IFAC World Congress 2023
Invited Open Track Proposal

Marine Robotics: the Breeze of Innovation and Remote Access to the Sea

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Abstract: Autonomous marine systems represent an extremely attractive research field that poses formidable challenges both from a theoretical and a practical standpoint. Many core problems in these areas are still open, and considerable research work is required to address and solve them. The complexity of the problems at hand requires a multifaceted approach to system analysis and design to exploit the use of methods and tools from dynamical systems theory, automatic control, networked systems, identification and estimation, computer vision, communications, sensing and measurements to yield practical systems capable of executing complex scientific and extended missions at sea in an efficient and reliable manner.
For these reasons, there is a strong interest in bringing together the marine robotics community with specialists of complementary areas to foster new synergies and promote joint research activities aimed at solving both theoretical and practical problems with far reaching implications on scientific, commercial, and societal marine-related issues. It is against this backdrop of ideas that we submit an invited open track proposal entitled *Marine Robotics: the Breeze of Innovation and Remote Access to the Sea*, aimed at bringing attention to this exciting field of research and promoting the cross fertilization of ideas required to bring new theoretical and practical advances to bear on the development of innovative systems.

1. INTRODUCTION

Seas and oceans compose the 70% of the Earth surface, with exploration, exploitation and maintenance in such environment representing complex challenges for the human beings. Since such water bodies are forbidden environments for the human presence, advanced technological tools, namely marine robotic platforms, have to be employed for the aim of observation, data gathering and intervention in both surface and underwater scenarios: USVs (Unmanned Surface Vehicles), ROVs (Remotely Operated Vehicles) and AUVs (Autonomous Underwater Vehicles) are the engineering solution that have allowed the access to seas and oceans in the last 30 years.
Over these last decades the research in this field has focused on the design and development of reliable and robust machines capable of performing demanding tasks and providing high autonomous capabilities, as well as accurate sensing capabilities. Because marine robotics technology has reached a consolidated level of reliability, new trends are now emerging in the research community: the focus is rapidly moving in the direction of providing an effective support towards important scientific and societal issues such as plastic pollution, climate change, monitoring of polar regions, secure access to underwater resources and border control, to name a few.
Such global interests can be tackled by an efficient employment of autonomous systems, which can be exploited for a wide range of diverse applications: exploration of deep water areas, precise multi-spectral sampling, extended patrolling and autonomous intervention.
The evolution, capability and reliability of these machines is strictly bond to the development and employment of more and more advanced control systems which provide extreme levels of autonomy, allowing for instance the optimal exploitation of innovative hardware, performance- and/or energy-oriented automatic controls, high-fidelity navigation systems, multi-target guidance algorithm, aggregated mission planning and execution monitoring architectures, just to list a few research topics in the field of marine robotics.
Eventually, due to the recent and well known Covid19 pandemic situation, the human race experienced the destructive effects of forced distancing and isolation, forbidding

or hardly limiting routine processes and activities. The research and industrial activities at sea have been affected by the limited access of personnel to resources, infrastructures and operative scenarios, causing production delays, drop of maintenance activities, money loss, etc. For these reasons a giant step forward has been done in the direction of remote access to technological tools, platforms, infrastructures and data, allowing human personnel to remotely access marine scenarios through innovative technological solutions thus overcoming the physical distancing limitations.

2. OBJECTIVES

It is paramount to have the availability of technological tools and innovative methodologies to explore the oceans, collect large amounts of data and, when needed, perform intervention operations, keeping into account three main key-points:

- improve the efficiency of the operations (which is strictly related to the cost reduction);
- reduce the impact on the surrounding environment (i.e. avoid destructive actions);
- provide safety to the humans involved (reducing the exposure of human operators to risks).

To achieve these goals, we can rely on robotic technologies that nowadays can certainly be characterized as a consolidated solution. In the last 30 years an impressive number of both prototype and commercial robotic platforms have been designed and developed for a wide range of operations: ROVs have been and are currently employed for exploration of unknown areas, observation of wrecks and intervention on submerged infrastructures (e.g. Oil & Gas); USVs are nowadays efficiently exploited for wide area data gathering in coastal and harbor environments, even if a legislation is still lacking. With the increasing computing power provided by the current electronics availability and the dramatic improvement of acoustic-based navigation and communication, the AUVs are gaining their space in the market of underwater applications.
Furthermore, a number of non-conventional prototypes have risen such as the soft-robotic systems. Such autonomous agents are designed to cope with strict specific objectives like energy harvesting, silent operations, extended operational duration; to reach such advanced goals their design is often based on nature mimicking and thus it is possible to find prototypes of robotic fishes, octopuses, eels and jellyfishes that requires cutting-edge control schemes to exploit the expected capabilities at their finest.
In order to exponentially increase the capabilities and performance of autonomous marine systems, an increasingly investigated trend in marine robotics is the development of multi-vehicle frameworks, where each agent of the team cooperates with its neighbours in order to achieve global mission objectives. This concept allows for the improvement of overall performance, the reduction of mission execution time and the increase of operative areas. On the other hand, the development of cooperative and coordinate robotic frameworks impose the tackling of different challenging technical and technological problems, in particular in marine environments where harsh conditions, external disturbances, and physical constraints require additional efforts in order to develop reliable solutions. In particular, the problem of a correct and certified interaction among very diversified autonomous agents should be addressed and solved, for example through systems providing distributed scalable computing and trustable functionalities, such as blockchains, AI, IoT networks and other smart systems.
As stated in the introduction section, the next game-changing step is to envision and start building the path towards the remote exploitation of platforms, infrastructure (both hardware and software) and data, allowing the users and operators to avail of the robotic-based solution to access the marine environment overcoming the need of the physical presence in the operational scenario. On the research and development side, this approach allows a much faster cooperative design, realization and integration of heterogeneous multi-modules frameworks composed by physical agents and software components world-wide accessible. On the application side, new exploitation ideas can be developed in the context of both industrial and touristic/recreational activities. Remote observation and maintenance of coastal areas, harbor premises, patrolling of protected environments, secure access and maintenance of underwater infrastructures and ship hull inspection are some examples of industrial application that can avail of the remote access to autonomous robots dramatically speeding up the intervention time, with a direct cost reduction. The employment of remotely teleoperated agents will be the key factor to create virtual tourism, allowing remote people to enjoy the (virtual) visits in underwater sites and protected parks, thus creating a brand new sector of market opportunities.

3. GOAL OF THE INVITED TRACK

Currently, new trends in the robotics and automatic control community are driving research towards challenging and unexpected frontiers. New technologies and smart approaches are steadily endowing autonomous systems with behaviours and skills that only a few years ago were not considered realistic to be realized in so little time. The same progress is being experienced in the marine robotics community, where innovation and new ideas arise as means to deal with highly challenging and dynamic marine environments. These represent an unlimited source of increasingly demanding user requirements as well as new and interesting questions and are the ultimate testing ground for new developments.
It is important to stress that the exploitation of autonomous vehicles requires the design and implementation of suitable advanced guidance, navigation, and control systems in order to provide the high level of reliability required to accomplish complex missions. The development of marine systems embraces many theoretical and practical issues: dynamical systems theory, automatic control, networked systems, identification and estimation, computer vision, informatics, cybersecurity and blockchain technology, communications, sensing and measurements, to name but a few.
The merging of different fields in robotics strongly encourages and fosters the creation of collaborations and the hybridization of approaches to obtain new methodologies

and create effective technological solutions. This is the case, for instance, with the renewed partnership between robotics and artificial intelligence (and especially in the mature field of machine learning), that today is growing and is leading to unexpected and exciting results in many different application fields of autonomous systems.
Indeed, an open invited track focusing on autonomous and intelligent system related to the marine environment, its challenges and accomplishments, as well as its still open problems and needs, can only be of great benefit and impact on the wider automatic control community, and is expected to create an innovative breeze of research activities and ideas shaping the forthcoming future.

4. PAST ACTIVITIES

The emerging trends are steadily impacting the design, development, and operation of advanced technological systems for seas and oceans exploration and exploitation. However, the magnitude of this endeavour has so far not been well reflected in the types and number of sessions devoted to such systems in conferences addressing a vast number of topics at the intersection of control, estimation, and networking. For example, in the IFAC World Congress in 2011 there were only 2 Regular Sessions on "Marine Systems Navigation, Guidance, and Control" plus 1 Invited Session on "Marine Vehicle Motion Planning, Navigation, and Control", in a total of 379 sessions.
At the time of the IFAC World Congress 2014, the organizers of the present track proposed an invited session on marine and maritime topics, entitled "Navigation, Control, and Sensing in the Marine Environment". The importance of such marine and maritime topics was especially highlighted by the success of such invited session (that in the end became a full-day track), where the impressive number of 20 papers plus 2 keynote talks was reached.
The same successful result was achieved with the organization of an Open Invited Track for the IFAC World Congress 2017 entitled "Marine and Maritime Robotics: Innovation and Challenges", composed by three sessions and collecting a total of 18 papers. These numbers prove the consolidated presence of the autonomous marine system community and our effort, with the proposal of this Open Invited Track, is to give a wider visibility to brand new results in the field, as well as fostering the birth of new ideas and tools for the improvement of automatic control theories and methodologies that can then be applied to the marine domain.
Despite the pandemic situation caused by Covid19 and the related travel limitations, that forced the IFAC World Congress 2020 to be in full virtual presence, a successful Open Invited Session, with the contribution of 16 invited papers, with the title "Marine Robotics: A New Wave of Autonomous Systems" was conducted, allowing the marine robotics community to maintain a strong presence and contribute in the area of automatic control. It is with this view in mind that we are submitting an Invited Open Track proposal entitled *Marine Robotics: the Breeze of Innovation and Remote Access to the Sea*, aimed at bringing attention to this exciting field of research and promoting the cross fertilization of ideas required to bring new theoretical and practical advances to bear on the development of innovative systems. We will encourage the presentation of communications on a number of subjects that include: i) advanced navigation, guidance and control, ii) cooperative system and networked motion planning, iii) remote and delayed control, iv) system modeling, identification, and simulation, v) combined vehicle-manipulator systems, vi) perception systems and sensor-based control, vii) condition monitoring and fault-tolerant robust control, viii) situation awareness and collision avoidance for autonomous agents, ix) bio-inspired systems and intelligent control, and x) machine learning and AI, to name a few. This will help steering current cutting-edge research to substantially improve the autonomy and reliability of marine vessels, robots, and systems, instilling little by little in the society a rising sense of confidence on the operation of robots in everyday life thus contributing to raising the awareness on the use of robotic platforms in industrial and civilian contexts. Our decision to submit the present proposal is to provide a strong contribution to the IFAC TCs on Marine Systems and Intelligent Autonomous Vehicles.
We expect our initiative to attract a well sized group of world-known experts in theoretical and practical issues related to the marine and maritime robotics domain and to foster the exchange of ideas with experts in other fields. At the same time, given the scope and depth of the issues that we tackle, the track is also expected to attract the attention of the IFAC-related community at large.

5. REFERENCE IFAC TECHNICAL COMMITTEE FOR EVALUATION

*CC*7 – **Transportation and Vehicle Systems → TC** 7.2**. Marine Systems**

IN MEMORY

The authors of this proposal, Marco Bibuli and Enrica Zereik, would like to dedicate this Open Invited Track in memory of **Giuseppe "Pino" Casalino** that recently and unexpectedly passed away. Pino has been for long an appreciated Full Professor at the University of Genova (Italy), where he taught Automatic Controls and Industrial Robotics courses; he was a pioneer in the field of adaptive and optimal control, leading the GRAAL Lab, where an uncountable number of Master and PhD students found their professional heaven. Recently, the University of Genova appointed him Professor Emeritus, recognizing the brilliant scientific results obtained in his career and the importance of his work.
We, Marco and Enrica, had the chance to be Pino's students during the University period, we were tutored and supervised by Pino during our Master and PhD theses. During our research careers, we crossed our paths again with Pino in different National and International Projects. In the end, we cannot find the words to express how lucky we are to have been his friends.