Proceedings of
Breaking the Surface 2023

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1. INTRODUCTION

The second summer school 2 networking event took place during the "Breaking the Surface (BtS)" workshop, from September 24th until October 1st in Kumbor, Montenegro, and 201 people participated. The BTS is the international interdisciplinary workshop on robotics and maritime innovations that has been held for 15 years and serves as a meeting point for experts and students involved in marine robotics application areas. This year's BTS has been organized by the collaborative efforts of the University of Montenegro and the Faculty of Electrical and Computer Engineering of the University of Zagreb (UNIZG-FER) and served as a venue for strengthening links with potential end-users of Underwater Sensor Networks (USNs) and R&I actors in USN application areas. The program was divided into four tracks (marine robotics, maritime archaeology, marine biology, and marine oceanography) and included 16 in-depth lectures, 3 company presentations, 9 tutorials, 6 demos, a localization challenge, and 3-minute thesis competitions for students, and presentations of MONUSEN hackathon finalists.

This deliverable describes the BtS 2023 organization, including the work program. The deliverable is accompanied with abstracts and presentations of the program presenters.

Dates: 24th September – 1st October 2023
Location: Kumbor, Montenegro
Website: https://bts.fer.hr/

2. ABOUT BREAKING THE SURFACE

Breaking the Surface - BtS workshop has been organized by UNIZG-FER (LABUST research group) for the last 14 years. Following the success of previous BTS workshops UoM together with UNIZG-FER hosted the BTS 2023 from September 24th to October 1st 2023, in Kumbor, Montenegro. During the years, BtS served as a meeting place of experts and students of marine robotics and the marine robotics application areas such as marine biology, marine archaeology, marine security, oceanography, marine geology, and oceanology. This is the world's first successful, multi-year field training programme that combines academic topics in marine robotics and robotics application areas and hands-on working experience in the sea, doing remote sensing and sampling for various ocean sciences. The program is organized in the form of plenary talks, hands-on tutorials and demonstrations of marine technologies, e.g. marine robotics (MAROB), marine biology and marine nature protection (MARBIO), maritime, nautical and ship archaeology (MARCH), oceanography (OCEAN), competitions for students, and company presentations.

BTS 2023 IN NUMBERS:
23 COUNTRIES   201 ATTENDEES   16 LECTURES   9 TUTORIALS   6 DEMOS   3 INDUSTRY TALKS

2.1 Participants and career stage distribution

The event registered 201 participants from 23 countries. The largest national groups were from Croatia (43 participants), Germany (22), Italy (18), Montenegro (14), Sweden (10), Cyprus (10), Israel (10), the United States (8), the United Kingdom (8), Norway (7), and Bosnia and Herzegovina (7). Smaller but significant

representation came from New Zealand (3), Greece (3), Portugal (2), Spain (2), Ireland (2), and the Netherlands (2). In addition, individual participants joined from Denmark, Estonia, Turkey, Australia, Canada, Kenya, and the Czech Republic.

The University of Montenegro, as the local organiser, contributed 14 participants across the full career spectrum: 7 First Stage Researchers (R1), 2 Recognised Researchers (R2), 1 Established Researcher (R3), and 4 Leading Researchers (R4). The University of Zagreb (FER), as co-organiser, contributed 28 participants: 9 R1 (MSc and PhD students), 7 R2 (postdocs and assistant professors), 1 R3 (associate professor), and 2 R4 (full/emeritus professors). In addition, 9 professional and technical staff contributed in engineering, project management, administrative, and design roles.

While detailed career-stage data were not collected for all international participants, it is clear that all stages (R1–R4) were represented across the event, with students mostly from Montenegro, Croatia, Germany, and Italy, and senior researchers ensuring mentorship and knowledge transfer.

3. BTS ORGANIZATION STRUCTURE

3.1. Committee Chairs

Prof. Zoran Vukić, PhD
Honorary General Chair

Prof. Nikola Mišković, PhD
General Chair

3.2. Programme committee

Bridget Buxton
University of Rhode Island
USA

Massimo Caccia
Italian National Research Council (CNR)
Italy

Fausto Ferreira
UNIZG FER
Croatia

Bill Kirkwood
Monterey Bay Aquarium Research Institute (MBARI)
USA

Jeff Neasham
Newcastle University, School of Engineering
United Kingdom

Irena Radić Rossi
University of Zadar
Croatia

Igor Radusinović

University of Montenegro, Faculty of
Electrical Engineering,

Montenegro

Ioannis Kyriakides

Cyprus Marine and Maritime Institute

Cyprus

Aviad Scheinin

University of Haifa

Israel

3.3. Local organizing committee

Igor Radusinović

Slavica Tomović

Žarko Zečević

4. PROGRAMME

The BTS programme consisted of:

- lectures where the latest scientific research and results are presented;
- field demonstrations that showcase the latest technology achievements made by research groups and companies;
- tutorials that offer hands-on experience working with complex and modern underwater systems;
- company presentations with insight from company professionals about their company and company products;
- student competitions that serve as a platform for applying the knowledge acquired from BTS lectures and tutorials to address real-world challenges in marine robotics and blue economy.

Fig. 1. BTS opening session.

Fig. 2. Group photo of BTS 2023 participants.

4.1 BTS Agenda

The daily lecture programme follows below with the list of talks and speakers and links to the abstracts, biographies and presentations of the lectures. The program is also available on the BTS 2023 website.

Day 1: 24th September		
Time	**Presentation title**	**Speakers**
16:30 - 18:00	Registration	
18:00 - 19:30	Welcome reception	Nikola Mišković – UNIZG-FER, Igor Radusinović - UoM

Day 2: 25th September		
Time	**Presentation title**	**Speakers**
08:45 - 09:00	Opening session	Nikola Mišković – UNIZG-FER, Slavica Tomović - UoM
09:00 - 09:45	Cyber-resilient multi-modal sensor fusion for autonomous navigation (abstract, presentation)	Roberto Galeazzi - Head of Centre, Technical University of Denmark
09:45 - 10:30	Trondheimsfjorden – a national test area for autonomous vessels (abstract, presentation)	Ulrik Jørgensen - Senior Research Scientist, SINTEF Ocean
10:30 - 11:00	Coffee break	
11:00 - 11:45	Three years of CMMI – advances in Cypriot marine robotics and maritime digitalization (abstract, presentation)	Geroge Rossides - Cyprus Marine and Maritime Institute
11:45 - 12:30	Company presentation: ABB (abstract, presentation)	Matko Barišić - ABB
12:30 - 13:45	Lunch break	
13:45 - 14:30	Company presentation: FAIRSCOPE (abstract, presentation)	Adam Larson, David La Guen Thibaut Pollina - Stanford University, FairScope

14:30 - 15:15	TUTORIAL 1 INTRO: Marine explorers society 20000 leagues ([abstract](), [presentation]())	Barbara Čolić, Hrvoje Čizmek - Marine Explorers Society – 20000 Leagues NGO
15:15 - 15:30	Break	
15:30 - 18:30	DEMO: FAIRSCOPE ([abstract]())	Adam Larson, David La Guen Thibaut Pollina - Stanford University, FairScope
15:30-18:30	TUTORIAL 1 HANDS-ON: Marine explorers society 20000 league ([abstract]())	Barbara Čolić, Hrvoje Čizmek - Marine Explorers Society – 20000 Leagues NGO
15:30-18:30	DEMO: H2OMNIX – Omnidirectional autonomous surface platform ([abstract]())	Juraj Obradovic, Luka Mandić – UNIZG-FER

Day 3: 26th September		
Time	**Presentation title**	**Speakers**
09:00 - 09:45	Oceanographic properties and circulation in the Adriatic Sea ([abstract](), [presentation]())	Miroslav Gačić - Institute of Oceanography and Applied Geophysics, Trieste
09:45 - 10:30	Using smart buoys to turn fishing gear into an ocean data platform ([abstract](), [presentation]())	Kortney Opshaug - Blue Ocean Gear
10:30 - 11:00	Coffee Break	
11:00 - 11:45	Underneath the Antarctic ice, mapping the seabed of the Atlantic Ocean, or in the water for weeks: recent successes for the AUVs of the national oceanography center ([abstract](), [presentation]())	Francesco Fanelli - National Oceanography Centre, UK
11:45 - 12:30	K2D: Towards a global scale monitoring system for oceans using subsea cables and autonomous sensing platforms ([abstract](), [presentation]())	Bruno Ferreira - INESC TEC, University of Porto
12:30 - 13:45	Lunch Break	
13:45 - 14:30	TUTORIAL 2 INTRO: Three-minute thesis (3mt) ([abstract](), presentation)	Roee Diamant – UNIZG-FER
14:30 - 15:15	TUTORIAL 3 INTRO: Underwater localization challenge ([abstract](), [presentation]())	Jeff Neasham – Newcastle University
15:15 - 15:30	Break	
15:30 - 18:30	DEMO: Blue Ocean gear ([abstract]())	Kortney Opshaug - Blue Ocean Gear
15:30-18:30	TUTORIAL 2 HANDS-ON: Three-minute thesis (3mt) ([abstract]())	Roee Diamant - UNIZG-FER
15:30-18:30	TUTORIAL 3 HANDS-ON: Underwater localization challenge ([abstract]())	Jeff Neasham - Newcastle University

Day 4: 27th September		
Time	**Presentation title**	**Speakers**
09:00 - 09:45	The challenges of apex marine predators research and conservation in Israel (abstract, presentation)	Aviad Scheinin - University of Haifa
09:45 - 10:30	Developing a swarm of low-cost floaters to acoustically perform in-situ fish stock assessment in remote areas (abstract, presentation)	Anja Babić – UNIZG-FER
10:30 - 11:00	Coffee Break	
11:00 - 11:45	Revitalizing coastal ecosystems: the intersection of 3d-printed artificial reefs, IoT, and robotics (abstract, presentation)	Manos Moraitis - Cyprus Marine and Maritime Institute
11:45 - 12:30	Cetaceans in the Adriatic – what can acoustics and machine learning teach us? (abstract, presentation)	Ana Širović - Norwegian University of Science and Technology
12:30 - 13:45	Lunch break	
13:45 - 14:30	TUTORIAL 4 INTRO: DeeperSense: AI methods for underwater visual-acoustic perception (abstract, presentation)	Izakh Fabian, Nuno Gracias Thomas Vogele, Bilal Wehbe - DeeperSense
13:45 - 18:30	TUTORIAL 3 HANDS-ON: Underwater localization challenge (abstract)	Jeff Neasham, Bruno Ferreira
14:30 - 15:15	Company presentation: LOBSTER robotics (abstract, presentation)	Stephen Rutten – LOBSTER robotics
15:15 – 15:30	Break	
15:30 - 18:30	TUTORIAL 5 HANDS-ON: Blueprint subsea – using multibeam sonar and acoustic navigation to improve situational awareness (abstract)	Simon Stockton, Rachael Reader, Robin Sharphouse - Blueprint Subsea
15:30-18:30	DEMO - Passive acoustic detection and localisation (PADAL) network for monitoring vessel activity (abstract)	Gavin Lowes, Jeff Neasham, Newcastle University (UNEW)
15:30-18:30	TUTORIAL 4 HANDS-ON: DeeperSense: AI methods for underwater visual-acoustic perception (abstract)	Izakh Fabian, Nuno Gracias Thomas Vogele, Bilal Wehbe - DeeperSense

Day 5: 28th September		
Time	**Presentation title**	**Speakers**
09:00 - 09:45	Underwater archaeology in Africa in the age of modern technological engineering (abstract, presentation)	Caesar Bita - National Museums of Kenya
09:45 - 10:30	New technologies to enhance subsea operations and autonomous environmental monitoring	Morel Groper - University of Haifa

Time	Presentation title	Speakers
	(abstract, presentation)	
10:30 - 11:00	Coffee Break	
11:00 - 11:45	Archaeological experience in the Neretva River, 2023 (abstract, presentation)	Irena Radić Rossi - University of Zadar
11:45 - 12:30	Novel robotic technologies for mapping and sampling the Mediterranean coralligenous (abstract, presentation)	Fabio Bruno - University of Calabria
12:30 - 13:45	Lunch Break	
13:45 - 14:30	TUTORIAL 6 INTRO: AKTI project and research center (abstract, presentation)	Xenia Loizidou - National Technical University of Athens
14:30 - 15:15	TUTORIAL 7 INTRO: Making underwater communications private and authentic (abstract, presentation)	Paolo Casari - University of Trento
15:15 - 15:30	Break	
15:30 - 18:30	TUTORIAL 6 HANDS-ON: AKTI project and research center (abstract)	Xenia Loizidou - National Technical University of Athens
15:30-18:30	DEMO: hull performance/dynamics and control of boats and marine robots (abstract)	Dirk Meyer, Thomas Glotzbach - Technische Hochschule Mittelhessen, University of Applied Sciences
15:30-18:30	TUTORIAL 7 HANDS-ON: Making underwater communications private and authentic (abstract)	Paolo Casari - University of Trento

Day 6: 29th September		
Time	**Presentation title**	**Speakers**
09:00 - 10:00	Three-minute thesis (3MT) competition (abstract)	
10:00 - 10:45	Hackathon results presentations (abstract)	
10:45 - 11:00	Coffee Break	
11:00 - 11:45	Localization challenge results presentations (abstract)	
11:45 - 12:30	An open-source low-cost glider for iterative development (abstract, presentation)	Krister Blanch - Chalmers University of Technology
12:30 - 13:45	Lunch Break	
13:45 - 14:30	TUTORIAL 8 INTRO: Biomimetics laboratory, Auckland bioengineering institute and fer, university of Zagreb (abstract, presentation)	Luka Mandić, Đula Nađ – UNIZG-FER Derek Orbaugh, Iain Anderson - Biomimetics Laboratory of the Auckland Bioengineering Institute
14:30 - 15:15	TUTORIAL 9 INTRO: GEM & FAIR data in marine robotics	Massimo Caccia - CNR

Time		
	(abstract, presentation)	
15:15 - 15:30	Break	
15:30 - 18:30	TUTORIAL 8 HANDS-ON: Biomimetics laboratory, Auckland bioengineering institute and fer, university of Zagreb (abstract)	Luka Mandić, Đula Nađ – UNIZG-FER Derek Orbaugh, Iain Anderson - Biomimetics Laboratory of the Auckland Bioengineering Institute
15:30-18:30	TUTORIAL 9 HANDS-ON: CNR (abstract)	Massimo Caccia, Marko Bibuli - CNR
15:30-18:30	DEMO: An open-source low-cost glider for iterative development (abstract)	Ted Sjöblom - Research Institutes of Sweden, Krister Blanch – Chalmers University of Technology
18:30 - 20:30	Dinner break	
20:30 - 23:00	Closing ceremony and Gala dinner	

Time	Presentation title
09:00 - 15:00	Field trip

4.2 Competitions for students and young researchers

4.2.1 Localisation challenge

The Underwater Localization Challenge at the BTS 2023 provided an excellent platform for MONUSEN researchers to engage with the complexities of underwater positioning in a GPS-denied environment. Equipped with an underwater acoustic modem, a GPS receiver, and access to a fast vessel, participants were tasked with locating a submerged miniature acoustic transponder using two-way acoustic ranging. The challenge was structured around three core objectives: speed in locating the transponder, the accuracy of the final position after data post-processing, and innovation in localization strategy. Subject-matter experts accompanied the teams through various phases, from preparation to data collection and analysis, providing nuanced insights and real-time troubleshooting. Hydrophones were also employed to offer a real-time visualization of acoustic activity, helping teams to adapt their strategies dynamically.

In total 5 teams participated. They collected acoustic range data both on the boat and offline, applying various algorithms and methodologies to counter the inherent challenges posed by underwater acoustics, such as severe multipath effects and noise from various sources. The final day of the workshop saw each team presenting their unique methodologies and outcomes, highlighting the educational and innovative value of the event. The winning team got within ~2m of the recorded position of the transponder (and may have been substantially closer as the transponder was expected to move slightly with the varying current in the Kumbor Straight.

The challenge served not only as an intensive learning experience but also as a forum for emerging talents to showcase their capabilities in addressing real-world challenges. While the data showed varying degrees of success in meeting the challenge objectives, the event as a whole marked a significant step forward in both academic learning and practical skill development in underwater localization.
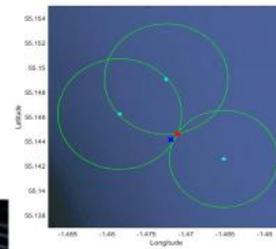
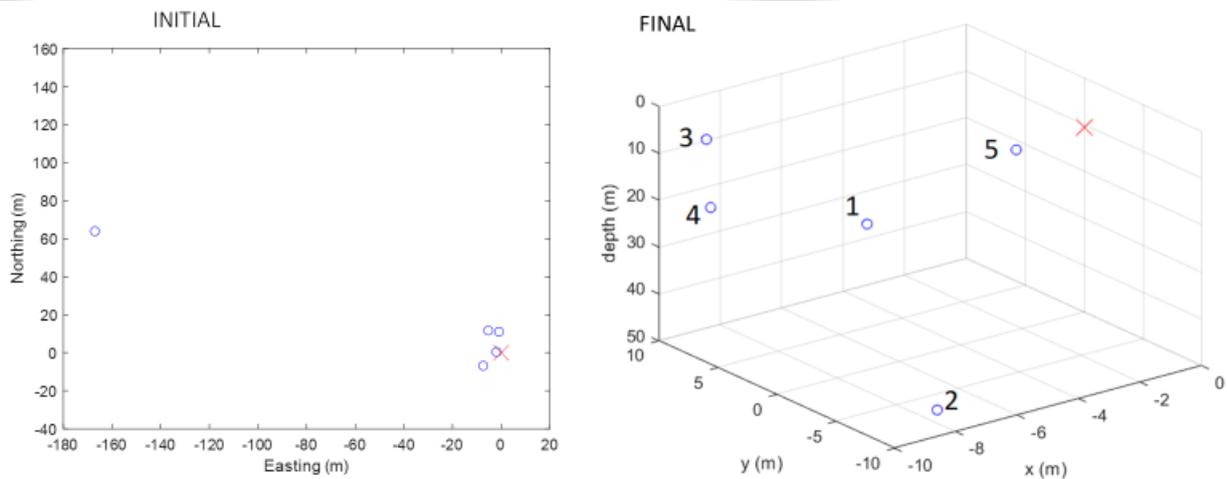Fig. 3. Localisation challenge intro (top) and presentation extract (bottom)

Fig. 4. UoM students participating in localisation challenge (top) and final localisation results (bottom)

4.2.2 Three-minute thesis competition

BTS 2023 also hosted a three-minute thesis (3MT) competition. The 3MT is an initiative to improve students research presentation skills in an elevator pitch style. 3MT is widely celebrated in North America as a competition: each student has 3 min to present his/her thesis using a single slide. A distinguished referee team from academy and industry as well as the audience evaluated the three best pitches. The event included:

- A tutorial on pitch making - How to open pitch, structure and data delivery.
- Hands-on experience in pitch making with expert feedback.
- Pitch competition – students tried out 3min pitch on referees and the audience.

Six students participated in this competition.

Fig. 5. minute thesis competition.

4.2.3 The MONUSEN hackathon final

Finalists of the first MONUSEN hackathon were selected on August 30th, 2023, and invited to participate at BTS summer school and present their solutions. As reported in Deliverable 5.5, the primary objective of the hackathon was to create a robust proof-of-concept system for long-term smart coastal water monitoring, capable of seamless integration with a real-time smart city infrastructure. This includes an Underwater Sensor Network (USN) where different sensors communicate among themselves. In accordance with industry needs, an application scenario for an aquaculture farm was defined. The students were tasked to design and simulate a system that can autonomously monitor Oyster larvae concentrations in real-time over larger areas and determine the location and depth of the optimal position for deployment of larvae collectors. During BTS, hackathon finalists had opportunity to test their solutions for detecting oyster larvae using vertical profilers and flow microscope in real underwater environment. On the last day of the summer school, the FOKe team from the University of Sarajevo was announced as the winner.

Fig. 6. Competition of MONUSEN hackathon finalists.

5. SURVEY RESULTS FROM MONUSEN RESEARCHERS ON SUMMER SCHOOL EXPERIENCE

In total 7 MONUSEN researchers and 6 students from University of Montenegro participated in the BTS summer school. Below we present the results of survey focused on the summer school experience, which offers a detailed overview of the UoM participants' perceptions and feedback.
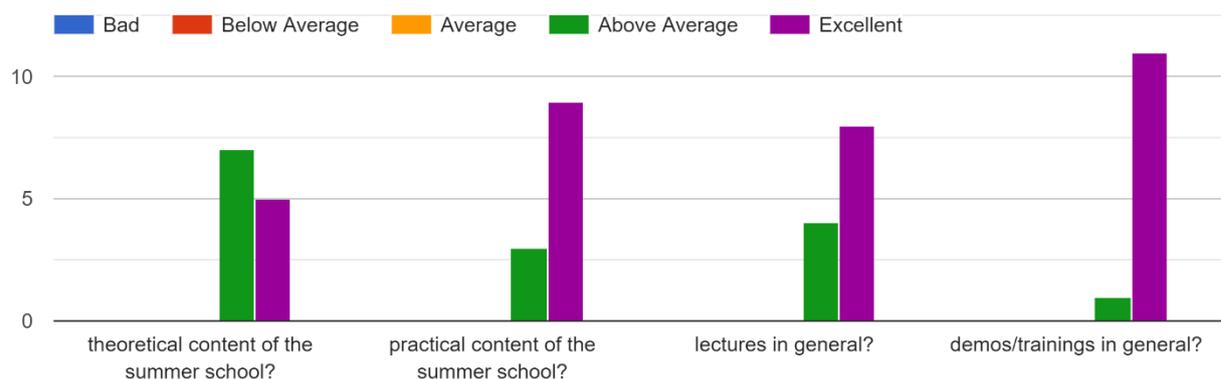
Q1. How would you rate the quality of: a) facilities (lecture rooms, wireless internet, etc.) b) organization of the summer school (agenda, breaks,...of the summer school (lectures, tutorials, demos)
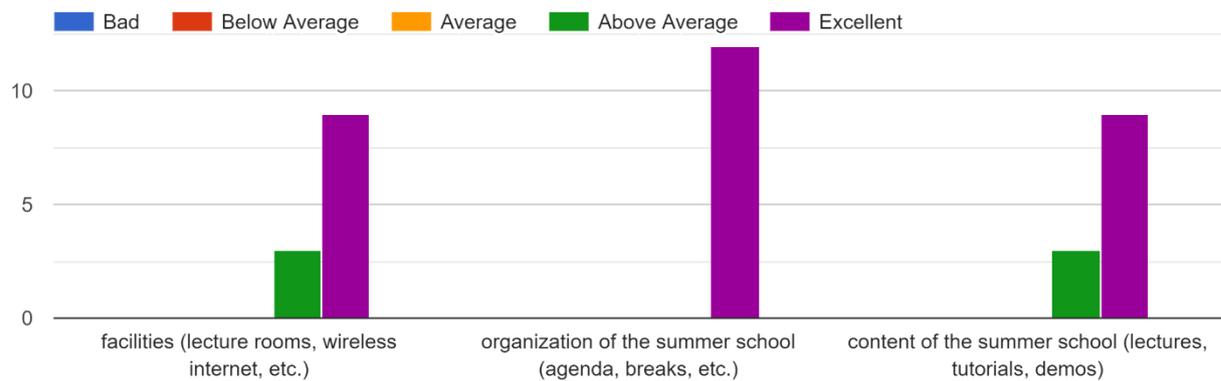
Q2. How would you rate your preparedness for the summer school topics?
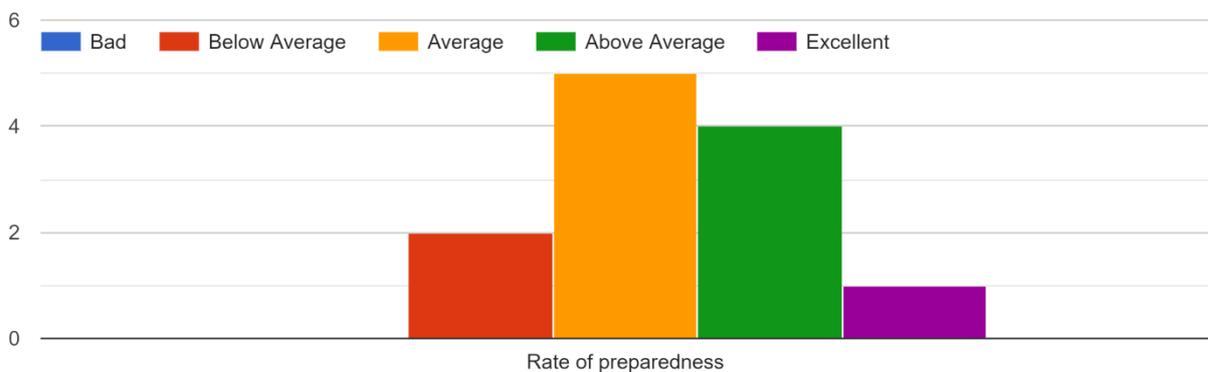
Q3. How satisfied were you with a) theoretical content of the summer school? b) practical content of the summer school? c) lectures in general? d) demos/trainings in general?

Q4. How would you rate the overall knowledge and effectiveness of your lecturers in presenting the summer school content?
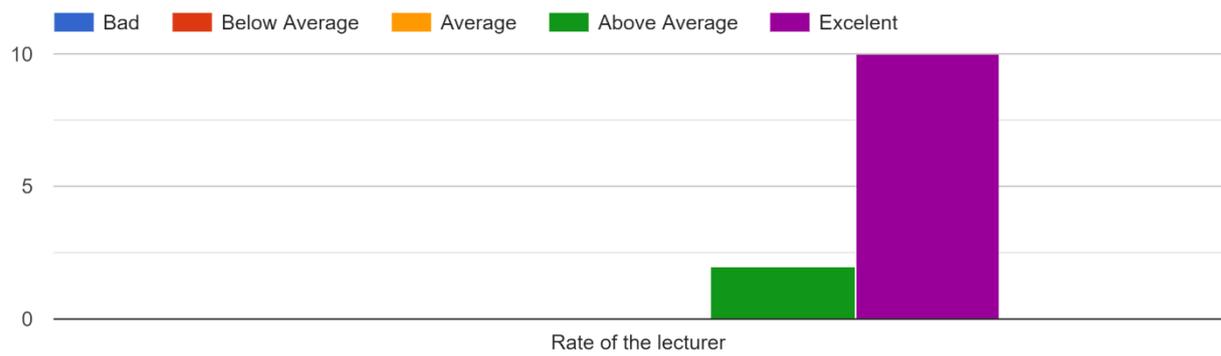
Q5. How did the quality of the summer school meet your expectations?
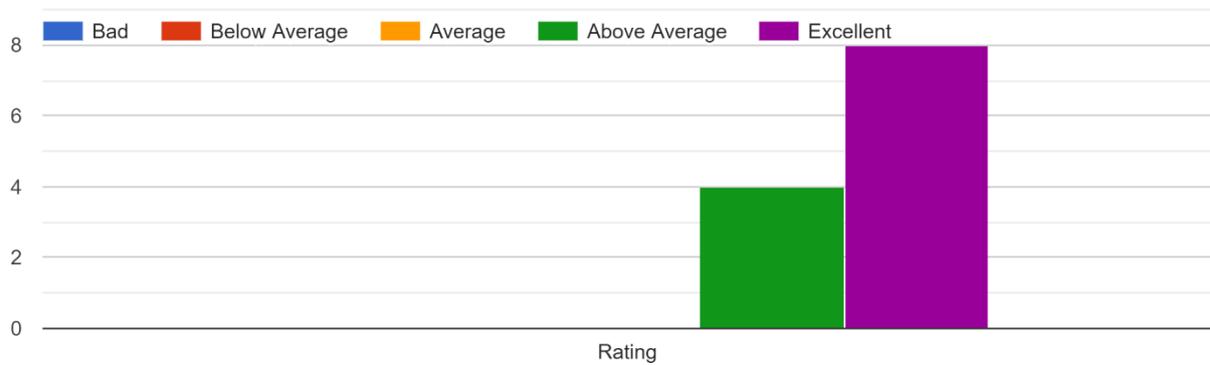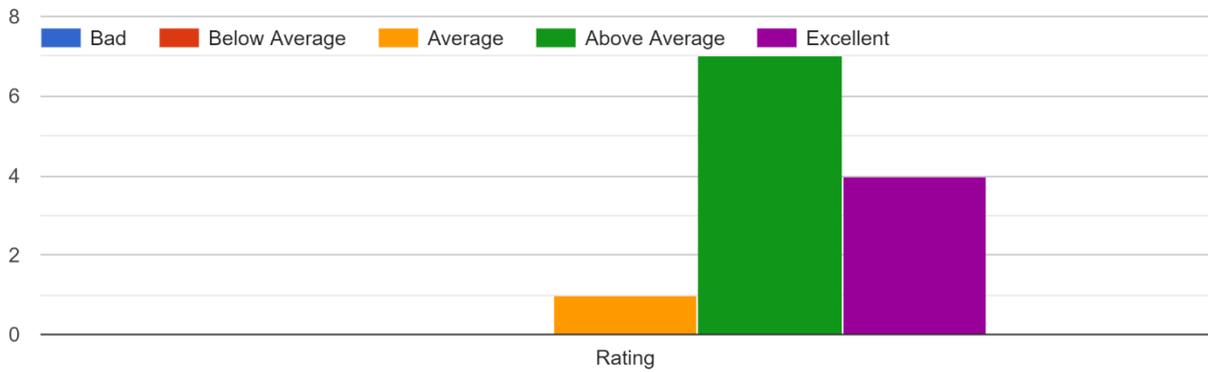

Q6. During the summer school, did you have the opportunity to conduct research experiments or collect data for future research?
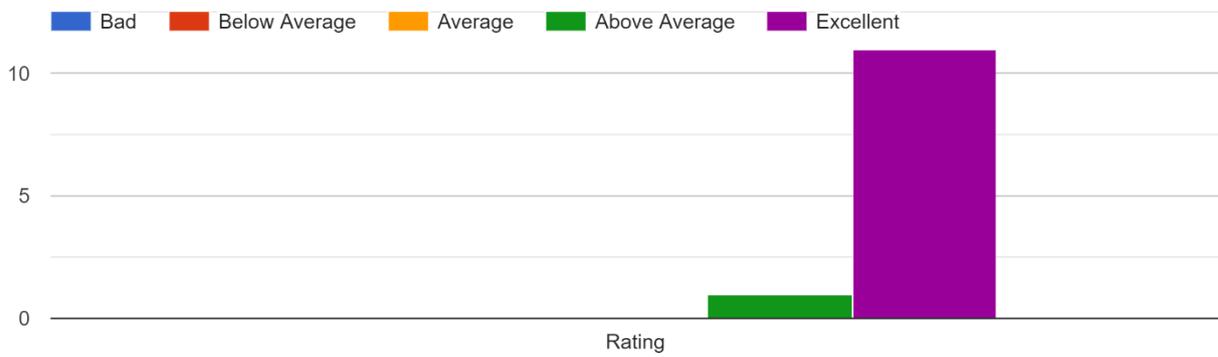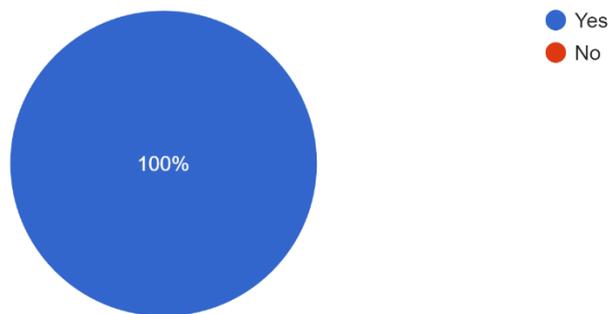
12 responses
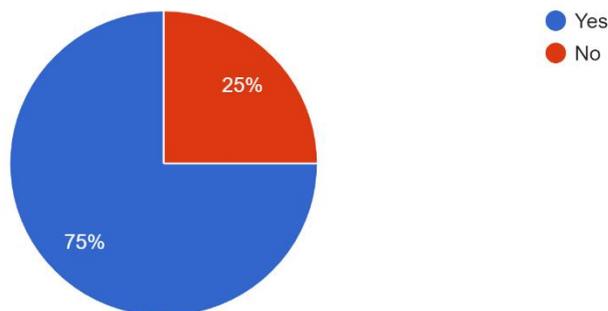
Q7. How would you rate the networking opportunities with other researchers in USN topics provided during the summer school?


Q8. How would you rate the support provided by the partner institutions (FER, CNR, UNEW) during the summer school?

Q9. Would you attend the next summer school that will be organized within the MONUSEN project?
12 responses

Q10. How would you rate your level of knowledge about underwater sensor networks after attending the summer school, compared with the kn...had about the topic before attending the school?

Rate of the knowledge after attending the tutorial
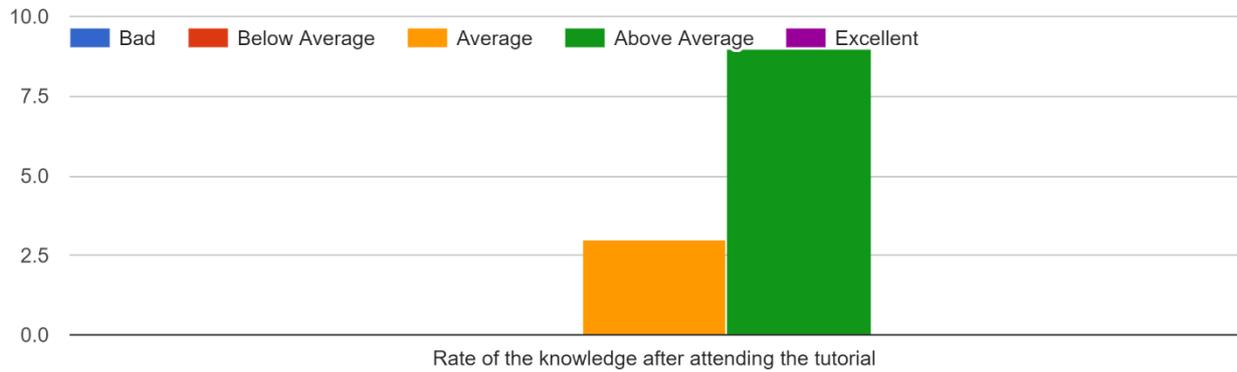
Q11. Which parts of the summer school did you find the MOST/LEAST useful?

7 responses

Lectures on Physical layer authentication methods were the most useful for me, as well as demos of University Newcastle.

I especially enjoyed localization challenge, but all the other parts of the summer school were very useful.

DEMOS and Tutorials

The most interesting parts were the demos and tutorials, where we had the opportunity to test and demonstrate the algorithms developed within the MONUSEN project.

Demos and tutorials.

The localisation challenge was one of the most useful parts.

The practical tutorials related to USV/AUV control were very useful

Q12. Do you have any further comments/recommendations on the lectures/demos/tutorials/organization?

6 responses

No

I suggest allocating more time for hands-on tutorials.

Keep up the good work and try to involve more Montenegrin students.

No.

Maybe more trainings and practical work.

Everything was well. Keep up the good work!