Search, identification and collection of marine litter with autonomous robots

SeaClear

https://seaclear-project.eu

D7.4

Workshop reports

WP7 — Dissemination and Exploitation

Grant Agreement no. 871295

Lead beneficiary: Technical University of Munich
Date: 02/01/2024
Type: PU
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R

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[1]R = Document, report, DEM = demonstrator, DEC = Websites, patents filing, etc. OTHER: Software, technical diagram, etc. ETHICS = Ethics

[2]PU=Public, CO=Confidential, only for members of the consortium (including the Commission Services), CI=Classified, as referred to in Commission Decision 2001/844/EC.

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Table of Contents

Definitions

- **Beneficiary:** A legal entity that is signatory of the EC Grant Agreement no. 871295.
- **Consortium:** The SeaClear Consortium, comprising the below-mentioned list of beneficiaries.
- **Consortium Agreement:** Agreement concluded amongst SeaClear Beneficiaries for the implementation of the Grant Agreement.
- **Channel:** Type of event which was organised or attended by project partner.
- **Grant Agreement:** The agreement signed between the beneficiaries and the EC for the undertaking of the SeaClear project (Grant Agreement no. 871295).

Beneficiaries of the SeaClear Consortium are referred to herein according to the following codes:

- **TU Delft:** Delft University of Technology.
- **DUNEA:** Regional Development Agency Dubrovnik-Neretva County - DUNEA.
- **Fraunhofer:** Fraunhofer Center for Maritime Logistics.
- **HPA:** Hamburg Port Authority.
- **Subsea Tech:** Subsea Tech SAS.
- **UTC:** Technical University of Cluj-Napoca.
- **TUM:** Technical University of Munich.
- **UNIDU:** University of Dubrovnik.

Abbreviations

In alphabetical order:

- **CA:** Consortium agreement.
- **D&E:** Dissemination and exploitation.
- **D**: Deliverable.
- **EC:** European commission.
- **ESA:** European Space Agency.
- **GA:** Grant agreement.
- **ICL:** Imperial College London.
- **ICONS:** Intelligent Control and Automation Sciences.

- **IFAC:** International Federation of Automatic Control.
- **IMDC:** International Marine Debris Conference.
- **M**: Milestone.
- **NOAA:** U.S. National Oceanic and Atmospheric Administration
- **NGO**: Non-governmental organization.
- **PI:** Principle investigator.
- **RL**: Reinforcement learning.
- **USV**: Unmanned surface vehicle.
- **UUV**: Unmanned underwater vehicle.
- **UNEP:** United Nations Environment Programme.
- **WP**: Work package.

Executive summary

The SeaClear project aims to develop an autonomous robotic team for finding and collecting seafloor litter in coastal waters. This deliverable details the workshop activities of SeaClear, and thus contributes to our D&E work package efforts. It also highlights the engagement with stakeholder categories to increase the potential impact during the project's lifetime. We start by listing the workshop activities organised by project partners to disseminate innovative results and reach various groups. Next, we continue to the diverse activities that SeaClear project partners took part in. Then, we conclude with an evaluation of the objectives and impacts of the D&E plan. This deliverable shows that we have implemented 17 events to disseminate project results. Those events cover 14 locations in 9 countries, 4 of which are non-EU countries. The events were distributed in 7 regional and 10 international events. On the audience level, we have reached approximately 940 participants categorized as the Scientific community, Industry, Policy makers, General public, and others. Those participants were reached through different channels to disseminate the results, raise awareness, and engage people with the project theme. The dissemination channels were Conferences, Workshops, Open events, and Roundtables.

1 Introduction and objectives

The SeaClear project have built a team of unmanned underwater, surface and aerial vehicles to find and collect litter from the seabed. A USV performs an initial bathymetry scan to creat a 3D map of the seafloor on which litter will then be located. The UAV, together with a smaller observation UUV, are tasked with finding litter and placing it on a map. A larger, collection UUV then collects each piece of litter in turn. The USV also acts as the hub of the system and lowers the basket in which litter is placed after collection. Figure 1 presents the overall concept of the project.

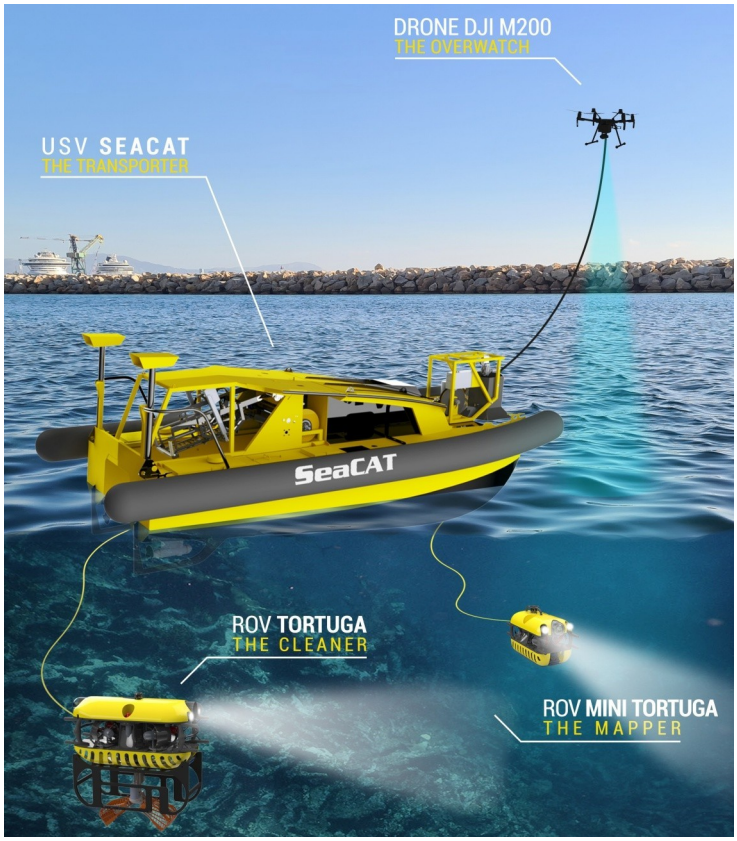

Figure 1: SeaClear concept. An unmanned surface vehicle acts as the hub of the system, an observation underwater vehicle maps the litter, and a collection underwater vehicle collects each piece of litter in turn, possibly also using a suction device to collect smaller litter. A UAV assists with detection and navigation surveillance.

This deliverable details the efforts to disseminate challenges, research approaches, and results to specific target audi- ence groups via workshop events. The remainder of this deliverable is structured as follows. Section 1 summarizes the contribution to the overall dissemination efforts. In section 2, we present details about the workshops that were organised by the SeaClear consortium and thus specifically shaped to address project-relevant topics. Finally, section 3 shows workshop events in which consortium members participated to disseminate and discuss project results or introduce the project to an audience.

1.1 Connection to dissemination plan

The Dissemination and Exploitation plan (D&E) involves implementation and participation in various activities to secure the promotion and use of the project results. The impacts of the implemented activities actively support the

achievement of the project impact. For the project presence, needless to mention that the project's visual identity was well presented and recognized in all events. The SeaClear logo, stickers, and rollups were very effective in raising awareness of project results and developing the project community. Moreover, the brochures, posters, and presenta- tions developed were very useful in creating project trustworthiness among end users and prospective stakeholders and supporting project outreach efforts.

1.2 Target groups of the workshop activities

The SeaClear project's consortium comprises several academic institutions, an SME, a regional development agency, and a port authority. Due to this diversity among partners and the span of the project results, we have targeted groups that we would like to connect to during this project. As a result of implementing D&E plane, we have reached the following audience categories:

Audience Category	Number of events
Scientific community	15
Industry	14
General public	14
Policy makers	13
Others	14

Table 1: Audience categories and their corresponding number of targeting events.

1.3 Channels and Platforms

The project partners utilized all possible communication channels to disseminate the project results. In addition to that, they organised and participated in external activities to spread project results.

Channels	Number
Conferences	5
Workshops	4
Open events	6
Roundtable	2

Table 2: Type of channels used to disseminate project results and corresponding numbers.

2 Workshops: Organization

This section lists the workshops in which the SeaClear consortium was the initiator, proposer, and/or organiser of the respective event.

2.1 BLUE EVENT, June 2021

The SeaClear partners, Regional Agency DUNEA and the University of Dubrovnik collaboration, implemented a manifestation called "BLUE EVENT": Marine environment as a driver of sustainable development, focusing on the circular economy and the problem of marine litter, with goals that include innovative environmental solutions in marine litter monitoring, collection and management.

Outcome/impact: Forming the community of practice for the marine litter problem in Dubrovnik Neretva County.

Participant/s: DUNEA, UNIDU

Number of attendance: 25

Audience: General public, policy makers, and others.

Location: Bistrina, Croatia

Figure 2: SeaClear presence in the Blue Event

2.2 Subsea Tech Open days, June 2022

The partners Subsea Tech, responsible for the SeaClear robots, celebrated Open Day 2022 and opened the company's doors to the public, and they engaged with different stakeholders who wanted to know more about the system which was demonstrated in front of the facilities.

Outcome/impact: Initiate contact with MRE plant operators (EDF, Engie & Ideol) to facilitate the participation of SEaClear project in future activities and events.

Organizer/s: SST

Number of attendance: 66

Audience: Industry, Institutional representatives, and general public.

Location: Marseille, France

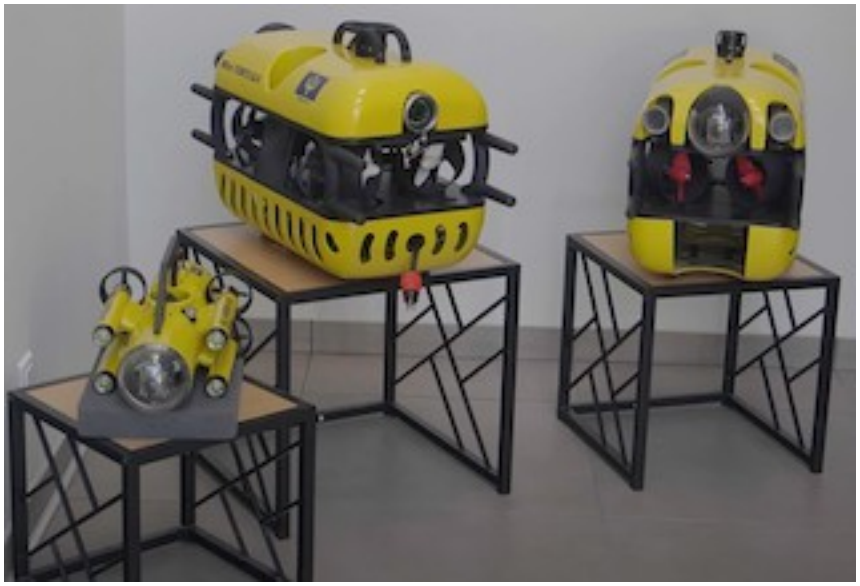

Figure 3: SeaClear project presented in Open days event

2.3 6th Conference on Intelligent Control and Automation Sciences: Open invited track, July 2022

The *Conference on Intelligent Control and Automation Sciences* (ICONS) series is one of the flagship conferences of the IFAC - International Federation of Automatic Control Society. According to the IFAC description: "ICONS serves as a platform for scientists, researchers, and practitioners to discuss their forefront research results and findings, to shape their future directions and development, and to exchange their knowledge and perspectives in the field of intelligent control, automation science, engineering, and its integration into industry and society. It constitutes the primary forum for cross-industry, multidisciplinary research, and provides an opportunity to have a unique and rich cultural experience with excellent technical and social programs."

Within the ICONS framework, Lucian Busoniu (UTC), Robert Babuska (advisory board, TUD) and Stefan Sosnowski (TUM) organised the technical session: "Reinforcement Learning and Machine Learning for Control". This open track provided a forum of interaction and an outlet for all areas of reinforcement learning (RL) and machine learning for control, from deep RL to data-driven control and more classical optimal control techniques. A full description of the session can be found in the appendix. Overall, 11 scientific papers were presented in the session.

Outcome/impact: This technical session provided the opportunity to disseminate specific research results on machine learning developed within SeaClear to an expert audience. Furthermore, cutting-edge research ideas were discussed and evaluated for their usefulness towards the project's goals.

Organizer/s: TUD, UTC, TUM

Number of attendance: 42

Audience: Scientific community and industry

Location: Cluj-Napoca, Romania

2.4 7th International Marine Debris Conference: Technical session, Sep. 2022

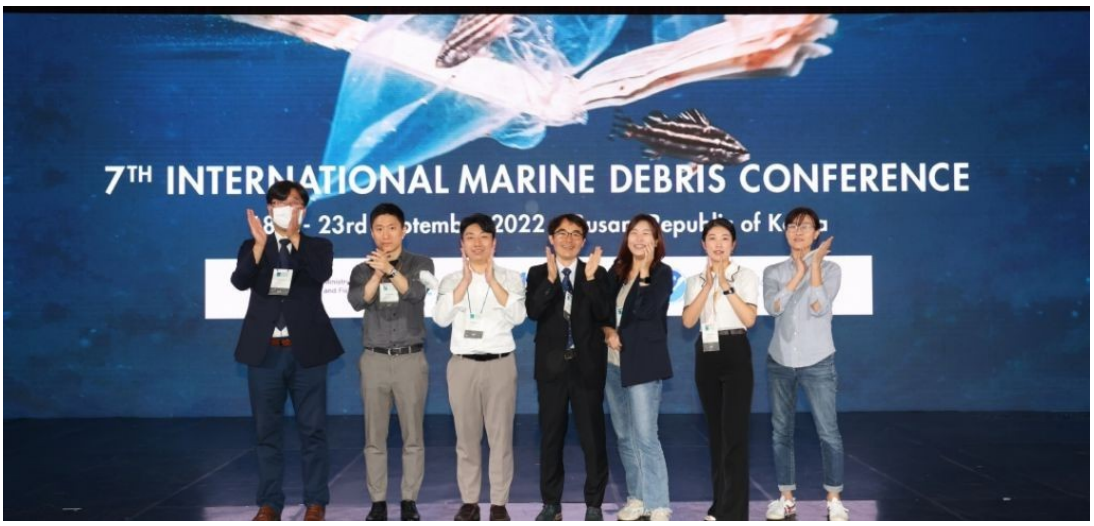

Figure 4: Closing ceremony of the 7th International Marine Debris Conference.

The International Marine Debris Conference (IMDC) is the premier global event dedicated to understanding and promoting action to address marine debris, or marine litter. It is co-hosted by the U.S. National Oceanic and Atmospheric Administration (NOAA) and the United Nations Environment Programme (UNEP). The 7IMDC brought together over 1000 participants from 89 countries and from all sectors, including academia, NGOs, governments, and the private sector. The SeaClear consortium organised a technical session together with The OceanCleanup, The SeaCleaners and the MAELSTROM / InnoPlastics EU Horizon2020 projects on the topic of "Innovative technology for searching, identifying and recovering marine debris". This session brought together researchers, innovators, orga- nizations and companies to exchange ideas and share experiences and lessons learned on the available technology and technological boundaries, ongoing research efforts and available systems. The information exchanged included new developments and a list of recommendations established for the design of the next generation of cleanup technology, maximizing marine debris harvest while limiting bycatch and environmental damage, and reducing the impact on the marine environment and the climate. The session talks addressed:

1. How cost-effective sensors improve storm water management and reduce plastic leakage and stressed out the critical component of the decision support tool using predictive modelling to identify litter hotspots environment more safely, cost-effectively and efficiently, before waste is lost to the environment. What really matter is cost, time and safety for the workers who manage the system.
2. SeaClear, our AI-supported collaborative robotic solution that autonomously collects waste from the seabed. Stefan focused on progress and challenges, including the robotics autonomy, and the search for other possible application areas and markets, as well as advances in machine learning.
3. In-No-Plastic (Innovative approaches towards prevention, removal and reuse of marine plastic litter) a three-year EU funded project. The goal of the project is to develop and demonstrate clean-up technologies targeting nano-, micro-, and macro-plastic in the aquatic ecosystems.

4. The development of the various technologies for the Ocean side at The Ocean Cleanup. After tests of different systems, in 2018 and 2019 they launched a new propulsed system, tested in 2021 successfully catching and retaining plastics. The Ocean Cleanup is monitoring the impact, including bycatch and CO2 emissions continuously.
5. The MAELSTROM project, a reliable multidisciplinary and scientifically sound approach for the assessment of marine debris distribution and impact on marine life in two demo sites in Portugal and the Venice coastal area in Italy.
6. Seabin™, a data-driven, cleantech and environmental organization operating in 53 countries. In July 2020, Seabin™ embarked on a 12-month pilot study after which the system proved to be impactful for the city servicing in providing a great understanding of marine litter accumulation.

Outcome/impact: Strengthening networks between similar efforts and fostering collaboration on complementary technological solutions. Establishing a direct connection between stakeholders, policy makers, and technology providers.

Organizer/s: TUD, UTC, TUM, CML, UNIDU.

Number of attendance: 100

Audience: Scientific community, industry, general public, policy makers, and others.

Location: Busan, Korea

2.5 European Control Conference: Tutorial session, June 2023

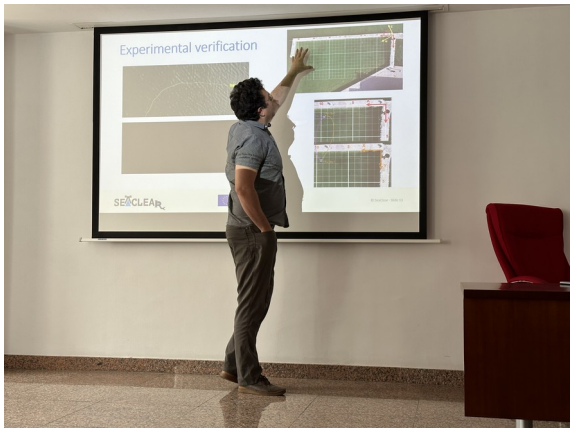

Figure 5: Dr. Tolic´ presenting at the ECC tutorial.

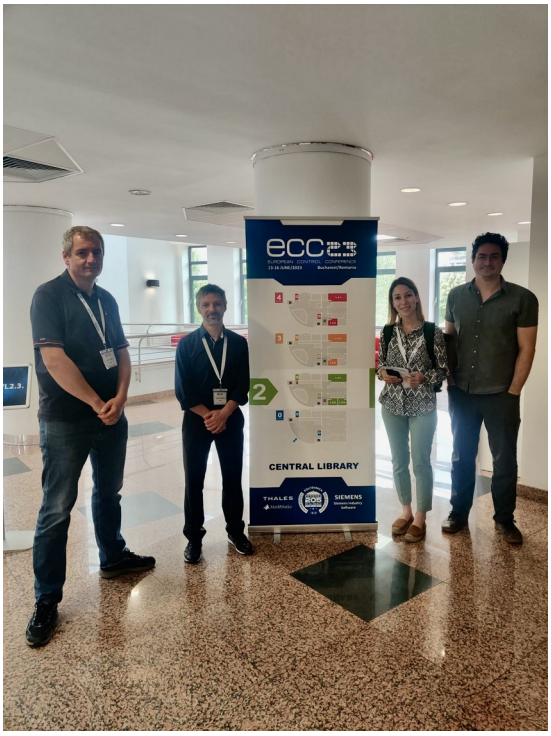

Figure 6: ECC tutorial speakers

The European Control Conference ECC is one of the top control conferences in Europe, hosted by the IEEE control systems society and the international federation of automatic control (IFAC). In this conference, the consortium organ- ised a tutorial workshop on "SeaClear: search, identification and collection of marine litter with autonomous robots". The tutorial presented the SeaClear European Horizon 2020 project, introducing the overall system, challenges and approach. A specific focus was placed on communication, sensing, and control aspects that are relevant for the audi- ence of the European Control Conference, paying special attention to practical challenges that arise in the operation of the system. The tutorial was designed to be useful for control engineering students, researchers, and practitioners with interests in marine and aerial robotics, nonlinear control and estimation, data-driven control, or artificial intelligence. A full description of the session can be found in the appendix.

Overall, five talks were held in a 120-minute session:

1. SeaClear: From System Design to Sea Trials (Cosmin Delea)
2. SeaClear: Litter Detection (Athina Illoudi)
3. SeaClear: Pose Estimation and Mapping (Lucian Busoniu)
4. SeaClear: The Control Perspective (Stefan Sosnowski)
5. SeaClear: UAV Control and Sensing (Domagoj Tolic)

Outcome/impact: Sharing experience and information on new robotic teams and cleanup technologies with the control systems community. Raising awareness of the marine environment and the climate.

Organizer/s: TUD, UTC, TUM, CML, UNIDU.

Number of attendance: 15

Audience: Scientific community, industry experts, general public, policy makers, and others.

Location: Bucharest, Romania

2.6 IFAC World Congress 2023: Open invited track, July 2023

The IFAC World Congress is the largest event in the field of control science and technology, held every three years. The SeaClear consortium organised an open invited session with the topic: "Learning for Multi-Robot and Networked Systems". The aim of the session was to bring together novel results in computational-intelligence, machine-learning, networked-control and AI-based methods for multi-agent decision-making for multi-robot systems as well as for co- ordination in networked systems in general, addressing emerging challenges in decision-making for multi-robot sys- tems and coordination in networked systems, including dealing with highly uncertain or time-varying environments, restricted computational and communication resources, non-conventional environments (e.g. underwater multi-robot systems), etc. and present emerging relevant applications. A full description of the session can be found in the appendix.

Outcome/impact: Exchanging contributions covering the broad area of computational-intelligence, machine-learning, networked-control and AI-based methods for multi-agent decision-making in multi-robot systems as well as for coor- dination in networked systems in general.

Organizer/s: TUD, UTC, TUM.

Number of attendance: 30

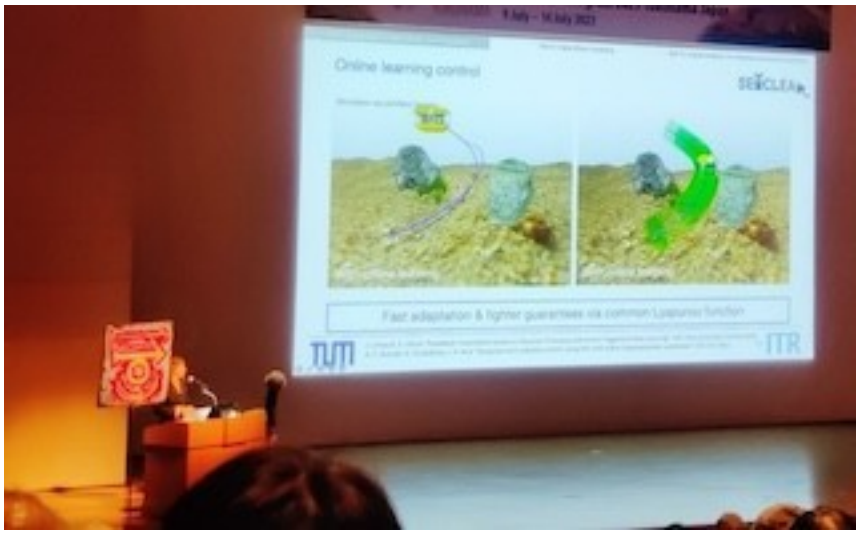

Figure 7: Project presentation at IFAC 2023

Audience: Scientific community, industry researchers and engineers, general public, policy makers, and others.

Location: Yokohama, Japan

3 Workshops: Participation

This section lists the workshop activities, in which the SeaClear consortium members presented the project and developments as external contributors.

3.1 European Robotics Forum(ERF2020), March 2020

The European Robotics Forum (ERF2020) is the meeting point for over a thousand decision makers, engineers, researchers, and a growing number of entrepreneurs and investors, as well as users and policy makers in the field of robotics from all over Europe and beyond. Cosmin Delea (Fraunhofer) introduced SeaClear project at a high-level to the European robotics community.

Outcome/impact: Exchange opinions about robotics with artificial intelligence experts around Europe to set out with the aim of becoming the first platform that uses autonomous robots for cost-effectively solving one of the world's most critical issues, namely marine litter.

Participant/s: Fraunhofer - CML

Number of attendance: 50

Audience: Scientific community, industry researchers and engineers, general public, policy makers, and others.

Location: Malaga, Spain

Figure 8: Fraunhofer introduce the SeaClear project

3.2 Space Powering the Green Deal and the Digital Economy Workshop, March 2020

Satellite technologies, in particular Earth Observation, have become indispensable in measuring progress towards the goals set by the UN 2030 Agenda for Sustainable Development and the Green Deal proposed by the European Commission. Europe's leadership in Earth Observation make an enormous wealth of data available for operational

monitoring of the environment and security in Europe. Ivana Palunko (UNIDU) presented the H2020 SeaClear Project as an environment monitoring practice.

Outcome/impact: Exchange of information and ideas between European experts to define further steps in strengthening cooperation and to explore opportunities for Croatian industry to become actively involved in ESA's programs and projects.

Participant/s: UNIDU

Number of attendance: 200

Audience: Scientific community, industry researchers and engineers, general public, policy makers, and others.

Location: Zagreb, Croatia

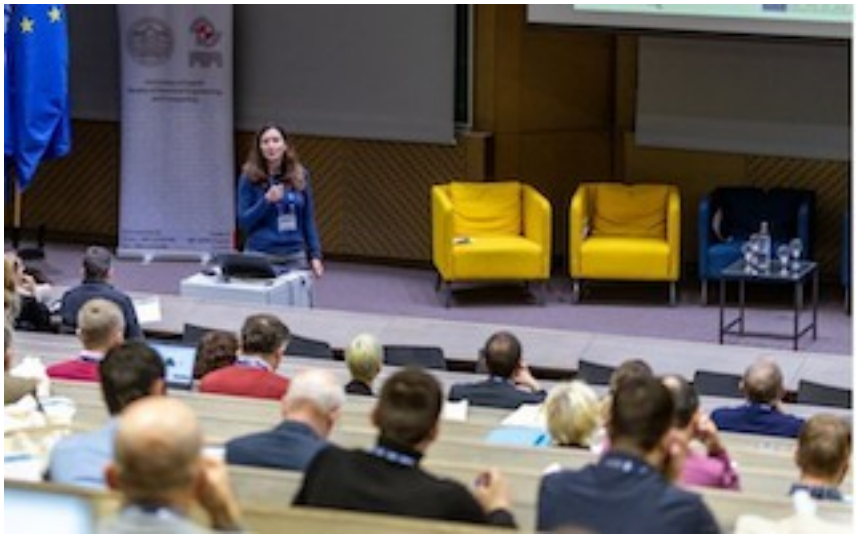

Figure 9: UNIDU presents the SeaClear project

3.3 Roundtable for Blue Economy & Blue technologies, Feb. 2021

Blue economy - Developing innovative technologies for sustainability of Adriatic sea: Marine Robotics for sea mon- itoring in the Adriatic Sea.

Outcome/impact: Fostering dialogue and exchange best practices in the field of Blue Economy and innovative blue technologies and enhancing cross-sectoral cooperation to support the creation of favourable framework conditions for a cross-border innovation ecosystem enabling growth, competitiveness and technological leadership in the field of underwater robotics and sensors

Participant/s: UNIDU.

Number of attendance: 20

Audience: Scientific community, industry, general public, policy makers, and others.

Location: Online

3.4 ICL-TUM PI workshop, July 2021

The ICL-TUM workshop was organised to deepen existing individual collaborations between research groups at both universities and systematically find common research topics of interest. TUM presented, among other topics, the Sea- Clear project as an example for the control challenges in extreme environments and an application for environmental robotics.

Outcome/impact: Initiation of cooperations between the Imperial College London and the Technical University of Munich with potential applications in environmental robotics.

Participant/s: TUM

Number of attendance: 95

Audience: Scientific community.

Location: Online

3.5 Dronedays, Oct. 2021

Heterogeneous Multi-Agent Systems for Monitoring and Preservation of Marine Environment: How bringing together state-of-the-art technologies from the fields of machine learning, sensing, manipulation, aerial and marine technolo- gies to be used for monitoring and preservation of marine environment.

Outcome/impact: Establishing links between industries, experts from academia and end users to develop unmanned aerial vehicles and their applications.

Participant/s: UNIDU.

Number of attendance: 25

Audience: Scientific community, industry, general public, policy makers, and others.

Location: Biograd na Moru, Croatia.

3.6 1st Innovamare Roadshow, April 2022

Demonstration activities of marine technologies for participants of Roadshow and public: SeaClear EU H2020 project as a marine and environment monitoring technology.

Outcome/impact: Offering opportunities for networking through dialogue, knowledge transfer, joint development of new project concepts and the establishment of partner consortia. **Participant/s:** UNIDU.

Number of attendance: 20

Audience: Scientific community, industry, general public, policy makers, and others.

Location: Dubrovnik, Croatia.

3.7 International Workshop for Removal of marine litter and circular economy: challenges and opportunities, June 2022

Presenting the efforts towards the removal of marine litter and the circular economy: Seaclear's machine learning for marine debris collection.

Outcome/impact: Widespread awareness of the plastic pollution problem in Venice

Participant/s: TUM

Number of attendance: 40

Audience: Scientific community, industry, general public, policy makers, and others.

Location: Venice, Italy

3.8 Automatica trade fair, June 2022

Automatica features the world's largest range of industrial and service robotics, assembly solutions, machine vision systems and components. It gives companies from all relevant branches of industry access to innovations, knowledge and trends with a great deal of business relevance: The Future of Environment, SeaClear project as an application.

Outcome/impact: Ability to manufacture higher-quality products with even greater efficiency.

Figure 10: TUM pitched SeaClear during the AI Society section

Participant/s: TUM

Number of attendance: 20

Audience: Scientific community, industry, general public, policy makers, and others.

Location: Munich, Germany

3.9 AI Days, Oct. 2022

Reinforcement learning and planning for robotics: Reinforcement learning for underwater mapping (SeaClear).

Outcome/impact: Strengthening the local AI community and creating links with specialists from the diaspora and from the Eastern European and international community.

Participant/s: UTC

Number of attendance: 10

Audience: Scientific community, industry, general public, policy makers, and others.

Location: Oradea, Romania.

Figure 11: AI days public event 2022

3.10 The 61st Workshop of Research Center for Complex Systems and Network Science, November 2022

This workshop was hosted by the Research Center for Complex Systems and Network Science at the Southeast University, China, for exchanging research ideas between universities and fostering collaborations. TUM highlighted the control challenges and research developments of the SeaClear system in a 60-minute presentation.

Outcome/impact: Dissemination of scientific achievements in SeaClear to an expert audience and raising awareness for the problem of underwater debris with students.

Participant/s: TUM

Number of attendance: 40

Audience: Scientific community.

Location: Nanjing, China

3.11 Conference on the protection of waters and seas from plastics and micro-plastics pollution, Nov. 2023

The conference focuses on the presentation of current policies and initiatives at the global, EU, regional, and national levels and the presentation of possible measures and solutions aimed at preventing, reducing, and solving the prob- lem of sea and water pollution with plastic and microplastic, all in the context of EU project possibilities: Horizon SEarch, identificAtion and Collection of marine Litter with Autonomous Robots (SEACLEAR) as a solution and good practice.

Outcome/impact: Possible collaboration and knowledge exchange with other EU projects, between the countries of the Adriatic-Ionian region that are facing similar problems.

Participant/s: DUNEA

Number of attendance: 150

Audience: Scientific community, industry, general public, policy makers, and others.

Location: Zagreb, Croatia

4 Summary and concluding remarks

The SeaClear project has actively engaged in a variety of workshops and conferences, demonstrating a strong commitment to knowledge sharing and community involvement. In total, the project has organised 17 events, including workshops, technical sessions, tutorial workshops, and open invited tracks. The consortium has also participated as external contributors in 11 additional workshops, further expanding their reach and impact. These workshops provided opportunities to present the project and its developments to diverse audiences, fostering collaborations and raising awareness about marine debris and cleanup technologies. The events have attracted a total of 940 attendees from various backgrounds, including the scientific community, industry experts, general public, policy makers, and others.

Overall, the SeaClear project has actively engaged with the community, involving a significant number of participants and promoting knowledge exchange between experts and stakeholders. The project's commitment to community involvement and collaboration is indicative of its dedication to addressing the pressing issue of marine litter and developing innovative solutions for its detection and collection.

Appendix

Reinforcement learning and machine learning for control

Open Invited Track at IFAC ICONS 2022

Lucian Bu¸soniu * **Robert Babuˇska** ** **Stefan Sosnowski** ***

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A key aspect of solving complex tasks is to learn from mistakes and improve strategies, control policies and models through experience. Recent advances in machine learning provide a way to improve control of dynamical systems through this approach, with particular success in robotics. Especially reinforcement learning (RL) offers a principled way to make sequential decisions in initially unknown problems, modeled as Markov decision processes. In control, this provides a way to perform optimal control in unknown nonlinear stochastic systems. The primary objective is to optimize a cumulative reward or cost over time. Over the last decade, the integration of deep neural networks and deep learning techniques into RL has led to the highly successful field of deep RL, with impressive applications in game playing and artificial intelligence, robotics, and so on. Alongside deep RL, control-oriented approaches to solve Markov decision processes keep advancing, such as those from adaptive dynamic programming (ADP), optimal control, etc. Moreover, more general machine learning approaches such as data-driven control seem promising, bringing together model-based and learning-based control systems. They offer a principled way to generate control policies directly from data, which enables considering uncertainty in the models and measurements in the control design. This can lead to safe control and learning approaches, which is essential for safety-critical systems and in general for the transfer from simulation to the real world.

This open track provides a forum of interaction and an outlet for all areas of RL and machine learning for control, from deep RL to data-driven control and more classical optimal control techniques. We welcome algorithmic, analytical, and application-oriented contributions. Our application focus is robotics, but we are also interested in other showcases in engineering, artificial intelligence, operations research, economics, medicine, and other relevant fields. We moreover invite surveys by established researchers in the field.

We are especially interested in the promising interactions between artificial-intelligence and control-theoretic approaches to RL, with the open issues they entail, including stable RL control of unknown systems. Synergy between artificial intelligence and control theory in RL can lead to major breakthroughs such as computationally efficient algorithms with strong, simultaneous performance and stability guarantees.

Topics of interest include, but are not limited to:

- RL and nonlinear optimal control algorithms
- Deep RL
- Adaptive dynamic programming
- Synergy of RL and nonlinear control: model-predictive control, Lyapunov design etc.
- Online and batch methods for deep RL, self-supervised learning in RL
- Model-based/model-learning RL
- Safe reinforcement learning
- Data-driven control for dynamical systems
- Performance and complexity analysis of RL and non- linear optimal control
- Stability analysis of RL and nonlinear optimal control
- Bridging model-based and learning-based control systems
- Applications to robotics and other areas (see above)
- Multiagent and distributed RL
- Policy search methods
- Exploration techniques
- Partially observable Markov decision processes
- Emerging and novel perspectives

Additional information:

- The website of the open track is at http://busoniu.net/rltrack2022 and will include updates about the track.
- The conference website is at https://icons2022.utcluj.ro/.
- The initial paper submission deadline is December 15th, 2022. A track code will be supplied for paper submission.

General

TS-3.1 Innovative technology for searching, identifying and recovering marine debris

15:30 - 17:00

Thursday, 22 September 2022

Chaired By
Dr. Stefan Sosnowski (Technical University of Munich (TUM)) , Mr. Laurent Lebreton (The Ocean Cleanup) , Ms. Gwenaële Coat (The SeaCleaners) , Dr. Davide Poletto (Venice Lagoon Plastic Free)

Venue
Room 201-202

DESCRIPTION

Short description

We bring together initiatives addressing the challenge to intercept and remove plastic pollution from waterways and the ocean, providing a platform for exchanging ideas, experience and identifying potential complementary solutions.

Full description

The recovery of plastic debris from waterways and the ocean is a challenging endeavor and is seen as the last resort after all the other upstream mitigation strategies have failed. While future efforts should focus on prevention to reduce new inputs, teams of engineers and innovators have started in parallel to deploy technology to extract the legacy pollution. The scope of the challenges associated with marine debris and the cost of addressing them make automated solutions for the search, identification and collection of marine debris particularly promising. A multitude of projects and initiatives innovate on different aspects of the problem, ranging from debris localization and quantification efforts to collection from the surface, water column and seabed. Potential synergies in these multi-disciplinary efforts are important to explore and exploit to significantly advance the state of the art.

This session will bring together researchers, innovators, organizations and companies to exchange ideas, share experience and lessons learned on the available technology and technological boundaries, ongoing research efforts and available systems. It should be a space to share information on new developments and establish a list of recommendations for the design of the next generation of cleanup technology, maximizing marine debris harvest while limiting bycatch and environmental damage, and reducing the impact on the marine environment and the climate. In particular, we aim at strengthening networks between similar efforts and fostering collaboration on complementary technological solutions, learning from the different recovery strategies and ask relevant questions to address concerns on cleanup activities. For stakeholders and policy makers, this session can serve as a forum on available solutions and direct connection to technology providers.

Cost effective sensors improve storm water management and reduce plastic leakage

» Dr. Britta Denise Hardesty (CSIRO), Ms. Justine Barrett (CSIRO), Dr. Chris Wilcox (Commonwealth Scientific and Industrial Research Organisation)

View Presentation

SeaClear: Autonomous robots clean the sea"oor

» Dr. Stefan Sosnowski (Technical University of Munich (TUM)), Prof. Bart De Schutter (Technical University of Delft), Prof. Lucian Busoniu (Technical University of Cluj-Napoca), Mr. Yves Chardard (SUBSEA TECH Marine and Underwater Technologies), Mr. Cosmin Delea (Fraunhofer - Center for Maritime Logistics and Services), Ms. Claudia Hertel-ten Eikelder (Hamburg Port Authority AöR (HPA)), Prof. Ivana Palunko (University of Dubrovnik), Ms. Iva Pozniak (Regional Development Agency Dubrovnik-Neretva County-DUNEA)

View Presentation

In-No-Plastic (Innovative approaches towards prevention, removal and reuse of marine plastic litter)

» Mr. Salman Shahzad (BlueXprt B.V), Dr. Davide Poletto (Venice Lagoon Plastic Free)

View Presentation

Innovating our way towards cleaner oceans – ups and downs of a large-scale operational effort to develop and scale technologies aimed at the removal of "oating plastic debris worldwide. An intermediate status report and invitation to discussion.

» Mr. Arjen Tjallema (The Ocean Cleanup), Mr. Laurent Lebreton (The Ocean Cleanup)

View Presentation

HOW TO TACKLE THE MARINE LITTER THREAT: THE INNOVATIVE SOLUTIONS PROPOSED BY THE MAELSTROM PROJECT WITHIN A CIRCULAR ECONOMY FRAMEWORK

» Dr. Fantina Madricardo (CNR ISMAR)

View Presentation

Seabin™ as an innovative technology for recovery and identification of marine debris, macro and microplastics, and pollutants

» Mr. Solomon Wadani (Seabin Foundation), Mrs. Mahi Paquette (Seabin Foundation), Mr. Peter Ceglinski (Seabin™)

View Presentation

Second International Workshop | 1 June 2022

Removal of Marine Litter and Circular Economy: Challenges and opportunities

PARTNER OF THE EUROPEAN GREEN WEEK

CNR-ISMAR, Arsenale, Tesa 104 Castello 2737/F, 30122 • Venice (Italy)

Link online:
https://cnronline.webex.com/cnronline/j.php?MTID=m7f138cc9a33e6851cbd0e3e778ab916d

in cooperation with:

Co-funded by the European Union

MAELSTROM InNoPlastic

Removal of Marine Litter and Circular Economy: Challenges and opportunities

1 June 2022

WELCOMING

10.00 **Introduction to the International Workshop**
CNR ISMAR and VLPF

10.10 13th Commission for Environment and Territory
Sen.Andrea Ferrazzi,
Senate of the Republic of Italy

PART 1 **INTRODUCTION**

10.20 **Introduction to H2020 MAELSTROM**
Fantina Madricardo, CNR ISMAR (Italy)

10.30 **Introduction to H2020 InNoPlastic**
James Comeford, Sintef (Norway),

10.40 **Introduction to H2020 SEACLEAR**
Stephan Sosnowski, Technical University of Munich (Germany)

10.50 **Introduction to ITA-HR INTERREG MARLESS**
Andrea Torresan, ARPA Veneto (Italy)

11.00 **Round Table with Q&A**

11.10 Break

PART 2 **ML MONITORING AND REMOVAL TECHNOLOGIES**
Chaired by: Fantina Madricardo CNR (Italy)

11.20 **ML monitoring with the MAELSTROM app**
VLPF/GEES Recycling (Italy)

11.30 **SWAMP for MAELSTROM**
CNR-INM (Italy)

11.40 **Underwater cable robot for the Seabed Cleaning Platform (MAELSTROM)**
Tecnalia (Spain)

11.50 **Machine learning for marine debris collection (SEACLEAR)**
Technical University of Munich (Germany)

12.00 **Aquatic robot for surface marine litter collection (MARLESS)**
UniBo (Italy)

12.10 **SEEKer Robot (InNoPlastics)**
Probotica (Croatia)

12.20 **MAELSTROM Bubble Barrier**
The Great Bubble Barrier (The Netherlands)

12.30 **River Cleaning**
MOLD (Italy)

12.40 **Innovative Microplastics filtration system for washing machines and marinas**
Clera.One (Slovenia)

12.50 **WasteShark**
RanMarine Technology (The Netherlands)

13.00 **Round Table with Q&A**

13.15 **Lunch break**

PART 3 **CIRCULAR ECONOMY OF MARINE LITTER**
Chaired by: Davide Poletto VLPF (Italy)

14.40 **MAELSTROM ML Low Temperature pyrolysis**
Sintol Srl (Italy)

14.50 **MAELSTROM Floating solar panels**
University of Malta (Malta)

15.00 **New life to upcycled plastic with Large Format 3D Printing: the Beluga case study**
Caracol (Italy)

MAELSTROM InNoPlastic

Removal of Marine Litter and Circular Economy: Challenges and opportunities

1 June 2022

15.10 **MARLESS Plastic pyrolysis in a circular economy perspective**
University of Bologna (Italy)

15.20 **Potential Exploitation of Marine Litter for fashion accessories and footwear sector**
EMI (italy)- ISDI (Malta)

15.30 **HAAS Synchronicity Ressourcing manufacturing: the Waste Value Makers**
Synchronicity (France)

15.40 **Innoplastic - Societal Awareness of marine litter pollution and remediation in Europe**
University of Ca' Foscari and VLPF (Italy)

15.50 **Round Table with Q&A**

17.00 **CLOSURE OF THE MEETING**

Are you a researcher, practitioner, policymaker, operator or entrepreneur working within the topics of marine plastic litter remediation and circular economy?

Join our Stakeholder's Forum and contribute to the design of a Joint Strategy to increase the communication and dissemination efforts of ongoing initiatives within the European space and beyond, at: www.maelstrom-h2020.eu

Scan me!

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MAELSTROM

InNoPlastic

Second International Workshop | 1 June 2022

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www.maelstrom-h2020.eu

www.innoplastic.eu

Participation in the International Workshop is limited to invited lecturers and guests

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SeaClear: Search, identification and collection of marine litter with autonomous robots

Lucian Buşoniu, Cosmin Delea, Bart De Schutter, Athina Ilioudi, Ivana Palunko, Stefan Sosnowski

***Abstract*— The objective of this tutorial is to present the SeaClear European Horizon 2020 project, which is developing the first autonomous robotic team for search, identification, and collection of underwater robotic litter. The autonomous robotic team consists of an observation unmanned underwater vehicle that searches for litter, a second underwater vehicle that collects the found litter using a combined gripper-suction device, an unmanned aerial vehicle to detect both litter and the locations of the underwater vehicles, and a surface vehicle that is the hub of the system. After introducing the overall system and approach, we detail communication, sensing, and control aspects that are relevant for the audience of the European Control Conference, paying special attention to practical challenges that arise in the operation of the system. Our tutorial will be useful to control engineering students, researchers, and practitioners with interests in marine and aerial robotics, nonlinear control and estimation, data-driven control, or artificial intelligence.**

***Index Terms*— marine robotics, UAVs, data-driven control, deep learning, pose estimation, mapping.**

MOTIVATION, OBJECTIVES, AND AUDIENCE

Today's oceans contain tens of millions tons of waste, with approximately 94% located on the seafloor. Existing collection efforts have focused mostly on surface waste, with only a few local efforts to gather underwater waste, always using human divers. The SeaClear project works on developing the first autonomous robotic team for underwater litter collection. The core of the SeaClear approach is a mixed team of Unmanned Underwater, Surface, and Aerial Vehicles – UUV, USV, UAV – to find and collect litter from the seabed, focusing on coastal areas since that is where waste inflow concentrates; see Figure 1. The UAV (DJI Matrice M210 RTK) and an observation UUV (MiniTortuga; all the marine robots are developed by project partner SubseaTech, France) detect and map the litter. A collection UUV (Tortuga) then collects the litter detected, using a combined suction-gripper manipulator. An USV (SeaCat) acts as the hub of the system, providing power and computation resources to the other robots. Our key objective is to operate the robots autonomously, and to that end we require novel developments in litter detection, mapping, and robot control. We demonstrate the system in two case studies: one in port cleaning (Hamburg, spring/summer 2023), and the other in a touristic area (Dubrovnik, autumn 2023).

The goal of this tutorial session is to present the SeaClear system and approach, starting from the overall concept, robotic hardware, and system architecture (Section I), and thereafter placing the focus on *communication, sensing, and control* aspects that are relevant for the audience of the European Control Conference. On sensing, we discuss our deep-learning-based method for litter detection from UUV camera images (Section II), as well as UUV pose estimation challenges and litter mapping techniques (Section III). For UUV control, we use a data-augmented model-based control approach that combines known dynamic models of underwater systems with Gaussian processes (Section IV). We close the session by presenting sensing and control methods for the "eye in the sky" of our system, the UAV (Section V). Each of these sections outlines the content of its corresponding talk, and also mentions the presenter with their brief biography.

Our intended audience consists of control engineering researchers and practitioners with interests in marine and aerial robotics, data-driven control, nonlinear control and estimation, or artificial intelligence. Our talks are sufficiently self-contained to be followed by an ECC attendant at any level of expertise, from graduate students onwards.

I. SEACLEAR: FROM SYSTEM DESIGN TO SEA TRIALS

LEAD TALK

We begin by describing the overall SeaClear robotic system, comprising the concept, system architecture, communication interfaces, operation and evaluation of the system. Within SeaClear, a group of heterogenous unmanned vehicles provide underwater litter cleaning services in ports and coastal areas. A high degree of complexity results from operating in unstructured environments, subject to environmental disturbances (such as tidal currents, winds), marine traffic or legal requirements. The SeaClear systems aims to provide a model workflow for managing fleets of unmanned vehicles for waterborne applications. The system architecture builds upon the envisioned service, which needs to be accessed from anywhere in the world, by various entities, with different roles in the operation. The communication system is designed to reduce the throughput requirements for transferring information over broadband wireless communication, while still giving extensive information to all system end-users and, most importantly, to the operative personnel. Lastly, the implementation and performance of SeaClear service are evaluated through sea trials conducted in representative environments.

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Open invited track for IFAC World Congress 2023, Yokohama, Japan
on

Learning for multi-robot and networked systems

Invited track submission code: `5fic1`

Organizers:

Bart De Schutter, Delft University of Technology (b.deschutter@tudelft.nl) Lucian Busoniu, University of Cluj-Napoca (lucian@busoniu.net)
Stefan Sosnowski, Technical University of Munich (sosnowski@tum.de)

Abstract

Multi-robot systems involve two or more autonomous robots that are working together to achieve one or more well-defined objectives. Individual robots may be rather simple and by themselves unable to achieve the desired goals. However, the real power – and at the same time also the major challenge – lies in the cooperation and coordination of the individual robots so as to jointly achieve the specified objectives. Multi-robot interaction is moreover subject to challenges stemming from the networked and communication structure of the system. Although multi-robot systems have attracted significant attention worldwide, research in this area is still in its infancy. This open invited track aims at bringing together contributions covering the broad area of computational-intelligence, machine-learning, networked-control and AI-based methods for multi-agent decision-making in multi-robot systems as well as for coordination in networked systems in general. In addition to papers proposing new fundamental results, we also explicitly solicit papers that show the potential of multi-robot interaction and coordination in networked systems in experimental set-ups and real-life applications. Authoritative survey papers are also welcome.

Choice of an IFAC technical committee for evaluation

TC 3.2, Computational intelligence in control
Keyword: Machine learning in modelling, prediction, control and automation

Details and topics

This open invited session aims to:

- bring together novel results in computational-intelligence, machine-learning, networked-control and AI-based methods for multi-agent decision-making for multi-robot systems as well as for coordination in networked systems in general,
- address emerging challenges in decision-making for multi-robot systems and coordination in networked systems, including dealing with highly uncertain or

time-varying environments, restricted computational and communication resources, non-conventional environments (e.g. underwater multi-robot systems), etc.
- present emerging relevant applications.

We encourage the submission of research on *multi-robot and networked systems* related, but not limited to:

- computational intelligence for multi-agent systems
- robust decision-making methods for multi-robot systems
- hybrid computational intelligence techniques
- reinforcement learning
- transfer learning
- learning for prediction and control
- distributed and federated learning
- adaptive dynamic programming for multi-agent systems
- networked systems and cooperative control
- game theory for multi-robot interaction
- neuro-fuzzy and deep learning approaches
- applications and demonstrations

For additional information and updates, see the website of the open track at https://seaclear-project.eu/103-ifac-world-congress-2023-proposal.