Creating a remote access-ready infrastructure for the future

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I. Extended Abstract

Due to its inherent characteristics, marine robotics trials require more complex logistics when compared to other robotics fields. Often, high potential research groups are impeded to put into practice their research due to the cost and logistics of deploying marine robots. In recent times, offering access to other research teams has been a focus of several projects. LABUST participates in one of these (EUMarineRobots) [1] and offers its robots and infrastructure to other partners. The Marine Robotics Research Infrastructure Network (EUMarineRobots) projecthas the main goal of opening up key national and regional marine robotics research infrastructures (RIs) to all researchers in order to optimise their use. The project successfully attracted the best researchers around the world through a series of Transnational Access (TNA) actions.

With the COVID-19 pandemic, TNA trials within the EUMarineRobots project initially planned to take place physically have been transformed to remote access trials. Leveraging from previous work in virtual reality and from recently completed installations, LABUST could easily encompass these trials. A summary of these recent remote trials is included as an example of remote infrastructure access in marine robotics.

In the case of LABUST, the construction of a new laboratory (including a new pool) was completed during the COVID-19 pandemic. This infrastructure was made ready to encompass remote trials given this emergent need and leveraging on previous virtual reality experience. Moreover, LABUST has prepared its infrastructure to allow any partner in the world to easily collaborate and test algorithms and devices without the need for physical presence. This is important in the context of marine robotics education as well. LABUST participates in the Intelligent Marine systems - a Pathway towards sustAinable eduCation, knowledge and empowermenT (IMPACT) project [2], a project with a significant educational component.

A. Infrastructure sharing

Sharing infrastructures and providing access/funding to third-parties has become more popular over the past few years. This has been done across different areas and through different instruments. For instance, in Europe, several EU-funded projects dealt with sharing infrastructures/robots through either equipment loans, competitive access through competitions or open calls and grants for joint experiments through open calls and cascade funding. The full paper will include a thorough state of the art analysis.

As mentioned, multiple ways of providing access to infrastructure or support to third parties can be found in the literature. While the example of trials described in Section I-E is related to the framework of the EUMarineRobots project, the LABUST infrastructure can potentially be used through any of the models above mentioned. The infrastructure can also be explored in the context of e-learning in marine robotics educational projects such as IMPACT and others.

B. LABUST infrastructure

Having overgrown its existing laboratory facilities and planning to extend physical experiment possibilities, LABUST decided to invest in new laboratory infrastructure at its home institution, Faculty of Electrical Engineering and Computing, University of Zagreb. As it happens, 2020 was a year that made arise a whole new set of challenges for marine researchers, rending physical collaboration, joint experiments, equipment sharing and field trials close to impossible. A considerable part of initial concerns in building a new laboratory went exactly into addressing these issues. The question is how to create infrastructure ready to tackle pandemic and post-pandemic consequences that are still to come and newly established global social norms while enabling researchers, scientists, students, and professionals to maintain or even extend opportunities for scientific progress.

C. Physical infrastructure

The laboratory is positioned on an area of $200\,m^2$, with $80\,m^2$ allotted for the workshop and offices and $120\,m^2$ for the pool area. The pool itself has an area of $32\,m^2$ and depth of $3\,m$ with a dedicated crane for vehicle deployment. For monitoring underwater and surface activities, the pool is equipped with four underwater cameras and three ceiling cameras covering the complete pool. The cameras are supplied by SwimPro [3] which provide infrastructure for detailed swim analysis in sports. Currently, tracking algorithms, using the seven camera streams, are being implemented for autonomous

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Fig. 1. LABUST pool facilities in Zagreb, Croatia

tracking of multiple surface and underwater vehicles. The pool area is also equipped with the Pozyx Ultra-Wideband (UWB) real-time localisation system. This system provides alternative tracking for surface vehicles, and opens the door for heterogeneous applications and experiments with hover capable micro Unmanned Aerial Vehicles (UAVs).

The pool size of $7.8\,m \times 4.1\,m$ enables testing of small surface platforms such as the H2OmniX [4], while the $3\,m$ of depth allows testing with similarly sized AUVs or ROVs. The pool bottom and sides are currently greyed out. However, for future applications, these will be covered with natural underwater photography to facilitate students' research in underwater SLAM and visual localisation applications.

D. Network infrastructure and remote access

Mission control and vehicle communication use the ROS suite. ROS provides a publisher-subscriber communication model for exchanging messages between devices in the distributed system, which has become a standard in today's robotic systems. Devices can be connected to the local network either by Ethernet cable or using WiFi. The Internet Gateway for the network is configured with a VPN so that devices can connect to the internal network via the Internet, if provided with valid credentials. The cameras described in I-C are provided with a static IP and can publish current video stream to the ROS topics using ROS gscam tool [1]. Thus, the camera streams are provided to remote users providing real-time feedback and improving situational awareness. Depending on the use case, a vehicle Command and Control Centre (CCC) can be instantiated.

The CCC is designed as a Graphical User Interface (GUI) dashboard where mission vehicles can be monitored, supervised and controlled with a predefined mission-specific tasks, which is connected to the ROS infrastructure for exchanging data. The CCC is implemented in Python as a HTTP server and serves as an endpoint for remotely controlling mission execution. Server API is implemented only by using JSON message format for data exchange. Every mission has its own command set and each command executor is implemented as HTTP POST request handler on the server. Each command comes with it's own set of parameters that can also be remotely set using the HTTP POST request. Also, every mission comes with the set of monitoring and supervision parameters that can be obtained remotely by using HTTP GET requests.

[1] http://wiki.ros.org/gscam

E. Remote access trials

The first remote trials using the setup described in the previous section took place in late March and the beginning of April 2021. These trials were performed in the framework of a EUMarineRobots TNA action. The end-user of the remote access trials was Auckland Bioengineering Institute (ABI) from the University of Auckland, New Zealand. The goal of these trials was to test novel diver-robot underwater interaction modalities introducing smart wearable sensors. The University of Auckland developed a smart diving glove with incorporated strain sensors capable of detecting hand gestures The gesture is processed directly on the glove and sent over an acoustic link to the underwater vehicle. Once the gesture is successfully received, an acknowledgment is sent back to the glove and communicated in the form of haptic vibration and LED flashes, which can also be used to ask the diver simple safety questions making the communication go both ways.

Performing remote trials with a partner in New Zealand restricted the trials time to early morning and late evening times due to timezone difference of 12 hours and availability booking the local pool in Auckland. Nonetheless, after each team tested their own experiment parts separately, setup and basic test were conducted to close the communication loop over the internet. Feedback from cameras as described in I-C was provided to the partners in New Zealand for situational awareness. A few days later, the tests were completed successfully using a real diver in the pool in Auckland, and the D2 underwater vehicle in the LABUST pool in Zagreb.

More details on the trials will be included in the final paper. However, a video of the trials prepared by our partners from the University of Auckland, New Zealand, is available on https://www.youtube.com/watch?v=RmhOUCYnMyg

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