

The Singapore Autonomous Underwater Vehicle Challenge (SAUVC) : An Effort to Engage and Expose Young Engineers to Challenges of Underwater Robotics

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Abstract—The Singapore Autonomous Underwater Vehicle Challenge, dubbed as SAUVC, is an effort by the IEEE Oceanic Engineering Society Singapore Chapter to engage and expose the tertiary students to the challenges of AUV design. The programme was started in 2013 and was originally intended to create awareness among the local students on the importance of underwater robotics and its relevance to Singapore. However, it grew into an international competition from its very inception as it was felt that opening up the competition at an international level would add diversity to the design approaches. The competition is designed in a swimming pool format and requires the AUV to perform a series of tasks, which requires a good understanding of sensors and algorithms to navigate underwater. The teams were also required to present their designs and share their experiences to an invited audience. To increase the level participation at the international level the organising committee decided not to charge any registration fee. To boost local participation, the teams from Singapore were provided limited financial support to build their AUVs initially. Also the organising committee explored with the respective institutions on the possibility of awarding credits to the team members. So far we have conducted three competitions and it is a matter of pride for the organisers that the programme has been successful in nurturing a local team from National University of Singapore, which went on to perform well in the AUVSI Robosub competition and rise to 5th position in its second year of participation. The programme has been well supported by the National University of Singapore, DSO National Laboratories and the Singapore-MIT Alliance for Research & Technology. It has also been able to attract many sponsors including IEEE Oceanic Engineering Society, Office of Naval Research (Global) and both local and international industrial partners.

I. INTRODUCTION

Informal learning is always fun, exciting and probably most rewarding experience, especially when carried out by a group individuals with different skills. Participating in challenges like

autonomous underwater vehicles (AUV) competitions provide an opportunity for the students to experience the value of such informal learning beyond the classroom knowledge as there is no formal course on AUV being taught in many of the universities. The first international AUV competition was initiated by the Association for Unmanned Vehicle Systems International (AUVSI) Foundation in US in the year 1998 [1]. The competition named Robosub, and co-sponsored by Office of Naval Research is now a widely contested competition with over 30 international student teams participating every year. In 2006 a similar competition was initiated in Europe namely Student Autonomous Underwater Vehicle Challenge, Europe (SAUC-E) [2]. Most student teams participating in this competition are from Europe and the competition is well supported by the Centre for Maritime Research and Experimentation (CMRE). In 2011, National Institution of Ocean Technology (NIOT), India started a national level AUV competition, viz., Student Autonomous underwater Vehicle (SAVe) competition in collaboration with their local chapter of IEEE Oceanographic Engineering Society (OES) and Ocean Society of India. The competition is open to only student teams from different parts of India.

The IEEE OES Singapore chapter started the Singapore AUV Challenge in 2013 with a view to expose local students to the engineering challenges of AUV design and also to develop an appreciation for the AUV related technologies. However realising the fact that there is no Asian equivalent of Robosub or SAUC-E, the advisory committee and the organising committee decided to make it as an international challenge, specifically for the students in the Asia Pacific region. The organisers have been successful in organising three

competitions so far with some success. In this paper we carry out an assesment on the success of this competition with regard to its objectives by analysing team participation, team feedback, sponsorship support and collaborations as well as the volunteer support received. We also look at the difficulties faced by the organising committee during the course of these events and how we managed to overcome them. Finally we take a look at the future of this event and possibilities jointly organising an event at the Asia Pacific level.

II. OBJECTIVES OF THE SAUVC

The organising committee of the SAUVC is largely constituted by IEEE OES local chapter members who are also staff from National University of Singapore (NUS), DSO National Laboratories as well as the Singapore-MIT Alliance Research & Technology (SMART). These institutions are actively engaged in developing or using autonomous underwater vehicles and platforms for their research. The AUVs have become an integral part of many ocean going research projects and there are many commercial off the shelf solutions available. However, most of these AUVs are 'buy and use' type and also very expensive. There is little or no flexibility to adapt them as a research platform to test out some 'own ideas'. This necessitates the need for these institutions to build their own AUVs and to engage qualified researchers for the job. None of the tertiary institutions in Singapore offer a course in underwater technologies in relation to AUVs or acoustics and hence the students have no appreciation or awareness of related technologies and system engineering. Therefore it was felt that organising an event like the SAUVC would generate enough interest in the local tertiary students and making the event international would provide an opportunity to exchange ideas with students from overseas institutions some of whom are already participating in the events like Robosub, SAUC-E and SAVe etc. Thus the SAUVC was born. The following are the key objectives of the SAUVC

- To provide opportunities for students to experience the challenges of system engineering
- To develop an appreciation, understanding and skills in AUV related technologies
- To expose students to AUV technologies and increase awareness and interest in careers related to marine robotics
- To provide learning ground for students with an interest in other international AUV competitions

Apart from the main objectives listed above, the organising committee recommended that the teams may also be given an opportunity to present their designs through a 20min presentation. This presentation was scheduled prior to the qualifying round. A 30min talk by a leading researcher in the field of autonomous platforms was also scheduled to provide the students an update on the current status of relevant underwater autonomous platform technologies and their applications.

A. *Organising committee, Advisory Committee and Volunteers*

The organising committee comprised mostly IEEE OES local chapter members and volunteers from some institutions in Singapore. An advisory committee comprising of faculty members from different tertiary institutions in Singapore was also formed. Most of these members were part of the organising committee that ran land-based robotic competitions held in Singapore and was helpful in formulating teams from their respective institutions. Some of them also served in the advisory role for their respective student teams. This approach was to ensure reasonably good level of participation from local institutions. It was also at the recommendation of advisory committee that the event went international, though the original plan was to have a local competition and to develop local talents in the field of underwater robotics.

IEEE OES local chapter has been closely following the international competitions held elsewhere. They have been in regular contact with other IEEE OES chapters in the region who were running similar competitions. The local chapter also developed contacts with potential teams who were participating in those competitions. This we felt that would give an edge to a successful competition, from a participation level, if organised under IEEE OES Singapore chapter. Moreover IEEE OES, the main society based in US, extended full support for the competition. Similarly, the local chapter has been organising an industrial workshop where some of the local industries in the underwater equipment related business used to participate. This opened up an opportunity to work with them on the AUV competition as well through their sponsorships and support. This relationship has been working very well so far in our last three competitions. Different sub-committees were formed from the members of organising committee to help and execute various organisational tasks. The overall committee was headed by a Chairman with a Co-Chairman in the supporting role. The main sub-committees were the Logistics Committee who were in charge of finding a suitable venue for the event and also make arrangements for its running over the three days. A Sponsorship Committee to bring in money to meet all the expenses associated with the competition was also formed. This was important because the participants are not charged any registration fee (to encourage their participation) and hence the only way to meet all the event expenses such as pool and function room rentals, lunch for all the participants and officials over three days, prize money and organisation of presentation ceremony, registration kit for the participants and all other miscellaneous costs were to be realised through sponsorships and cash support. A student liaison sub-committee was formed to work with the teams and to provide all the technical and administrative helps required. This committee has been working closely with the institutions and teams to ensure maximum participation. The Treasurer looks after all the income and expenditures to make sure our commitments do not over run the budget and the Secretary of the Committee was responsible for making meeting notes and circulating them among the committee members. Finally, we

also have a Webmaster who is responsible for updating and maintaining the website with relevant contents.

It was not possible to run the event with the Organisation Committee members alone. We therefore engaged many volunteers who have been providing their whole-hearted support for the event. Volunteers provided dive support to set up props for the competition and underwater cameras in the pool. The underwater cameras were used to record the tasks the AUVs performed underwater, which was linked to a monitor on the surface for public viewing. The registration of participants in the day of the events was also handled by volunteers. Some of them were also entrusted with the task of monitoring the compliance to the safety regulations by the participants and public.

III. EVENT ORGANISATION

The SAUVC event were organised over three days. The first day was used primarily for setting up the props in the swimming pool and also give some time for the teams to practice. The second day was largely used for presentation by the team leaders on their AUV followed by qualifying rounds in the pool. We also organised a talk on AUV/ROV technologies prior to the team presentation. The third day was used mainly for the final rounds of competition. In the evening of the third day a prize giving ceremony along with a BBQ dinner was also organised.

Though there was no prior announcement made on the awards to be given to the winners, the team that won the first position was awarded S\$5000 while the second and third placed teams bagged S\$3000 and S\$2000 respectively. Consolation prizes ranging from S\$500 to S\$1000 were also given to teams who cleared the qualifying rounds.

A. Venue

Unlike the Robosub and SUAC-E, where the competitions were organised either in an open air diver's training pool or harbour, the SAUVC was organised in a swimming pool due to lack of similar facilities in Singapore. Moreover the seawater conditions in Singapore was not conducive for tracking the progress of AUV mission with video camera due to very poor visibility in the murky waters. Heavy vessel traffic and busy ports forced us to keep the operations away from sea.

Though there are a number of public swimming pools in Singapore, getting one for conducting an event like the SAUVC was not possible as it might inconvenience the public. Hence we tried to look at swimming pools within the academic institutions. As this is an outreach activity for students, our thinking was that working with an educational institution would provide more visibility to the competition among the students. The first and third competitions were held in the olympic size swimming pool at the Singapore Polytechnic and the second event was held at the Nanyang Technological University's swimming complex. Figure 1 shows participants and viewers anxiously waiting for the AUV to surface at the designated zone during the SAUVC 2015 competition.



Fig. 1. Happy and anxious moments at the SAUVC competition

B. Event Publicity

A website www.sauvc.org [3] has been setup to showcase the event details, including photos and videos of past competitions. The website is also linked to a Facebook page which is believed to be a more engaging platform for the students of current generation. The students can post progress and queries on the Facebook page and the same will be attended to by one of the committee members. We have also published the reports on the competition in the IEEE OES newsletter, BEACON and also advertised one of the recent competitions. Publicity was also given through other IEEE OES chapters in the region. The organisation of the competition was also posted on the IEEE Singapore Section website. Apart from these, personal contacts in various institutions were also used to spread the word about the competition.

C. Sponsorship

The competition was held without any registration fee for the participants. Hence all the expenses related to running of the competition had to be met through sponsorship support. The successful organisation of the SAUVC event would not have been possible without sponsorship support from various organisations listed here. The Office of Naval Research (Global) was one of the major supporter of the event. IEEE OES was another major supporter and so was NUS and Centre for Sensing and Monitoring (CENSAM), SMART, Singapore. The organisers, IEEE OES local chapter, also supported the event financially. There was excellent support from Industry. Atlas Elektronik GmbH, Germany; Thales Solutions Asia, Singapore; EvoLogics Pte, Germany, Liquid Robotics were the major supporters of the event from the industry. Local companies like ST Electronics, National Instruments, IXBLUE Singapore, Sea and Land Technologies and Lita Ocean Pte Ltd were the other supporters of the event. The Singapore Polytechnic provided the swimming pool free of cost for our last competition which helped to save some money.

D. Competition Format, Tasks and Rules of Competition

The design of the tasks had to consider the constraints imposed by the swimming pool environment. Moreover the

organising committee felt that too complex a task initially would affect the participation level as it might scare away some of the beginners. Even so, most of the tasks required to be completed by the AUV were still challenging in terms of the design of the vehicle and its sensing and navigational capability requirements. Some of the tasks and rules of competition have been revised as we moved from one event to the next based on the inputs from participating teams as well as some of our sponsors.

In the sections that follow, we look at the details of the three competitions held in the years 2013, 2014 and 2015 respectively.

IV. THE SAUVC 2013

The SAUVC 2013 competition was open to teams consisting of up to five full-time students registered with any university or Polytechnic with a mentor from their department or faculty. In order to monitor the progress, the local teams were required to give a presentation to the organising committee. The overseas teams were required to upload their presentation on to a web-site setup for the same and the committee provided feedback to the teams which helped them to fine tune their designs.

To generate interest in local teams, financial support up to S\$3000 was made available through a local sponsor. This money was disbursed in two instalments against the progress made by the teams which was assessed based on their presentation to the organising committee. As it was felt that this would not be a sustainable model, the support was not provided for future competitions.

For the SAUVC 2013 competition the AUV was required to start from a designated starting point, pass through a gate without touching any part of it and then drop a ball by bumping against a flare carrying a golf ball before finally surfacing at a location marked on the surface of the pool as shown in Figure 2. To aid the navigation by AUV, a black line connecting the different task points was provided, except for the last link from the flare to the surfacing zone. Being a swimming pool based competition and also to be fair with teams from different backgrounds, certain constraints on the AUV specifications were imposed for this competition. These are listed below.

- 1) The vehicle should be autonomous and no communication with the vehicle is permitted during the mission
- 2) The dimension of the vehicle shall not exceed $0.5m \times 0.5m \times 0.7m$ in the fully extended state
- 3) The vehicle should have self contained power source and it should not exceed 24VDC
- 4) Internal combustion engines and compressors are not allowed
- 5) The cost of the commercial parts, including software, for the vehicle should not exceed S\$10K

The purpose of these constraints was to build an AUV that would do just the tasks defined for it and to prevent any over design. Especially the last constraint on the cost of the commercial parts used in the vehicle was intended to encourage

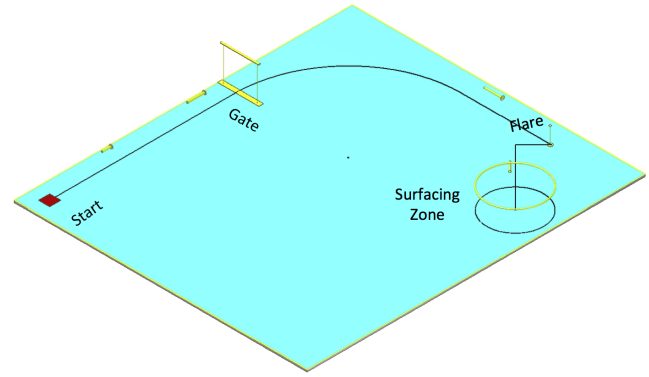


Fig. 2. Graphic showing the tasks for the AUV for the SAUVC 2013 competition

students to come out with their own designs rather than buy and use COTS solutions.

16 teams registered for the SAUVC 2013 event initially and of which 10 teams had presented their designs during the check point. However, only 7 teams turned up for the event and five of them were local teams. The two overseas teams were from Russia and India. Only the Russian team from Far Eastern Federal University (FEFU) was able to complete all the tasks and bagged the first prize. The team with their AUV is shown in Figure 3. The team from National University of Singapore was a close second. Though they managed to complete most of the tasks, the last task of surfacing within the specified zone could not be achieved. Most of the other teams were only able to clear the qualifying rounds, which included a straight 10m run, and some team's AUVs managed to pass through the gate, the first task of the competition. Mr Jerry Carrol from IEEE OES was the Chief Guest for the function. He interacted with the participants (Figure 4) and gave away the prizes to the winners during the barbeque dinner.

Feedback from the participating teams was collected to know how did they rate the organisation of the overall event and also on what areas we need to improve.

V. THE SAUVC 2014

As the organisation of the SAUVC 2013 was largely successful and the participants gave very encouraging feedbacks, the organising committee decided to go ahead with the SAUVC 2014 competition. In the SAUVC 2013 competition most of the navigational tasks by the AUV could be achieved by the use of optical sensors (cameras) and dead-reckoning from a knowledge of the geometry of the task field set up. An acoustic component was however added to the SAUVC 2014 competition based on the feedback from some of the sponsors of the event, who were primaso that they can justify their support to the event. Two pingers of different frequencies were added to the grid used to mark the surfacing zone so



Fig. 3. The team FEFU from Russia, who won the SAUVC 2013 competition, with their AUV



Fig. 4. The chief guest of the SAUVC 2013 event Mr Jerry Carroll interacting with one of the teams

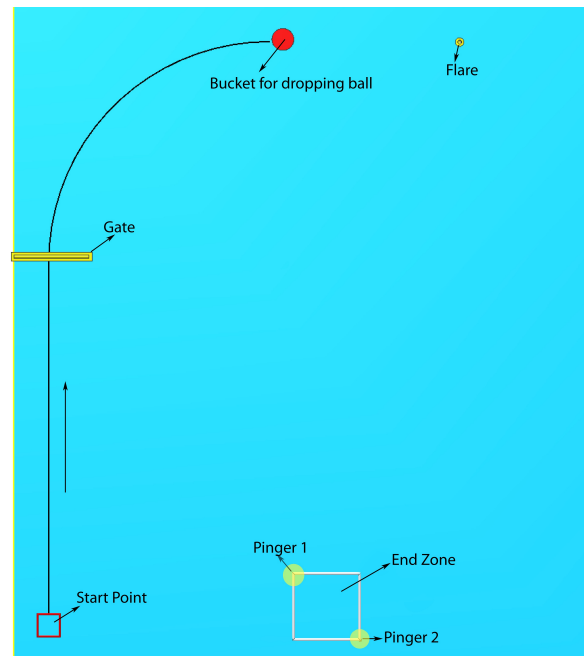


Fig. 5. The graphics showing the tasks for the SAUVC 2014 and 2015

that the teams can make use of the beamforming algorithms in locating the pingers and thus navigate to the surfacing zone. Visual markers were reduced and eliminated so that the task was hard to achieve without acoustics. As the SAUVC was also intended as a feeder competition for international AUV challenges like Robosub where the use of acoustic sensors is essential, it made sense to include such a component into the game field. An additional task was also added to the game field, which required the AUV to drop a golf ball into a basin placed on the floor of the pool and located between the gate and the flare. There was no line to follow after dropping the ball into the basin. So navigation to the flare could be by dead reckoning and to the surfacing zone by acoustic localisation. As the surfacing zone was shifted between the competition, it was difficult to use a dead reckoning to reach the zone. The task setup for the SAUVC 2014 is shown in Figure 5.

Another notable change in the event organisation was that the teams were required to pay a refundable registration fee of S\$500. In our 2013 competition some of the teams who had registered did not turn up and the committee was not informed early enough. This has led to extra expenditure and wastage of food and other materials. It was felt that a returnable registration fee would make the teams more responsible. There were 16 teams registered initially for the competition and 10 of them paid the refundable registration fee. However, on the final day only four teams turned up. Some of the teams had informed us early enough that they are unable to come due to lack of funding support for their travel and they were given back their registration fee. However, two overseas teams failed to inform us in advance and they had to forfeit their registration fee. Out of the four teams who came for the competition, two were from overseas (though different from those participated



Fig. 9. The SAUVC 2015 champions, team Bumblebee from National University of Singapore. A team from NUS also won the SAUVC 2014 competition

level, achievements, sponsorship support and also the student feedback to make an assessment on its success.

A. Participation Level

One of the main objectives of the competition was to engage as many student teams as possible in the SAUVC, specifically from local tertiary institutions. Seven student teams participated in the SAUVC 2013 competition, of which, five teams were local and two teams were from overseas (one from Russia and the other from India). Of the five local teams, four teams were from the universities and one from polytechnic. The increased local participation level was possibly due to the limited financial support provided to the local teams and also being the first time such a competition is being held in Singapore, students were curious to explore.

In the SAUVC 2014 there were only four teams, two local teams and two overseas teams. This low participation level, though gave some worries for the organisers on the future of this competition, was not due to the lack of interest from the teams as 10 teams had paid the refundable registration fee. The main reason was the lack of funds for them to travel to Singapore and also to meet the expenses during the competition. This time the two overseas teams different from the year before which demonstrated the reach of the competition at an international level.

In the SAUVC 2015 event the participation level went up to 9 teams and of these 7 teams were overseas and represented by 5 countries, viz., India, Malaysia, Russia, China and USA. This again demonstrated the international reach of the competition. However the competition has been not able to spur more interest in the local teams. This is something the organisers would look more closely into and resolve for future competitions

B. Achievements

One of the major achievements have been the formation of a local AUV team from National University of Singapore which went on to participate in the Robosub competition. The experience they gained through local competition has helped

to secure 7th position in the Robosub competition in 2013 among 30 odd international teams and also win the best entry award. The team went on to claim the 5th position in 2014 Robosub competition and has been a regular participant of the SAUVC competition. Another achievement was that a couple of young engineers from NUS, who have participated in the 2013 SAUVC competition is pursuing a carrier in a local start-up company which manufactures underwater modems and autonomous surface vehicles.

The competition helped to get more members into the IEEE OES local chapter which runs the competition. We also know that at least three other teams who contested in the SAUVC 2015 competition have signed up for the Robosub 2015 competition. They all wanted to use the opportunity as a learning ground before they field their AUVs for the Robosub competition. So, in some way the SAUVC serves as a feeder competition for international AUV challenges like Robosub.

We have received positive feedback from all the participants so far and their desire to continue to participate. This is indeed a source of encouragement. There is also a request to run a AUV workshop for the teams, which we plan to take up from the next competition onwards. This is expected to provide some training ground specifically in the underwater acoustics to the team members.

C. Sponsorship Support

The successful organisation of any event involves money to meet various expenses associated with the running of the event. The only way to generate this finance for the SAUVC was through sponsorships as for our events we have not been charging the students any registration fee. Though it was hardwork to generate the required finances, it is a matter of satisfaction that many sponsors came forward to support the event and make it a success. During the first two events some sponsors were keen to do an exhibition display their underwater robots and related products at the event venue so that the students can see the level of technologies available in underwater robotics.

D. Feedback from Teams

Feedback from the teams on the organisational matters is the best way to gauge how successful was the SAUVC competition. A set of questions were given to the members of the teams asking for their valuable feedback on various aspects of the competition such as the timing, duration, level of tasks, event venue, rules and regulations etc. They were also asked what they liked and did not like about the competition and provide inputs towards improving the event performance. The organisers are happy that the feedback received so far was very positive and encouraging. Table I shows a summary of some of the questions asked and the responses received from team members.

VIII. CHALLENGES FACED AND RESOLUTIONS

There were three major challenges that the organisers faced during the SAUVC events. The first one was having as many

TABLE I
FEEDBACK FROM TEAM MEMBERS

Questions	Responses
How did you find the organisation of the event	43% - Excellent 57% - Good
How did you find the difficulty of AUV tasks	85% - Just right 15% - Too difficult
How did you find the pace of the event	85% - Just right 15% - Too slow
Did you find the event provided a good learning experience for you	57% - Excellent 43% - Good
Was it clear and easy for you to understand the rules and regulations	15% - Very clear 85% - Clear, but needed some clarifications
Was the timing convenient for you	85% - Very convenient 15% - Clash with exams Mixed responses
What did you like about the event	- Interactions with other teams - Excellent arrangements - Friendly organizers Mixed responses
What we could have done better	- Indoor swimming pool as competition venue - Rules were little confusing - Late confirmation on acceptance of team - Increase the complexity of the game
Would you participate or encourage others to participate if the event is held again	100% - Yes

teams as possible locally. It is evident from the previous paragraphs that though the participation level on an average was satisfactory, the local participation level in the last two competitions was far too low compared to the first competition. Though we encouraged the institutions to give credits to the students who are taking part in the SAUVC Competition based on their work involved or even accept some of the components of the AUV design as part of their final year project, still it did not help to improve the participation. We have also tried to work with students in some local universities directly, but that also did not produce any desirable result. However, we feel that there is an interest locally and internationally to participate in the SAUVC competition.

The second challenge faced was in finding a suitable venue for the event. Singapore has many public swimming pools, but none of them could be sourced for the competition as its primary purpose is to serve the needs of the public and closing the pool for 3 days for the competition may not be in the best interest of them. We then turned our attention to educational institutions. This also made sense in a way that we could showcase it as a student outreach programme. Even so it was not easy to get the swimming pool as this

was the first time ever a swimming is being used for such an activity in Singapore and hence there were some reservations as they feared it would damage the pool and also may lead to contamination by chemicals. After long hard negotiations we were able to convince the pool authorities and they opened up the pool. The first and third competitions were held in the swimming pool of Singapore Polytechnic while the second event was held in the Nanyang Technology University swimming complex. Though we had to pay for renting the pool in the first two instances, during the last competition we made the Singapore Polytechnic as a co-sponsor of the event and they waived the fee. We may try and continue to operate along this line for future competitions as well.

IX. CONCLUSION AND FUTURE PLANS

The Singapore Autonomous Underwater Vehicle Challenge has completed three successful events so far. It has provided an avenue for many international student teams to showcase their underwater robotic skills as part of an informal learning. The tasks designed for the competition have been challenging from all aspects of AUV design. The participation levels were satisfactory and the feedbacks received were very good. The event has contributed in the development of a local AUV team which continues to participate and win accolades in other international competitions. It is our assessment that the SAUVC competition has been a great learning ground for tertiary students, both local and international, in understanding the challenges of AUV design and algorithms for navigation and tracking. As there is no equivalent of Robosub and SAUC-E in the Asia region we believe that this competition would continue to attract international student teams from the Asia Pacific region. The future competitions would continue to engage more students and also conduct workshops for the students in underwater acoustics. We plan to include senior researchers from different organisations to share their underwater robot experience with the students and also teach them relevant skills. We are also considering to organise this event with more participation and support from other IEEE OES chapters in the region.

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