OpenROV –

A low cost ROV (not only) for hydrography students

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Nowadays, underwater vehicles are more and more popular. Especially for investigations in shallow or not safely accessible areas for shipping they offer a good alternative. But often, the high acquisition costs are a great hurdle for companies and scientific institutions. The HafenCity University Hamburg purchases a small ROV out of a student initiative. The following article introduces the OpenROV concept and technical features, the gained previous experiences, and also dips into possible future projects.

HCU Hamburg | OpenROV | ROV | hydrography education | experiences

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Acknowledgments
Thanks to Markéta Pokorná (Ph.D.) for supporting us in the matter of ordering our OpenROV, and also to Tanja Dufek (M.Sc.) for helping and supporting us in different situations as well as for showing that kind of motivation for this project.

Introduction

Unmanned vehicles of all sorts are becoming more and more significant in underwater applications. High resolution hydrographic surveys in deep sea or oceanographic measurements and water sampling can be efficiently conducted with autonomous underwater vehicles (AUV) with very little to no human input during the mission. Remotely operated vehicles (ROV), while being less time efficient, have the upside of an instant feedback of various sensor data during operations. This gives the possibility of reacting on specific conditions in the area of interest and adjusting missions to fit certain needs and improve results.

This makes ROVs a great choice for a wide range of applications in situations where it is not possible for human divers to work (high depths, harmful environments, etc.) or where financial limitations or runtime requirements are critical.

Large work class underwater robots can be used for construction purposes, for example in drilling operations, with equipment like manipulator arms or specialised machinery. ROVs can be equipped with sampling devices for scientific research or conduct small scale micro bathymetric surveys with echo sounders, LIDAR or photogrammetric cameras. And ROVs can simply be used with an onboard camera for visual video observations. These so called eyeball class ROVs are very widely used in archeology (ship wreck exploration), biology (visual habitat investigation) or for inspection of submerged constructions or objects of any kind.

What all of these vehicles have in common, is that they are very costly and that even small commercial underwater robots are usually beyond the budget of enthusiasts and hobbyists which limits the use of these devices to commercial or scientific purposes with little to no chance for private use.

To overcome this barrier, hobby explorers have to rely on do-it-yourself solutions which usually require a lot of work. Luckily, a project called OpenROV came to live in the last couple of years with the goal to ease the process of getting into underwater exploration both in terms of financial costs and timely efforts.

This article shall give an overview over the OpenROV project and the experiences the students of hydrography at HafenCity University Hamburg gained with their robot.

The OpenROV project

The co-founders of OpenROV, Eric Stackpole and David Lang, started working on an underwater robot to do an exploration in Hall City Cave in the Trinity Alps with the goal of finding a hidden gold treasure. The idea evolved into a prototype and became a crowdfunding campaign on Kickstarter in 2012. The campaign got funded within a few days and was a huge success. Eric and Dave created a startup company for further developing the OpenROV and distributing do-it-yourself kits to worldwide customers.

Over the last years a very thriving and enthusiastic community formed around the project consisting of people with various backgrounds like electrical engineering, robotics, programming, archeology, biology, hydrography, and many more. Due to the open source and open hardware design of the robot, the development of the OpenROV was influenced by all these different professions which made it into a versatile and widely usable device.

Specifications

The robot itself is a small shoe box sized battery powered device. It is tethered with a 100 m two wire tether with a topside adapter that lets the user plug it into the Ethernet port of any kind of computer. The OpenROV is controlled over an interface running on the robot itself which is accessible over an internet browser, with no need for additional software. On the hardware side the ROV features a tiltable HD camera, strong LED light, two 10 cm parallel scaling lasers and a 9-DOF inertial measurement unit (IMU) with a depth and temperature sensor. Three thrusters let the ROV move in all directions in (underwater) space. All electronic components are packed tightly into an acrylic pressure housing with a depth rating of about 100 m. The browser interface features a live stream of the camera plus a numerical stream of all the sensor data like compass data, depth, motion, temperature, and remaining battery power (Fig. 1). All systems can be controlled with the computers keyboard or a connected gamepad or joystick.

In the ROV the main software runs on a BeagleBone, and the hardware (sensors and thrusters) is controlled by an Arduino. Except for the custom made Arduino board and the IMU, all parts are available off the shelf. Therefore, people can easily build their own version aside from the original kit with similar hardware running on the OpenROV software. This makes the OpenROV a very hackable solution with expandability for a lot of sensors. Up to now the community showed add-ons like magnetically controlled gripper arms or acoustic modems for wireless communication. The OpenROV features the widely used I²C interface.

Recently, the company introduced a new robot, the OpenROV Trident, which is less hackable and expandable, but is basically a plug and play device, usable by everybody out of the box.

OpenROV at the HCU

At the HafenCity University Hamburg an OpenROV (#1058) was ordered in 2014 out of a student initiative. The main motivation for getting an ROV was to get students of hydrography in contact with basic ROV technologies and to have an expandable platform for student-driven projects and Master theses. With budget being a limiting factor, the OpenROV was a good chance to do that. Additionally, due to its open design, the ROV offers a great hands on hardware experience with low level electronic components as well as the interfacing of various devices and sensors within the software of the OpenROV. This also ties in to subjects within the hydrography study curriculum.

The robot comes as an unassembled kit and the building process includes preparation of the pressure housing and the main structure of the ROV as well as soldering and assembling the electronic parts (Fig. 2). During the process we learned a lot about the in's and out's of underwater technology and the mixed blessing of submerging sensitive electronics in watertight containers. A lot of troubleshooting had to be done and problem solving was one of the main tasks. Even though further improvements are possible we were successful and beside the things we learned which are useful for our professional future, building an ROV was a great teamwork experience and a lot of fun for all involved.

Past OpenROV experiences

Until now, the ROV was used only for a few small trials so that all participants of the building process became familiar with the steering and the browser interface. The chosen areas of operation were providing various conditions which was highly advantageous to gain an overview of the opportunities and limitations of the ROV.

The first impressions of the behaviour in the water were gathered in the river Elbe. Thanks to the Waterways and Shipping Administration (WSA) in Wedel, it was possible to do this in their small harbour basin which offers a shallow seceding and stone-fixed shoreline. Furthermore, the fact that the ROV cannot get in contact to the direct shipping traffic gave a reassuring feeling for testing. One of the main tasks during this first trial besides the steering experience was the equilibration of the ROV for getting neutral buoyancy. Actually, this was done by affixing stainless nuts and shims to the lower lateral struts. This offers a quick and easy possibility of modification depending on the properties of the site of operation. As a result of this trial it can be concluded that the river Elbe with its tidal currents and thereby the caused floating particles did not provide optimal conditions: The turbidity of the water leads to a severely restricted visibility (Fig. 3).

For a second deployment of the ROV, the Benthocosms of the Geomar Helmholtz Centre for Ocean research in Kiel were inspected. Contrary

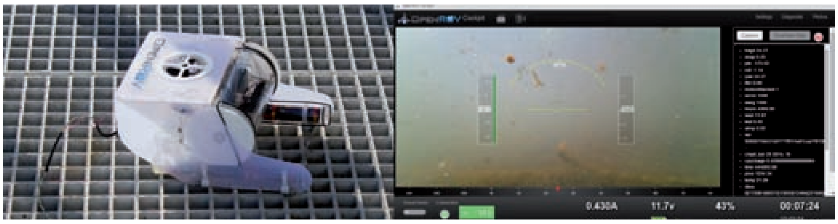

Fig. 1: OpenROV and its cockpit: Right panel with sensor information, bottom panel with technical information and compass, main display with camera output and depth

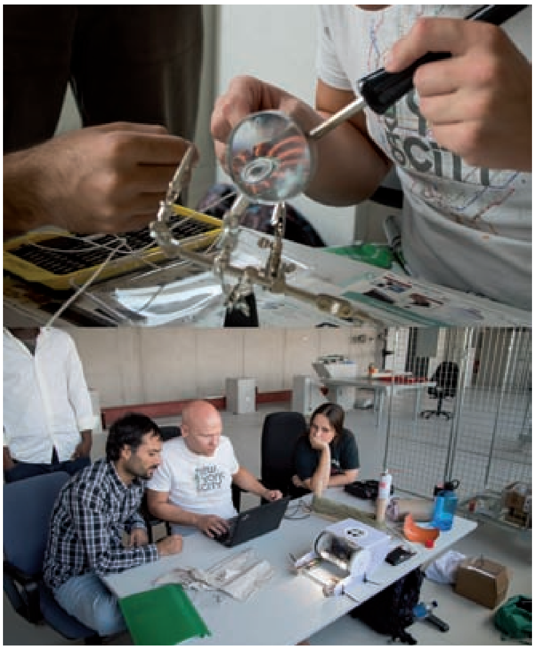

Fig. 2: Assembly-process of the OpenROV in the HCU Hamburg

Fig. 3: Impression of the first sea trial in the river Elbe, Wedel

Fig. 4: Impression of the marine life at the Geomar Benthocosm platform, Kiel

to the river Elbe, the Firth of Kiel offers clear water without strong turbidity so that it was possible to capture nice images of the local marine life (Fig. 4). Close to the Benthocosm platforms the currents were not as strong as apart, but nevertheless, the steering of the ROV proved to be challenging – not only because of the limitation of space. To evaluate the already assumed effect of strong currents to the engine performance, the ROV was steered in more open water. After a short steering period it could be seen that the strong currents almost completely prevent a precise controlling. Even through increased engine performance it was not possible to manoeuvre against the flow direction without being swept away.

Due to the fact that the first trials were only conducted by the assembly participants, the OceanLab of the Jacobs University Bremen has generously offered their indoor basin to introduce the ROV to younger hydrography students who should be able to use it for future research projects. This fresh water basin provides optimal testing conditions to ensure a smooth demonstration without the disturbance of currents or turbidity (Fig. 5).

Since July, the HCU also owns a small testing basin built by the Mechanical Engineering department of the Helmut Schmidt University Hamburg. With this basin it is possible to check performed adjustments without the need of a suitable operation area outside of the university. Especially for future projects and related further development this may accelerate the proceeding and lead to increased flexibility. Furthermore, it allows to present the ROV and its features to a larger audience during open house days like the »Night of Knowledge« or to introduce the department of Hydrography to potential students.

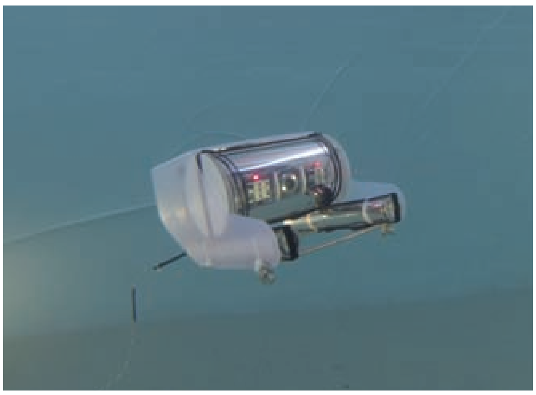

Fig. 5: ROV diving in the fresh water basin of the Jacobs University Bremen

Future projects and perspectives

Actually, the ROV is involved in a Master thesis concerning an image-based technique for three-dimensional modelling. Therefore, additionally to the already installed wide angle camera, a second camera with a higher resolution is planned to be placed outside of the tubing housing. First auspicious tests outside of the water were already performed and will hopefully soon be followed by several field trials in areas with an interesting marine life such as the Kreidesee Hemmoor.

Only using the actual installed systems, the ROV provides a great platform for various underwater investigations and explorations. Besides the possibility of visual inspections of wrecks or other obstacles it would also be conceivable to use it for the inspection of hull-mounted sensors or other submerged vessel equipment. This application provides a cost- and time-effective alternative which can be realised with low effort to get first impressions of possible damages. But also the inspection of harbour constructions such as quay walls, bridge piers or dolphins can be the basis for further ROV projects carried out by the hydrography students. As already done in Kiel, the observation of marine biology also offers a wide field of possibilities.

The OpenROV provides a lot of potential for further expandabilities and technical upgrades. The attachment of a single beam echo sounder together with an altimeter for example would offer additional interesting topics and projects. What can also be very promising, especially for the investigation of underwater environments as in the river Elbe, is the mounting of an acoustic camera system to gather images independent of prevailing light- and turbidity-conditions.

Conclusion

With the OpenROV, a low-cost underwater vehicle was offered to a broadly based range of users. The building-kit structure of the ROV enables an application-specific configuration. The growing number of the user community allows an exchange of information and experiences – especially by using appropriate fora such as the OpenExplorer or the OpenROV Blog. Even though strong currents and turbidity can restrict the usage, it is a worthwhile purchase. It is particularly suitable for universities because the assembly process as well as operation and maintenance can be integrated within the teaching activities.

To get an overview of all introduced ROV campaigns, the background and insights, the HCU runs an OpenExplorer profile (https://openexplorer.com/profile/openrov1058). After each expedition, a digital field journal was created and so all projects can be reviewed by everyone who is interested. For an insight into the behaviour of the ROV in the water, also a YouTube-channel (OpenROV #1058) is available. In small video sequences the viewer can receive an impression of different trials. ⚓