



SCIENCE AND TECHNOLOGY ORGANIZATION
CENTRE FOR MARITIME RESEARCH AND EXPERIMENTATION



Reprint Series

CMRE-PR-2019-022

Fostering marine robotics through competitions: from SAUC-E to ERL Emergency 2018

Gabriele Ferri, Fausto Ferreira, Vladimir Djapic

May 2019

Originally presented at:

OCEANS 2018 MTS/IEEE Charleston, 22-25 October 2018
doi: [10.1109/OCEANS.2018.8604580](https://doi.org/10.1109/OCEANS.2018.8604580)

About CMRE

The Centre for Maritime Research and Experimentation (CMRE) is a world-class NATO scientific research and experimentation facility located in La Spezia, Italy.

The CMRE was established by the North Atlantic Council on 1 July 2012 as part of the NATO Science & Technology Organization. The CMRE and its predecessors have served NATO for over 50 years as the SACLANT Anti-Submarine Warfare Centre, SACLANT Undersea Research Centre, NATO Undersea Research Centre (NURC) and now as part of the Science & Technology Organization.

CMRE conducts state-of-the-art scientific research and experimentation ranging from concept development to prototype demonstration in an operational environment and has produced leaders in ocean science, modelling and simulation, acoustics and other disciplines, as well as producing critical results and understanding that have been built into the operational concepts of NATO and the nations.

CMRE conducts hands-on scientific and engineering research for the direct benefit of its NATO Customers. It operates two research vessels that enable science and technology solutions to be explored and exploited at sea. The largest of these vessels, the NRV Alliance, is a global class vessel that is acoustically extremely quiet.

CMRE is a leading example of enabling nations to work more effectively and efficiently together by prioritizing national needs, focusing on research and technology challenges, both in and out of the maritime environment, through the collective Power of its world-class scientists, engineers, and specialized laboratories in collaboration with the many partners in and out of the scientific domain.



Copyright © IEEE, 2018. NATO member nations have unlimited rights to use, modify, reproduce, release, perform, display or disclose these materials, and to authorize others to do so for government purposes. Any reproductions marked with this legend must also reproduce these markings. All other rights and uses except those permitted by copyright law are reserved by the copyright owner.

NOTE: The CMRE Reprint series reprints papers and articles published by CMRE authors in the open literature as an effort to widely disseminate CMRE products. Users are encouraged to cite the original article where possible.

Fostering marine robotics through competitions: from SAUC-E to ERL Emergency 2018

Gabriele Ferri¹, Fausto Ferreira¹, Vladimir Djapic²

Abstract—Marine robotics competitions and challenges are today very popular in the robotics community. Their value mainly lies in the opportunities they provide to teams (both student and professional) for developing and testing their robots in real world scenarios. Robotics competition can be divided into two categories: student competitions and Grand Challenges. The Grand Challenges provide difficult technical challenges to push research groups. On the other hand, student competitions are more focused on the training perspective. Student robotics competitions are the perfect driver to push students to experiment what they have learned at school in realistic conditions. In this way they are the best complement to the academic curriculum, where often the hands-on experience is lacking. Furthermore, they also boost the non-technical skills from management to team work since these skills are essential to succeed. The Centre for Maritime Research and Experimentation (CMRE) strongly shares this view and has been organising competitions since 2010. CMRE has fostered the grow of many students along the years. In this paper, we will analyse first the competitions we have organised along the years and the performance of the participating teams presenting several case studies. The broader impact of competitions in the field of robotics and on the general public will also be briefly discussed. We believe this is the key point to guarantee the competition periodicity and sustainability over the years.

I. INTRODUCTION

Marine robotics is a complex research field due to its inherently unstructured and challenging environment. One of the biggest barriers for research groups to approach the marine environment is the complexity and cost of the preparation and execution of experiments at sea. This is especially true for research groups which are new to the marine domain and, more in general, for academic groups which do not have the same resources as big industrial players. In particular, what is generally missing is a strong support by technical personnel experienced in the underwater domain. Competitions can be the perfect opportunity to support and push research teams during the development and testing of their systems in real world scenarios. Robotics competitions can be divided into two categories: Grand Challenges and student competitions. In Grand Challenges (such as the DARPA Grand Challenge [1]) a difficult technical/scientific

problem is proposed to teams. The main objective of this kind of competitions is to push the state of the art, providing means and motivations to research groups to develop more capable systems and algorithms to adequately address, and solve, the challenge of interest.

Student competitions are instead more focused on the educational aspect. Teams are supported throughout a learning path not only to improve their technical skills through hands-on experience in the field (often not adequately addressed by the academic curriculum), but also to develop managerial and team work capabilities which are essential for their future professional life. At the Centre for Maritime Research and Experimentation (CMRE) we strongly believe in the role of robotics competitions in the education of new generations of engineers and scientists [2], [3] and we have been organising competitions since 2010. Our attitude towards competitions is to propose a *hybrid* challenge. For hybrid we mean that complex tasks are proposed (sometimes very challenging from the technical point of view), but at the same time we support and encourage the student aspect of the competition. For marine robotics competitions, one important feature is where they are held, if in pools or in real-world environments. Some competitions around the world ¹ [4] are organised in pools. The conditions (e.g. high visibility), calm and fresh water, are in general more suited to less expert teams, such as high-school students. As RobotX², and RoboBoat ³, our competitions are held in sea water basins. Even if it is logistically more complex to organise competitions in real world environments, we believe that proposing realistic conditions to the teams is fundamental for their growth over time.

The Student Autonomous Underwater Challenge-Europe (SAUC-E) [3] has been running since 2006 and has been organised since 2010 by CMRE at its on-site sea basin. This year it has been included in ERL Emergency Robots 2018 event. SAUC-E is the flagship European competition for student AUVs and is widely recognised by the community as the most realistic student competition in marine robotics [4]. The good experience with SAUC-E organisation led CMRE to participate in the euRathlon project starting in 2013. After the success of euRathlon ⁴, the European Robotics League (ERL) Emergency Robots 2017 ⁵ was its natural follow-up. The euRathlon 2015 Grand Challenge [5] was

¹Gabriele Ferri and Fausto Ferreira are with NATO Science and Technology Centre for Maritime Research and Experimentation (CMRE), Viale San Bartolomeo 400, 19126 La Spezia, Italy. Gabriele.Ferri, Fausto.Ferreira@cmre.nato.int, ²Vladimir Djapic is with American Haval Motor Technology, Farmington Hills, MI 48335, USA vladimir.djapic@havalus.com,

This work was partly supported by the FP7 Coordination and support action EURATHLON project, grant agreement No 601205, the EU Horizon 2020 RockEU2 project under grant agreement No 688441 and EU Horizon 2020 SciRoc project under grant agreement No 780086

¹<http://www.auvsifoundation.org/competition/robosub>

²<http://www.robotx.org/>

³<http://www.auvsifoundation.org/competition/roboboat>

⁴www.eurathlon.eu

⁵www.robotics-league.eu

the first world competition with land, marine and aerial robots cooperation and as ERL Emergency Robots 2017 was inspired by the 2011 Fukushima accident. euRathlon 2015 Grand Challenge and ERL Emergency Robots 2017 were locally organised by CMRE and held in a real-world environment. The competitions were held in a harbour area in front of a real power plant, the Tor del Sale Piombino plant in Italy. In 2018, another ERL Emergency Robots event took place, this time back to La Spezia (as SAUC-E).

Together with realistic conditions, our competitions aim to push teams towards autonomy (in terms of adaptive missions) and multi-robot operations. It is not easy to achieve this, especially in the marine domain, where most of the times the problems are more related to the engineering aspects to have a reliable vehicle capable to navigate. However, we have been trying to achieve this by modifying the proposed tasks over the years and supporting the team activities.

In this paper, we analyse the evolution of the competitions along the last 5 years in Section II. Then, we present the experience of some of the teams that have participated multiple times in Section III. Section IV details our efforts to support team participation, through the involvement of sponsors and the building of a community using the competitions as venue. Finally, Section V concludes the paper with an overview of ideas for the future of competitions.

II. ANALYSIS OF THE COMPETITIONS

The first competition analysed is SAUC-E [3]. SAUC-E is an underwater robots competition dedicated to student teams. It started in 2006 in the UK and after several editions in the UK and France, has been hosted by CMRE in La Spezia, Italy, without interruption since 2010 (except in 2015 and 2017 in Piombino, Italy integrated in euRathlon and ERL Emergency competitions). SAUC-E is dedicated to University teams (consisting of at least 75% student members) that need to design and build Autonomous Underwater Vehicles (AUVs) capable of performing realistic missions, such as autonomous navigation, structure inspection, passing a gate (composed of two buoys), light detection and "black box"/pinger search. SAUC-E is recognised as the most realistic underwater robotics student competition [4] as it takes place in an open water sea basin. The changing conditions of low visibility, turbulence, salty water, tides, and currents have provided a perfect training ground for the young engineers over the years. Until 2012, only AUVs were competing but as part of the effort of pushing multi-robot cooperation, since 2013, teams can participate with Autonomous Surface Vehicles (ASVs) for a cooperative task. In 2013, 2014 and 2016 (the years that the competition was marine robotics based only), the cooperative task could be performed with an AUV from one team and an ASV from another team. This fostered cooperation among different teams and a fair play spirit as both teams could benefit from the collaboration. To support student teams and to encourage the team growth, points can be scored throughout the week. This provides student teams more opportunities to fulfil the proposed tasks

and encourages them to test their vehicles at sea. For more information on the scoring, please refer to [6].

SAUC-E challenged the teams over the years raising the bar in terms of perception tasks (e.g. numbers to be recognized underwater, mosaicking of the area to be provided, etc.), collaboration (the cooperative tasks with another vehicle) and sensing (the use of acoustics to detect the pinger). In addition, we push the teams towards complex missions awarding the completion of multiple tasks sequentially. At the same time, we also guarantee the possibility to less expert teams which participate for the first time to fulfil some tasks. The gate task has this function, since "only" a controlled navigation is required to reach the buoy area and to pass across them.

In 2014, besides SAUC-E, euRathlon 2014 sea robotics competition took place in the same place and back-to-back (week after). This competition was organised within the euRathlon⁶ project, a European project funded by the Framework Program 7 (FP7) running from 2013 to 2015. The final goal of the project was to have a cooperation between land, sea and aerial robots in the euRathlon 2015 Grand Challenge. As preparation for that final Challenge, a land robotics competition was carried out in Germany in 2013. In 2014, the euRathlon 2014 marine robotics competition was held in La Spezia, Italy. Even if euRathlon 2014 was held in the same sea basin as SAUC-E 2014, the tasks were different as well as the philosophy behind.

First of all, each task was considered a competition (scenario) in itself and thus every day a new task was judged separately. The tasks were somehow similar to SAUC-E, but there were three new harder tasks. One was underwater manipulation, the only one where the AUV could be connected to a cable from shore (acting as a Remotely Operated Vehicle). Another was plume following, where a plume made of a few buoys had to be followed depending on their position and number. Finally, there was for the first time a long-range navigation task which was held outside the SAUC-E's arena (50 m x 25 m) and the CMRE's sea basin to the open sea.

Proposing different tasks as separate competitions, allows to better evaluate the robot performance in terms of functionalities. For instance, if one task involves only navigation the team can be judged on that functionality (more details in [7]). This can help teams to focus on particular topics and can better show them which are their weaknesses to work on. euRathlon 2014 was not a student-based competition even if the number of mixed teams academia-industry was small as it was the first time the competition was open to industry. It was a preparatory event to the euRathlon 2015 multi-domain Grand Challenge, so the challenge aspect was emphasize by evaluating the teams in one time-slot.

The euRathlon 2015 Grand Challenge [8], [5] was the final competition of the euRathlon project. It was the first world competition where land, marine and aerial robots had to cooperate in a search and rescue scenario inspired by the 2011 Fukushima accident. The scenarios of this

⁶<http://www.eurathlon.eu>

multi-domain competition took place in increasing order of complexity: single trials, double-domain scenarios (land+sea, land+air, sea+air) and finally the Grand Challenge (three domains). Here the marine tasks were similar to the ones in euRathlon 2014. The big difference is that now a group of tasks (that in 2014 constituted single competitions daily) were put together in one single scenario and had to be executed sequentially/in parallel. Moreover, the dimension of the arena doubled and new tasks were added like searching for a mannequin. Finally, for the first time, the AUVs had to cooperate with land and/or aerial vehicles. They could do it through an ASV or the control station but this pushed teams from different domains to collaborate as most teams did not have the three types of robots.

In 2016, SAUC-E was organised again at CMRE premises. Most of the tasks from euRathlon 2015 were repropounded to challenge again the teams on the same tasks, but in less harsh environmental conditions (e.g. better visibility). This aimed to not reduce the difficulty level and to train the student teams to face the European Robotics League challenge in the following years.

The European Robotics League (ERL)⁷ Emergency Robots [9] is an outdoor robotics competition funded by the EU Horizon 2020 Program. It is the follow-up of the euRathlon competition and it is also inspired by the 2011 Fukushima disaster. The ERL Emergency Robots competition was part of the RockEU2 Coordination Action from 2016 to 2018, led by euRobotics and supported by SPARC. Since February 2018 it is of the SciRoc⁸ EU project. The ERL Emergency Robots Major Tournament took place in Piombino, Italy in September 2017 in the same scenario of euRathlon 2015 Grand Challenge. ERL Emergency Robots was not a student-based competition like SAUC-E and several mixed teams attended the competition. The tasks were similar to euRathlon 2015 Grand Challenge with some new twists, added tasks and added inter-domain cooperative tasks. For instance, the mannequin was located in a area full of rubble, AUVs had more inspection and object detection tasks, an emergency kit had to be delivered by the land and air robot to a missing worker (mannequin). The arena was again increased with respect both to SAUC-E and to euRathlon 2015.

In ERL Emergency 2018, the competition came back to La Spezia, Italy and used the same arena as SAUC-E. This was because in 2018 the ERL Emergency league proposed a Local Tournament instead of a Major Tournament. Indeed, a double domain competition took place (land+sea) instead of the full three domain competition. Again, new tasks were added like vertical dock wall mapping and extra object recognition tasks.

As mentioned before, our competitions are characterised by real world conditions, a push towards autonomy in the sense of autonomous perception and adaptive missions and multi-robot cooperation. We have been proposing this

by increasing the complexity level of the tasks over the years. Both in SAUC-E and in euRathlon/ERL Emergency 2017 the conditions in the marine domain were challenging. However, while in CMRE's arena the visibility is in general acceptable (<2-3 m) and cameras can be used for perception, the Piombino's arena (2015 and 2017 competitions) was characterised by a very poor visibility. The competition area was in a protected harbour with shallow water (~ 4 m) and the visibility was generally < 1 m. Fig. 1 illustrates the poor visibility encountered. Even though the objects were bright orange or yellow, in some cases they were hardly visible. These conditions heavily impacted the competition since they forced the teams to use acoustic sensors (as described in the next section) and increased the difficulties in the object recognition and navigation tasks. The policy of raising the competition task complexity showed its results. Its outcome is discussed in the next section analysing the cases of several teams which took part in our competitions.

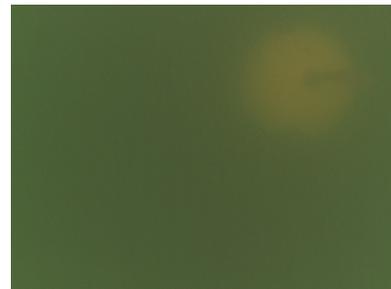


Fig. 1. An orange buoy is hardly seen underwater. Credit: University of Girona

III. TEAMS CASE STUDIES

In this section we will present several case studies of very different teams looking at the evolution of the team along the years. We will start with the AUV Team TomKyle, a team that since 2014 has never missed one competition and is now one of the best participant teams. The other examples treated in this paper are the UNIFI Robotics Team, the University of Girona team, the OUBOT team and Robdos team. The examples were chosen to give an overview selecting teams that participated multiple times.

A. AUV Team TomKyle

This team comes from the University of Applied Sciences in Kiel, Germany. It participated for the first time in 2014. As a rookie team, AUV Team Tomkyle won the SAUC-E 2014 Best Journal Paper, showing a good team organisation and a principled approach to the design and realisation of an underwater vehicle. In their first participation, the in-water performance was limited (they were able nonetheless to pass the gate successfully). Over the years, however, the team was able both to improve the vehicle integrating new sensors (e.g. a multi-beam sonar) and to increase the performance considerably. This led AUV Team Tomkyle to be ranked at the podium places in the following competitions, for instance they were 3rd as a marine team at the euRathlon 2015 Grand Challenge (2nd *ex aequo* in the Grand Challenge

⁷<http://robotics-league.eu>

⁸<http://sciroc.eu>

evolved over the years to a new version, the SPARUS II, that eventually reached the level of being commercialised. A spin-off company has been generated from the University which is an example of technology transfer helped by robotics competitions. University of Girona won again ERL Emergency 2017 together with the same teams in all double domains it participated (land+sea and sea+air) and in the Grand Challenge (land+sea+air).

The University of Girona is the perfect example of the importance of continuity in a team. Strongly supported by their academic and technical advisors, the University of Girona team was able to integrate new students to more senior PhD students. This is crucial to pass on the knowledge about the vehicle and a way to improve the robustness of operations. This makes the team used to operating the vehicle at sea and it demonstrates decisive in our competition. On the other hand, a periodic competition can be a spur for the research group to set up every year a prepared team and provides an opportunity for the integration of younger students in the team. Another improvement has been seen in the multi-robot, multi-domain coordination in ERL 2017. Having kept the same multi-domain team in 2015 and 2017 made of 3 different partners from different countries, allowed the three groups to define months in advance details about the communication. Again, the periodicity of competitions is beneficial for the cross-fertilisation and networking between different domains and can lead to better results, new ideas and new projects.

D. OUBOT

Starting from 2014, AUVs were loaned to less experienced teams in the marine domain. This was done to facilitate the participation of research groups expert in other fields of interest. OUBOT team was one of the teams selected after an open call. They benefited from this loan for euRathlon 2015. OUBOT team comes from the University of Obuda in Hungary and had no previous experience in marine robotics. After getting the loaned vehicle, they got a training course of a week at the producer and within less than 6 months they had to compete at euRathlon 2015. Even if they had no prior experience, they showed good results at sea placing themselves in 4th out of 7 teams in one of the single domain trials. They had especially good results in object recognition capitalising on their computer vision experience and performing better than other more experienced teams. At ERL Emergency 2017, they had again the same loaned platform but for less months and, above all, without the DVL sensor. This increased their navigation issues and distracted their attention from real-time perception tasks. However, the acquired experience and the received awards (e.g. the thrusters received for the Navigation Special Award in 2017) encouraged them to start designing their own vehicle.

Loaning common platform to teams is beneficial under different points of view. First, it allows groups not expert in the marine domain to become interested in this type of robotics. In this way, we can enlarge the community and benefit in underwater scenarios of the results of other

communities (e.g. computer vision). Second, it is important for benchmarking algorithms since teams will use a common hardware and results from different software can be compared. The support by sponsors and professional organisations is crucial to pursue this approach to enlarge the participation in the competitions.

E. ROBDOS

ROBDOS team also benefited from the loan of an AUV since 2014 to 2015. This team comes from the Polytechnic University of Madrid and Robdos company in Spain and is one example of a mixed industry-academia. The students started their participation in our events with a limited experience in marine robotics. In 2014, at their first attendance, ROBDOS team won the System Integration Award of SAUC-E'14 testifying their effort in system integration. They had the opportunity to keep the vehicle and improve their skills for the euRathlon 2015 Grand Challenge where they were able to accomplish some basic navigation tasks at sea. Their learning experience was so significant that they decided to build their own vehicle that was tested at sea in 2017 during ERL Emergency 2017. As a mixed industry-academia team, they had to face not only technical demanding problems during the realisation of the robot, but they had to manage sponsorship raising, budget allocation and test planning which are generally not stressed enough in normal university coursework.

IV. SUPPORT TO THE TEAMS AND COMMUNITY BUILDING

From our experience, the best way to support the teams' growth is to guarantee the periodicity of the competitions. Multiple participations allow teams to improve their strategies and their robots for the next editions driven by the experience acquired in managing the unavoidable practical problems. This is beneficial to deeply involve the teams in the proposed challenges, fostering an improvement in performance, a general increase in the vehicle robustness and the enhancement of the event management. Guaranteeing time at sea to the teams is also necessary. Only through extensive testing at sea a team can reach the needed confidence to achieve the assigned objectives. This is true in particular for teams not used to operate their robot at sea. Several teams have participated multiple times (the majority of the participants) and a "SAUC-E community" has been created over the years. This community of marine robotics is one of the most important results of our competitions. Most of these teams have participated also in the multi-domain competitions in 2015, 2017 and 2018, meaning that the effort to support the teams is worth and that the community building through competitions can extend beyond the marine robotics field.

Besides keeping the periodicity of the competitions, loaning platforms as in the case of OUBOT and ROBDOS teams is one way in which the organisation can support the teams and enlarge the marine community. Ideally, as in these two

cases, teams get enough experience with the loaned platforms to start building their own robot.

The question to be answered is: how to guarantee the competition periodicity and at the same time supporting the team participation?

One possible answer is: building a stronger and stronger community. CMRE and EU supported financially our competitions over the years. However, sponsors have been crucial for the event organisation. ONRG and IEEE Oceanic Engineering Society in particular supported our events in an important way. Involving supporters and sponsors is also needed to give prizes for the teams, not only cash prizes but also in-kind sponsorships such as free accommodation, thrusters and other equipment, internships, vouchers for conferences and other gifts. Over the years we have been receiving the support of the Italian Navy providing us the excellent sea basin in La Spezia and hosting the teams. This has been fundamental for keeping the competition affordable for student teams. The Italian Navy through its Naval Experimentation and Support Centre (C.S.S.N) which hosts the competition is interested in keeping in contact with the state of the art of underwater robotics and thus this is a win-win relationship. In the case of larger events, such as euRathlon 2015 or ERL Emergency Robots 2017, supporting the teams with travel funding (which was supported by the European Commission) is essential to allow team participation. However, covering the travel costs sometimes is not enough, and supporting the teams during the competition preparation phase becomes necessary. Cash prizes coming from the main sponsors can be of help for this. They allow the team to invest in better sensors or other hardware. Other in-kind sponsorships are also beneficial to the teams. The reason is two-fold: on the one hand, they can improve the training of the team members (e.g. internship or vouchers for a conference), on the other hand it puts the teams in contact with the industry world.

Competitions are indeed a good opportunity for fostering the industry-academia connections and building a broader community. This is especially true in the case of large multi-domain events. In both euRathlon 2015 Grand Challenge and ERL Emergency Robots 2017 we had more than 120 young and creative participants which could interact with top notch academic and industry robotics experts. Teams could enter in contact with the leading organisations in marine engineering and robotics, such as IEEE OES which was the Platinum sponsor. Moreover, several supporters/sponsors attend the competitions in various forms and are able to watch the teams live action and interact with the students. This is the way for them to perform talent hunting and at the same time to raise their interest on what they are investing in.

The networking made possible at these events is not limited to interactions between sponsors and teams. Supporters are part of the competition by either having an exhibition booth promoting their company, giving a talk to all the technical experts (teams, judges, visiting experts) or performing a demo in realistic conditions. For instance, at ERL Emergency 2017, a company sponsored the competition by providing an acoustic tracking system which was very

helpful for judges to have in real-time the positions of the teams' vehicles. This is part of the effort CMRE has been doing along the years to connect companies/spin-offs and student teams. In several competitions, there were mixed teams industry-academia and the interest from industry in getting more involved with competitions is growing. The connection is beneficial for teams since they can get access to new products and for companies (or universities) that can test and having a feedback on their prototypes.

The community building around marine robotics competitions can be measured over the years. Past students remain in contact with their teams. Other students become team leaders or academic supervisors of the teams themselves after some participations and several ex-participants come back to the competitions as judges.

Finally, the community building is not limited to the marine robotics field. ERL Emergency Robots 2017, as a major event, attracted a great interest in national TV and local and national newspapers and in the local community. In total, around 2,000 people attended the public programme, including several large parties of school students who visited the competition and attended robotics workshops, from elementary to high school groups. This impact on public interest is important for the teams for the dissemination of their institutions. This is also extremely important to attract sponsors and funding agencies. This keeps the competitions attractive to them and stimulates new investments. Raising the interest in the general public and sponsors creates the conditions for the sought competition periodicity and allows to better support team participations. This increases the level of the participant research groups/companies attracting more interest, and in this way creating a virtuous circle.

V. CONCLUSION

In this paper we have presented CMRE's multi-year experience in organising marine and multi-domain robotics competitions. In particular, we have introduced each competition and their evolution and then selected case studies of successful teams. Looking at the evolution of the teams, we can gather some good examples of the impact of competitions in their growth ranging from technology transfer to non-expert teams entering the marine robotics domain and a general level raising among teams that participate in multiple editions. We have shown also how competitions can contribute to community building and improving the connection between academia and industry. The connection is beneficial not only for networking purposes, but also to attract funding to support the teams. This is important to make the competitions popular and sustainable and creating a virtuous circle where teams, sponsors and general public are the most important components. Our plans for the future are to continue increasing the "SAUC-E community" and to move more and more towards tasks in which adaptive mission planning in reaction to real-time sensing is required.

ACKNOWLEDGMENT

The authors wish to thank all the participants in all the past competitions for their effort during the events, the organisation staff from CMRE and the euRathlon, RockEU2 and SciRoc project partners for their valuable input and collaboration. Furthermore, the authors would also like to thank the support of all the sponsors and supporters, in particular IEEE Oceanic Engineering Society and Office of Naval Research Global (ONRG) among many others.

REFERENCES

- [1] <http://www.theroboticschallenge.org>.
- [2] E. Lundquist and V. Djapic, "SAUC-E Offers Student Teams Realistic Challenge," *Maritime Reporter and Marine News* magazine, Jan 2012.
- [3] G. Ferri, F. Ferreira, and V. Djapic, "Boosting the talent of new generations of marine engineers through robotics competitions in realistic environments: The SAUC-E and euRathlon experience," in *OCEANS 2015 - Genova*, May 2015, pp. 1–6.
- [4] K. T. Harold Tay and V. Pallayil, "The Singapore AUV Challenge (SAUVC) 2016," in *IEEE OES Beacon Newsletter*, May 2016, Volume 5, Number 2., 206.
- [5] G. Ferri, F. Ferreira, V. Djapic, Y. Petillot, M. Palau, and A. Winfield, "The euRathlon 2015 Grand Challenge: The first outdoor multi-domain search and rescue robotics competition - a marine perspective," *Marine Technology Society Journal*, vol. 50, no. 4, pp. 81–97, 2016.
- [6] F. Ferreira, G. Ferri, Y. Petillot, X. Liu, M. P. Franco, M. Matteucci, F. J. P. Grau, and A. F. Winfield, "Scoring robotic competitions: Balancing judging promptness and meaningful performance evaluation," in *2018 IEEE International Conference on Autonomous Robot Systems and Competitions (ICARSC)*, April 2018, pp. 179–185.
- [7] Y. Petillot, F. Ferreira, and G. Ferri, "Performance measures to improve evaluation of teams in the euRathlon 2014 sea robotics competition," *IFAC-PapersOnLine*, vol. 48, no. 2, pp. 224–230, 2015. [Online]. Available: <http://www.sciencedirect.com/science/article/pii/S2405896315002761>
- [8] A. F. T. Winfield, M. P. Franco, B. Brueggemann, A. Castro, M. C. Limon, G. Ferri, F. Ferreira, X. Liu, Y. Petillot, J. Roning, F. Schneider, E. Stengler, D. Sosa, and A. Viguria, *euRathlon 2015: A Multi-domain Multi-robot Grand Challenge for Search and Rescue Robots*. Cham: Springer International Publishing, 2016, pp. 351–363. [Online]. Available: http://dx.doi.org/10.1007/978-3-319-40379-3_36
- [9] G. Ferri, F. Ferreira, and V. Djapic, "Multi-domain robotics competitions: the cmre experience from sauc-e to the european robotics league emergency robots," in *OCEANS 2017 - Aberdeen*, June 2017, pp. 1–7.

Document Data Sheet

<i>Security Classification</i>		<i>Project No.</i>
<i>Document Serial No.</i> CMRE-PR-2019-022	<i>Date of Issue</i> May 2019	<i>Total Pages</i> 7 pp.
<i>Author(s)</i> Gabriele Ferri, Fausto Ferreira, Vladimir Djapic		
<i>Title</i> Fostering marine robotics through competitions: from SAUC-E to ERL Emergency 2018		
<i>Abstract</i> <p>Marine robotics competitions and challenges are today very popular in the robotics community. Their value mainly lies in the opportunities they provide to teams (both student and professional) for developing and testing their robots in real world scenarios. Robotics competition can be divided into two categories: student competitions and Grand Challenges. The Grand Challenges provide difficult technical challenges to push research groups. On the other hand, student competitions are more focused on the training perspective. Student robotics competitions are the perfect driver to push students to experiment what they have learned at school in realistic conditions. In this way they are the best complement to the academic curriculum, where often the hands-on experience is lacking. Furthermore, they also boost the non-technical skills from management to team work since these skills are essential to succeed. The Centre for Maritime Research and Experimentation (CMRE) strongly shares this view and has been organising competitions since 2010. CMRE has fostered the growth of many students along the years. In this paper, we will analyse first the competitions we have organised along the years and the performance of the participating teams presenting several case studies. The broader impact of competitions in the field of robotics and on the general public will also be briefly discussed. We believe this is the key point to guarantee the competition periodicity and sustainability over the years.</p>		
<i>Keywords</i>		
<i>Issuing Organization</i> NATO Science and Technology Organization Centre for Maritime Research and Experimentation Viale San Bartolomeo 400, 19126 La Spezia, Italy [From N. America: STO CMRE Unit 31318, Box 19, APO AE 09613-1318]		Tel: +39 0187 527 361 Fax: +39 0187 527 700 E-mail: library@cmre.nato.int