commitment between cultural institutions and scientific researchers to pursue a solution toward the safeguard of this collective patrimony.

In this framework several ventures have been started, based on the effort of either national (THESAURUS – TecnicHe per l'Esplorazione Sottomarina Archeologica mediante l'Utilizzo di Robot aUtonomi in Sciami, PAR FAS 2007–2013 Regione Toscana) as well as international (ARROWS – ARchaeological RObot Systems for the World's Seas, European FP7 project) cooperating consortia [1–3]. These projects have been focused on the main purposes of mapping, diagnosing, cleaning and securing of underwater and coastal archeological sites.

To perform all the cited operations a marine vehicle, such as an autonomous underwater vehicle (AUV), can be profitably exploited. The vehicle can be equipped with properly selected sensors, in order to collect data from the surveyed environment in an optimal way.

Typical sensors that turn out to be useful in this frame are optical cameras coupled with acoustic sensors, like side scan sonars or multi-beam sonars. The data collected by the AUVs during the mission campaigns can be processed in order to detect targets of interest located on the seabed. The main approach adopted in the processing procedure is to emphasize the amount of regularity detected in the captured data, hence highlighting fragments of geometrical shapes, such as primitive curves, or homogeneous areas exhibiting similar textural patterns. A strong and persistent

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presence of these regularities is considered a clue for the presence of man-made targets on the seafloor.

The features are computed by processing the optical and acoustic collected data. The output result of the overall signal processing chain consists in the labeling of the represented environment in terms of more or less interesting scenarios. The term interesting usually refers to a quantitative index which numerically expresses our confidence about the presence of some specific sought object inside the environment. Hence it could be a score which, based on the number and relevance of the detected features, could indicate the likely presence of an interesting object. Given the generality of the proposed approach the object to be detected can be represented by a large variety of targets, here including archeological wrecks as well as flora specimens, posidonia prairies or corals or even underwater industry structures like oil and gas pipelines.

The methods developed to fulfill the cited purposes will be described in detail in the remaining part of the paper, which is organized as follows: Section 2 concerns a brief summary of the existing commercial solutions for underwater vehicles, in Section 3 the exploited sensors and their main features are discussed, Section 4 represents the paper's core and concerns the description of the main approach and the multiple techniques developed to the purpose of understanding and representing the underwater scenarios, finally Section 5 concludes the paper by discussing potential future prospects in the field of the underwater optical and acoustic signal analysis.

2. Vehicle platforms for underwater surveying

Among the technological systems employed to survey the underwater setting it is appropriate to spend a few considerations about the mobile platforms that are typically employed for maritime survey purposes and provide a brief presentation of their main properties and features.

These mobile platforms can be roughly grouped in two classes: the Remotely Operated Vehicles (ROV, Fig. 1a), that can be directly maneuvered by human operators thanks to a wired connection from a control platform to the vehicle itself, and vehicles that are designed to perform underwater missions without human supervision, i.e. the already mentioned AUVs (Fig. 1b). In the following

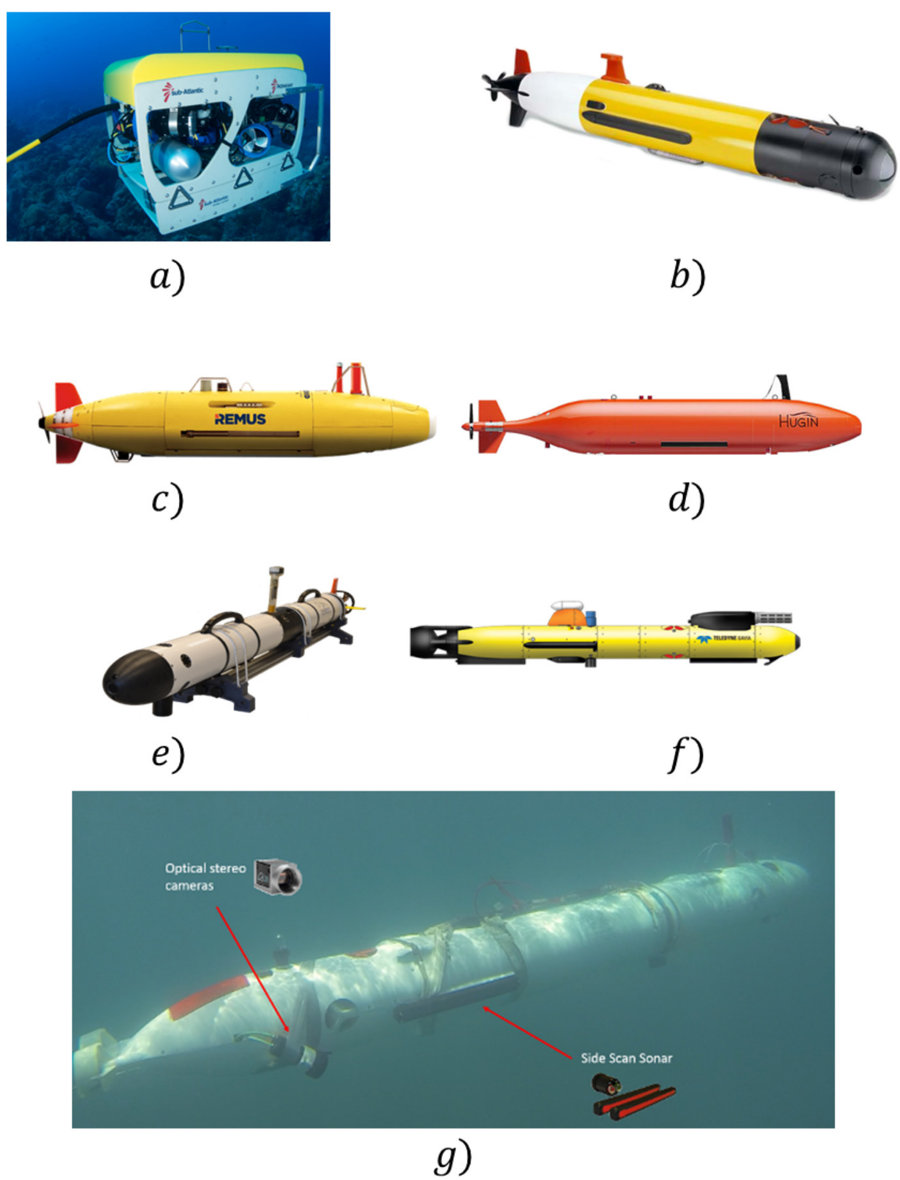

Fig. 1. Sub-Atlantic Mohawk (a), an example of commercial ROV vehicle (picture available at http://flowergarden.noaa.gov/). REMUS 100 (b), an example of commercial AUV (picture available at http://hydroid.com/remus-100-marine). Popular Commercial AUVs (c–f) and TifOne (g), the research AUV designed and implemented within the THESAURUS project. Details of the optical and acoustic payload mounting on TifOne are displayed.

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