Marine and Maritime Intelligent Robotics (MIR)

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Abstract

Exploring the oceans, much like space, requires innovative solutions and new technology. The growing demand to protect, exploit and learn about some of our most precious resources calls for particular knowledge and skills to respond to the challenges of a harsh and unforgiving environment.

The new Erasmus Mundus Joint Master's Degree (EMJMD) Programme in Marine and Maritime Intelligent Robotics (MIR) (http://www.master-mir.eu) combines robotics and Artificial Intelligence (AI) to advance marine and maritime science and its technological applications. It aims at building the capacity to enable advances in far reaching sea exploration, autonomous deep sea robots, teleoperations and the use of AI in these endeavours. The MIR programme is shaped to provide training in data science and state of the art applied robotics targeted at enhancing the efficiency, health, safety and environmental performance of the offshore industry and maritime operations.

The EMJMD MIR programme offers competitive scholarships to welcome students worldwide and provides them with a common space to develop their shared passion for marine robotics and AI. The programme fosters cultural exchange and sharing of individual experiences. The master's is conducted by a consortium of 4 well-established academic institutions in the domain of marine robotics research. The institutions are in 4 countries France (UTLN), Norway (NTNU), Portugal (UL-IST) and Spain (UJI), for which the ocean has played a key role in history and is anchored in society.

The goal of the programme is to develop specialists in marine and maritime intelligent robotic systems, providing them with: a) a solid theoretical background in the marine physical processes and technical skills in robotics engineering control systems and sensors, b) grounded knowledge in Artificial Intelligence, enabling them to develop cutting edge robotics solutions to real world challenges, c) applied knowledge in subsea and maritime application fields, including blue growth of maritime and offshore sectors, as well as deep sea surveillance, biodiversity monitoring, subsea resources exploration, offshore structure maintenance, e-navigation and maritime security enhancement.

Students completing the MIR Masters will be well equipped with skills and state of the art knowledge, enabling them to pursue a career in robotics engineering for the offshore oil and gas, renewable, naval, and maritime sectors. Additionally, the knowledge acquired in the use and function of intelligent robotics for the underwater environment will enable them to easily continue on to a PhD in multiple different fields, should they so desire.

The programme was designed to address global challenges identified by the consortium, the gap between industry and academia, the slow convergence of AI and robotics communities and the geopolitical and cultural differences among participating countries. The MIR programme contains a growing worldwide network of more than 58 academic and industrial associate partners spanning more than 21 countries and covering all oceans. Associate partners participate by providing industry-led lectures, internships, research collaborations and scholarships. Learning-by-doing courses cover the fundamentals of the marine environment, robotics and artificial intelligence, with an emphasis on the interconnections between these fields. A set of transversal skills is developed through courses in languages, scientific writing and entrepreneurship. Furthermore. the MIR consortium organises a yearly symposium hosting presentations from the students' work, keynotes from distinguished scholars, industry representatives and competitive challenges in AI and robotics.

While the first year of the course takes place at UTLN, each student specialises in one of the three study tracks, encompassing a 3rd semester at one of the other main partners' institutions. **Applied robotics for underwater intervention missions** (UJI) aims to endow underwater robots with the capability to interact with the environment using manipulators, thus paving the way for the development of advanced systems for close-range underwater infrastructures inspection and maintenance as well as materials sampling. **Safe Autonomous subsea operations** (NTNU) targets increasing the level of automation and autonomy in routine or otherwise tedious operations which can improve safety, efficiency and performance, supporting the human operator in decision-making and supervision and reducing human workload. **Cooperative marine robotics for scientific and commercial applications** (IST-UL) focuses on groups of autonomous marine robots working in cooperation, networked via aerial, acoustic, and optical links to dramatically improve the means available for ocean exploration and exploitation at unprecedented temporal and spatial scales.

MIR students write a master thesis related to their study track and supervised by one of the main partners and their work is presented at the MIR annual symposium. Graduates receive a double diploma from UTLN and the institution of their study track.

The MIR programme fills a gap in the current EU education landscape by responding to a pressing demand for specialists in ocean technology. It does so by building a consortium of actors around the globe with the common goal of advancing education and research in AI and robotics for ocean applications.

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I. Introduction

The UN has proclaimed a Decade of Ocean Science for Sustainable Development (2021-2030) to support efforts to reverse the cycle of decline in ocean health and gather ocean stakeholders worldwide behind a common framework. Increasing scientific knowledge, developing research capacity and transfer of marine technology, to improve ocean health and to enhance the contribution of marine biodiversity to the development of developing countries comprise one of the UN sustainable development targets (14a). The review of EU research agenda and programs such as HORIZON 2020 EU 3.2.5 on cross-cutting marine and maritime research emphasises the need to focus on technological challenges with a view to unlocking the potential of seas and oceans across the range of marine and maritime industries, while protecting the environment and adapting to climate change. The MarTERA project as well as Proteus, recognised that the EU research and innovation agenda needs broad systematic cooperation in all areas of waterborne transport, offshore activity, marine resources, maritime security, offshore oil and gas, and aquaculture stating that research and innovation activities in these fields cannot be tackled either at national levels, alone or solely by one sector.

Artificial intelligence (AI) has become an area of strategic importance and a key driver of EU economic development. The EC in its Communication on a European Approach to Artificial Intelligence [1] sets as a priority goal "being ahead of technological developments uptake by public and private sectors" stating the need for actions which a) connect and strengthen AI research centres across Europe, and b) support the development of AI applications in key sectors. Such sectors include Blue growth sectors considering their value to the EU economy. The EC, in its report on the EU AI landscape [2], states the need to attract young people through a diverse network and meaningful connectivity features in academia by supporting universities in their aim of collaborating with industry and holding open discussions on Europe's industrial and economic culture.

In parallel, the blue economy is consistently growing, currently creating jobs for over 3.5 million people. The sector is predicted to double by 2030 [EC, 2018a]. The need for skills and innovation advancement in the fields of robotics and artificial intelligence in a cross-cutting manner between the marine and maritime sector is highlighted [3]. However, the EC in its report on achieving the Blue Growth strategy [4] identified as a current challenge the lack of highly qualified and skilled professionals. It is widely established [4], [5] that actors in Blue Economy sectors are experiencing difficulties in finding the right employees and most expect these difficulties to persist in the near future. This is due to:

a) a skills gap between education offers and labour market needs, especially with regards to technological developments and innovation [3]
b) a lack of communication and cooperation between education and industry [4], [5]

The international, interdisciplinary, and inter-sectoral nature of these challenges demands a similarly integrated approach to train the experts who will be able to tackle them tomorrow. The EMJMD Master of Marine and Maritime Intelligent Robotics (MIR) we present here is designed to address these challenges.

In this paper we focus on the academic and scientific aspects of this new degree. In Section II we expose the needs analysis that motivated the creation and design of the MIR programme. Section III covers how the programme responds to these needs. Finally Section IV provides a detailed overview of MIR's course organization and implementation.

II. Needs analysis

A. Scientific needs

From a scientific angle we can see a paradigm shift in many fields of study towards a data-driven approach to knowledge acquisition and exploitation [6]. The recent explosion of data availability, computing power and advanced machine learning techniques has triggered key advances such as the use of Deep Learning (DL) in a wide variety of tasks [7]. This has led to on par performance with humans in many tasks that we considered exclusive to us, which we know today as Artificial Intelligence (AI). Reinforcement learning (RL) and its combination with DL have made great advances in game-playing solving [8], [9] and are showing great potential in other robot control tasks [10].

Despite its accomplishments and rapid spread across multiple disciplines, DL approaches present a set of challenges and limitations [11], [12], some of which are of special relevance when applied to marine robotics. DL methods are known to be data-hungry, opaque and brittle. These challenges are the target of current research and serve as evidence of a scientific need to continue advancing our knowledge in DL. Intelligent robotics is also an active topic of research facing multiple challenges for its widespread adoption [13]. To date, it has mainly remained in the academic sphere. However ongoing research results reveal its potential to play an important role in robotics. This trend is corroborated by the efforts of large companies such as DeepMind, OpenAI or Uber to advance the field. Some of the main RL limitations pointed out by [14] are: i) the curse of dimensionality, ii) the issue with real world samples, and iii) data inefficiency. Recent work has focused on using DL to solve some of these obstacles. These approaches are starting to produce satisfactory results [15], [16]. Furthermore, transfer learning, imitation learning or model-based RL are all proposed to overcome current challenges in robot learning. These scientific open ends in the use of AI for Robotics justify the need for an academic program that tackles both fields together.

From an application perspective, the study of oceans and our environment has been identified as one of the great opportunities for advancing science with Intelligent Robotics [17]. A recent UNESCO report [18] highlights the large economic and time costs of data gathering through traditional vessels with human operators. While the use of unmanned vehicles has been the focus of marine scientists for a long time [19], recent work is focusing on using AI techniques and robotics to increase autonomy and solve the problem of scale in ocean studies [20], [21]. Advancing marine intelligent robotics could be the next big step in improving our understanding of the oceans and our environment.

B. Academic needs

From the analysis of existing masters using https://studyportals.com/, https://www.findamasters.com/ and Google web searches using keywords like robotics, AI, offshore, marine, maritime technologies between April and June 2018, 50 master's programs were identified which attempt to link AI and Robotics with a predominance on humanoid and aircraft applications. The skills and techniques learned in these programs are not directly applicable to the harsh marine environment. Furthermore, masters in the following categories were identified: 23 in marine science, 23 in coastal/marine management, 16 in marine biology, 10 in marine biotechnology/aquaculture, 36 in marine/offshore engineering (marine technologies, engineering for renewables, coastal and offshore engineering), and 1 in marine law. A predominance in marine sciences, biology and management masters was identified. The other option is to specialise in a very specific sector such as oil and gas or offshore renewables. A detailed examination of the curricula of marine and offshore technology masters based on publicly accessible data resulted in the conclusion that, to date and the best of our knowledge, there is no MSc which combines AI, robotics, maritime systems, and marine science. The majority of relevant or complementary programs can be found in the UK at Heriot-Watt (HWU), Plymouth and Southampton universities. There has been no similar Erasmus Mundus (EM) program to date. Our review of current and past EM projects highlighted that there have been 7 EM on the marine environment or maritime technologies, as well as 3 EM on AI or Robotics but none which combines the four domains. Moreover, within the MIR consortium the Partner from UJI participated in the EMARO+ EM program which focused on advanced robotics, thus ensuring a transfer of lessons learnt and best practices to the MIR program.

III. MIR: AN INNOVATIVE PROGRAMME TO RESPOND TO THESE NEEDS

In the past 10 years we have seen how some of the skills that were traditionally attributed to humans and certain animals have been implemented in machines. This is what we know today as Artificial Intelligence (AI). The increasing availability of data, the exponential growth of computational power and the development of novel machine learning methods have fuelled qualitative performance improvements in tasks such as machine listening and computer vision. Deep Learning (DL) has been a key enabler of this evolution. This family of learning approaches has unlocked effective use of data through large expressive models (e.g. deep neural networks) and optimisation techniques. Applications of DL have surpassed human performance in difficult problems ranging from robust speech recognition [22] to medical diagnosis [23].

Robotics is a field in which DL is having a major impact. Machine perception has greatly improved with the adoption of DL. From personal assistants to self-driving cars, most, if not all intelligent systems contain necessary sensory modules implemented using neural networks. Robot sensing is not the only aspect affected by the advances of AI. Navigation, planning and control are all tasks that are currently being revisited from a data-driven machine learning perspective. Reinforcement Learning (RL) and its combination with DL, known as Deep Reinforcement Learning (DRL), has proven to be a successful framework to optimise game-playing agent behaviour, such as DeepMind's AlphaGo, OpenAI Five and most recently AlphaStar. The application of such techniques to automatically find optimal robot behaviour for a given task is an active topic of research [14], [10]. Known as robot learning, this work has the potential to drive important improvements in autonomous robots. Endowing robots with the ability to automatically learn a behaviour eases generalizing their application to unforeseen situations and uncertain scenarios and reduces human bias in control design. Moreover, robot learning translates the focus of the practitioner from working on specific behaviours of a particular agent to the design of the task and learning method. This paradigm shift could accelerate the development of autonomous robotics by reducing domain expertise requirements and by facilitating reuse of generic learning techniques with multiple agents and tasks.

Robot autonomy is of special importance in the marine and maritime sector. The harsh environment and lack of fixed infrastructures makes human supervision costly, insufficient or in some cases even impossible. We hypothesize that deep learning and deep reinforcement learning will play a key role in the next wave of marine and maritime intelligent robotics, just as it has revolutionised other fields.

These ideas guided the design of our program. The new generation of marine roboticists will require a skillset that combines knowledge of the marine environment, full understanding of robotics modelling and control, and mastery of AI approaches. While these abilities will provide a clear advantage to industries such as advanced underwater technology, offshore and deep sea, many of the competencies developed are transferable to other domains such as data science for oceanography [24] and climate research [25], marine systems modelling [26] and/or terrestrial robotics.

The AI block in Semester 1 covers the core fundamentals and advanced Machine Learning techniques. These cover the challenges in working with Big Data and common approaches to solve them. Standard procedures of working with data-driven techniques are introduced, as well as methods to transform, exploit and evaluate data, including visualisation, prediction and error analysis. The first semester also covers Deep Learning, by introducing the building blocks and principles behind it. The usual practices and applications will be presented. We will also focus on the current limitations identified in the scientific section of the needs analysis, namely, large data-requirements, opacity and fragility. These will be addressed in detail through dedicated laboratory work. The module delves into transfer learning, DL inspection and interpretability, generative models and adversarial examples. One last module in the AI block is dedicated to the Reinforcement Learning framework. It covers identifying and framing problems in RL, basic techniques to solve RL tasks. As was done in the DL module, in order to ensure academic excellence, we will concentrate on the current challenges of applying RL to robotics: high dimensionality, data inefficiency, the curse of real-world samples. We will introduce state-of-the-art solutions to overcome these obstacles such as the use of DL techniques in state modelling, simulators and on policy optimisation methods.

This methodology of training DL and RL diverges from that found in most existing and openly available courses. The latter have focused on proposing the different problems solved using DL or RL, mostly covering different modalities (image, audio, text) or tasks (game-playing, control) respectively. Our program innovatively focuses on case studies that exemplify the challenges and solutions proposed to overcome them. This prepares graduates to tackle real-world applications and to approach these from a realistic view-point.

In Semester 2 the AI & robotics block focuses on AI applications to autonomous robotics. A module on data-driven sensing dives into the use of DL for performing machine perception, including case studies on underwater computer vision, acoustic sensing and sea-surface and coastal monitoring. The module on adaptive autonomous robotic behaviour introduces deep reinforcement learning and robot learning, accompanied by practice work on task and scenario definition, and policy optimisation. The module on marine localization and mapping deals with positioning, ego-motion and environment characterization. Finally, a module is dedicated to explainable AI (XAI) covering the problem of DL opacity and interpretation of model decisions, it will also present solutions and active research in the field. During the second semester in order to ensure proper training in the most advanced and cutting-edge topics we invite distinguished lecturers that play a leading role in the field.

Another element of innovation in the MIR academic program is the use of case studies in a learning-by-doing manner. We propose working on real world data and realistic scenarios which have been previously solved in a research context. This approach develops the skill of autonomy and yet permits learning and contrasting results with previously published solutions. It also allows the participant to experience an ecologically valid research process from problem identification to communication.

A. Study Track 1. Applied Robotics for Underwater Intervention Missions: Methods and Applications

While commercially available Autonomous Underwater Vehicles (AUVs) are routinely used in survey missions, a new set of applications exist which clearly demand intervention capabilities [27]. The maintenance of permanent underwater observatories, submerged oil wells, cabled sensor networks, pipes and the deployment and recovery of benthic stations are but a few of them [28]. Nowadays, these tasks are addressed using manned submersibles or work-class ROVs (Remotely Operated Vehicles), equipped with teleoperated arms.

Current Intervention-AUVs (I-AUVs) prototypes are usually big and complex systems exhibiting only a limited set of functionalities including docking and fixed based manipulation on a subsea panel, as well as search and recovery of simple objects. Underlying the main drawbacks found in these aforementioned systems are the current technology limitations in several domains like wireless communications [29], human-robot interaction [30], multisensory based manipulation [31], control strategies for redundant robots [32], networking and cooperative robots [33], to mention but a few. Moreover, looking for increasing autonomy levels, cognition developments will be also a cornerstone, trying to replace dexterity associated with the human expert on the intervention domain by means of Artificial Intelligence (AI) procedures.

In summary, all the aforementioned technologies will be the key contents assumed in this specialization that is well connected with the previous foundation on robotics and AI developed during the previous semesters. It is also remarkable that special attention will be paid to connect the theoretical contents with practical work. To achieve this aim some trials will be carried out in water tank conditions with available underwater intervention vehicles. This will be crucial for understanding the main differences between the performance of I-AUV's and ROV's. All these infrastructures will be available at UJI. In short, different experiments will be designed to clarify the main concepts underlying the program (i.e. AI techniques for decision-making and learning, wireless communication, HRI, planning, navigation, perception, manipulation, etc.)

B. Study Track 2. Autonomy in subsea operations

At NTNU the Department of Marine Technology has specialized in methods and techniques which facilitate the assessment, development and sustainable operation of Norway's biggest export industries – oil and gas extraction at sea, ship technology with corresponding equipment industry, fisheries and aquaculture technology – as well as newer developments including offshore renewable energy, coastal infrastructure and marine robotics for mapping and monitoring the ocean environment, including polar regions. NTNU educates 80% of all engineers in Norway, and holds engineering tracks in building environment, energy and petroleum, minerals, manufacturing, oceans, ICT and cybernetics. NTNU takes a multi-disciplinary approach and students learn to work across disciplines through projects such as Experts in teams. Big data and AI are key enabling technologies which are now changing the field of engineering and marine robotics. Competence is being developed in all areas of engineering on how to improve operations by use of digital solutions. The teaching philosophy is research-based education. This is ensured by teaching personnel (professors) bringing latest research into the portfolio. All professors are required to perform research, publish results in open access as well as supervise several PhD candidates. This ensures an appropriate level of research in education. Also, all courses are required to have a digital component, provide digital exams and digital lecture solutions. This contributes to ensuring excellence in education.

C. Study Track 3. Cooperative marine robotics for scientific and commercial applications

We are entering a new era where the use of groups of autonomous marine robots working in cooperation, networked via aerial, acoustic, and optical links will dramatically improve the means available for ocean exploration and exploitation at unprecedented temporal and spatial scales. New theoretical frameworks and cutting-edge technologies are required to bring about this revolution in the field of marine robotics, "leveraging on the transformative advances and growth of the fields of machine learning and artificial intelligence". This leap forward will hinge on the availability of a new breed of research engineer with the capacity to master the concepts and techniques required to design, implement, and field test advanced systems for multiple robotic vehicle operations, with a view to increase the safety, efficiency, and efficacy of operations at sea in a multitude of scientific and commercial scenarios.

At the core of the systems required for cooperative multiple vehicle operations are those in charge of cooperative motion planning with temporal and energy cost criteria, cooperative navigation and control, and networked operations that are often enabled via acoustic communication links that exhibit low bandwidth and are plagued with latency and temporary communication losses. The study track proposed by IST-UL, entitled Cooperative Marine Robotics for Scientific and Commercial Applications, leverages on the know-how and experience of its staff members, and aims to afford students the expertise required to advance R&D in this challenging and promising area of work. The theoretical background required will be acquired by proper choice of the courses taught at IST-UL and at the other partner institutions. The students opting for this track will also be given the opportunity to familiarize themselves with the process of going from theory to practice by participating in sea tests with real vehicles that are property of IST and include ASVs, AUVs, ROVs, and Hybrid ROV/AUV systems. Whenever possible, the master thesis in this track will include the implementation of at least one representative system (e.g. motion planning, navigation, or control) on-board a group of vehicles and the evaluation of its performance using the infrastructures and tests facilities available at IST-UL. During this phase, the students will benefit from the guidance and assistance of the research engineers at IST-UL that are responsible for the deployment, maintenance, and operation of the in-house developed robotic systems and associated software suites for seamless system implementation.

IV. Overview of MIR's organisation and implementation

The structure of the MIR programme, shown in Table I in conjunction with the foreseen staff mobility and joint activities facilitates the integrated delivery of competencies across the consortium. It is complemented with opportunities for acquisition of specialist knowledge and skills, based on student interests following student-centred learning approaches. The structure of the MIR (summarised below) contains several complementary activities such as the industry introduction days, the introductions to the study track specialisations and the annual symposium and championship.

TABLE I
Overview of the programme's academic organisation.

	Study track 1: Applied robotics for underwater intervention missions	Study track 2: Safe autonomous subsea operations	Study track 3: Cooperative marine robotics for scientific & commercial applications
Semester 1 30 ECTS	Induction weeks (2-week induction with joint industry introduction days)		
	UTLN 4 ECTS Induction week & transversal skills (scientific English, Innovation management, etc.) 8 ECTS Marine science and environment 9 ECTS Artificial intelligence 9 ECTS Robotics		
Semester 2 30 ECTS	UTLN 4 ECTS Transversal skills (reliability and risk assessment, AI fairness & transparency, etc.) 14 ECTS AI & robotics, and its applications taught by UTLN and guest lecturers 4.5 ECTS Joint introduction to study track specialisations (UJI, NTNU, IST) 9 ECTS Industry led seminars (options) 2.5 ECTS Entrepreneurship industry & research project		
	MIR Joint Annual Symposium & Championship (1 week to be held at different partner each year)		
Semester 3 30 ECTS	UJI # underwater interventions Thesis with principal supervision at UJI	NTNU # deep sea operations Thesis with principal supervision at NTNU or UTLN	IST # cooperative robotics Thesis with principal supervision at IST
Semester 4* 30 ECTS	**Thesis can also jointly be carried out at any associated partner*		
	MIR Joint Annual Symposium & Championship (1 week to be held at different partner each year)		

The first 2 semesters are carried out at the University of Toulon (UTLN) to secure greater cohesion among student cohorts. The first year capitalizes on the relevant multi-disciplinary teaching and research domains of the university in marine sciences, robotics and AI. This period also ensures direct access to industry partners the majority of whom are geographically located in the vicinity of UTLN. However, modules have been jointly designed with consortium partners and integration and internationalisation is secured through extensive staff and visiting scholar mobility during this period. The first semester (30 ECTS) starts with a two-week induction period focusing on language and transversal skills acquisition including socializing events for the students. Industry involvement is foreseen from day one. Additionally, Semester 1 is divided into three thematic blocks. Block 1 on Marine environment (6 ECTS) Block 2 on Robotics and control (10 ECTS), and Block 3 on Artificial Intelligence (8 ECTS). In Block 0, 4 ECTS are allocated for language and interdisciplinary transversal skills development based on industry needs analysis. The aim of the first semester is to provide all students with the fundamental building blocks of knowledge and skills in the interdisciplinary fields of marine science, robotics and AI.

Semester 2 held at UTLN is again divided into 3 thematic blocks. In Block 1 (14 ECTS) on advanced topics in marine intelligent robotics, the students learn how the fundamental knowledge in robotics, artificial intelligence and the marine environment that they acquired during the first semester is used to solve specific problems. Modules in this block will include case studies of AI and robotic applications to the marine and maritime blue growth sectors, such as ship detection, classification and tracking, deep sea biodiversity monitoring, or ocean dynamics characterisation from satellite imaging. Block 2 (6 ECTS) focuses on applied marine intelligent robotics and consists of professional and industry related modules. This block exemplifies industry integration in the MIR study program. The modules were developed based on the industry needs analysis and in collaboration with industry associate partners (see Table II). They will be taught mainly by professionals from leading marine robotics and AI industries or R&D centres. This will provide state-of-the-art, real-world case study materials to students as well as opportunities to visit industry premises. This block will be taught in the form of seminars providing the possibility of blended learning with industry professionals in the frame of industry continued education, should this be required to ensure the long-term sustainability of the program. Block 3 consists of introductory modules to all 3 study tracks taught by relevant visiting staff from each partner university. This again ensures that students obtain an integrated overview of the different skills provided by the MIR program regardless of study track selected. Block 0 in this second semester covers more transversal skills more specific to the target domain. It includes modules on reliability and risk assessment management, on international law with relation to unmanned marine vehicles, and a module on trustworthy and explainable AI, addressing the ethical and professional responsibility issues related to the use of AI.

During the third semester (30 ECTS), all students move to the university of their selected study track. The curriculum in each specialization track has been jointly defined by consortium partners and is offered by the partner university with the best expertise in the field. The common modules on scientific research methods and thesis preparation will be based on the jointly developed thesis guidelines.

During the 4th semester students carry out their thesis research. Each student will be jointly supervised by a minimum of two academic advisors, from two different institutions of the program (the principal supervisor being from the hosting program partner institution). Students can conduct their thesis at associated academic partner institutions, however, the student's principal supervisor will be from one of the 4 program partner institutions. Students also have the possibility and are encouraged to conduct their thesis as part of an internship with one of the numerous associate industry partners of the consortium. In this case a student is assigned one industry supervisor and two academic supervisors. Under this scenario the principle supervisor must be a program partner of the consortium. During their thesis work students will focus on a specific research topic for approximately 6 months. Students work independently albeit under supervision of their thesis supervisors and industry advisors. A joint online procedure for internship publication and management is foreseen as well as common internship guidelines. Through the thesis work, students apply the knowledge and techniques they gained during the courses in the three previous semesters. The final product is a written thesis report in the format of a research paper, following joint thesis guidelines. Thesis students also present and discuss their results at the Annual Symposium.

The MIR program involves several additional specific activities summarised below:

MIR annual symposium and championships
: Held at the end of June each year in a different partner institution, an international event which regroups physically all partners and provides the opportunity for MIR students, academic and industry associate partners to present their work and deliberate on state-of-the-art MIR challenges. During this symposium the marine intelligent robotics championships will be organized in which, students' teams as well as industries can participate. The symposium is foreseen to be a widely publicized event attracting participants from around the globe creating high visibility for the MIR program as well as an excellent networking opportunity for the students themselves.

Joint induction weeks
: The first 2 weeks of the first semester are dedicated to effectively integrate MIR students within their new socio-cultural and professional environment. Activities focusing on transversal skill development as well as acclimatisation of non-EU students with EU higher education practices and principles.

MIR website and online course management platform
: A common MIR website will be created in accordance with Erasmus+ guidelines. Additionally, an online course management platform will be developed to assist students in planning their studies, projects and activities. It will also serve to coordinate, monitor and report actions between different government bodies of the MIR consortium.

MIR webinars
: Although virtual teaching methods will not replace in-person teaching, it is proposed that key webinars be progressively developed. These will be made accessible online to all MIR students and partners and, wherever possible, to the larger public. An open webinar will be requested from each visiting lecturer or industry seminar expert.

Joint industry seminars
: During the second semester it is foreseen that seminars, in the form of intense block courses, will be conducted by industry leaders in selected topics.

TABLE II
LIST OF ASSOCIATE PARTNERS OF MIR

Artificial intelligence	German Research Centre for Artificial Intelligence (DFKI), Germany French national research institute for the digital sciences (INRIA), France Sofresud company, France Toulon Var Technologies (TVT), Innovation association, South of France
Autonomous Systems	Genova University, Italy University of Montpellier, France ECA Robotics company, France Cybernetix company, France Water Linked AS, Norway Spin.Works company, Portugal ixBlue company, France CNIM company, France
Robotics/ engineering	University of Sidi Mohamed Ben Abdellah, Morocco Institute of Technology of Cambodia, Cambodia Antonine University, Lebanon Hanoi University of Science and Technology (HUST), Vietnam Universiti Kuala Lumpur, Malaysia National Engineering school of Sousse, Tunisia Khalifa University of Science & Technology, Abu Dhabi, United Arab Emirates Universidad Nacional de San Agustin de Arequipa, Peru Universidad Pontificia Bolivariana, Bolivia Taras Shevchenko National University of Kyiv, Ukraine THALES company, France BlueEye, Norway IQUA robotics, Spain Robotnik company, Spain Ingenieria y Soluciones De Movilidad S.L. (INGESOM) company, Spain Abyssal company, Portugal Nexeya company, France Alierys company, France Searov company, France Subsea tech company, France IADYS, France
Marine Sciences	University of Bremen, MARUM, Germany French Ocean Institute, IFREMER, France Universitat de les Illes Balears, Spain Aquaculture Institute of Torre de la Sal, Spain Fundación CEIMAR, Spain National Vietnam Hanoï University of Science VNU-HUS, Vietnam Fundaçao Universidade de Brasilia, Brazil Universidad de Chile, Chile Geosurveys company, Portugal IN2SEA company, Portugal Chamber of commerce and industry, Var region, France Kietta company, France
Maritime Systems	National Superior Maritime School (ENSM), France National Engineering School (ENSTA Bretagne), France University of the Aegean, Greece Nelson Mandela University, South Africa Vietnam Academy of Science and Technology, Vietnam NAVAL Group company, France Strategis - Maritime Information, Communication and Technologies Cluster, Greece Alseamar company, France Seaproven company, France Stat Marine, UK

V. CONCLUSION

We have presented the scientific and academic reflections that have motivated the creation and design of the new Erasmus Mundus MIR master's degree. We show how a partnership of 4 main academic higher education institutions and over 50 associate industrial and academic international organisations aims to respond to current societal needs in the field of marine science and technology. To do so we have conceived an innovative programme that combines learning-by-doing teaching in robotics and AI focused on applications to the marine environment. After a 1-year delay caused by the COVID-19 worldwide pandemic, the first class is set to start in September 2021 with the arrival of 25 students from 9 different nations.

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