RAO-II: AN AUV FOR UNDERWATER INSPECTION

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Abstract
AIRSUB is a research project funded by the Spanish Ministry of Science and Technology whose aim is to explore the industrial applications of underwater robots. The Systems, Robotics and Vision Group (SRV) from the University of the Balearic Islands (UIB) is responsible for the sub-project of cable/pipeline inspection [1]. To this purpose, an Autonomous Underwater Vehicle (AUV) is under development as a platform to test the vision algorithms, control strategies and software architectures devised in the last years. This paper describes the main characteristics of the new platform, which is based on a commercial Remotely Operated Vehicle (ROV). The original vehicle has been deeply modified in structure as well as in its electric, electronic and sensorial facets to obtain fully autonomous operation.

1. Introduction
Since 1997, the SRV group of the UIB has been working on developing systems for the automatic inspection of underwater installations. As a result of this line of research, the group has developed image processing algorithms [2] and control architectures [3] for the detection and tracking of underwater power cables, as well as of other elongated structures, such as oil, gas or waste water pipes. As an answer to the need of a suitable experimental platform to test vision algorithms and control architectures in scenarios such as test pools and open sea, the development of a new vehicle, which was projected 2-3 years ago, is almost completed.

The starting point for the vehicle structure has been a low-cost commercial ROV from JWFisher intended to work at a depth of up to 150 m. Changes have been introduced at several levels: the sensorial capabilities, the onboard processing units, the lighting system and the power source, as well as in the vehicle structure. At present, the vehicle is under test in a pool and the efforts are centred on tuning the parameters of its hydrodynamic model. Further tasks should face the adjustment of all the parameters of the cable tracking algorithm and control architecture to obtain a fully functional vehicle.

2. Navigation sensors
Navigation sensors are responsible for gathering the information from the environment required for a proper and safe navigation. New sensors for that purpose in the RAO-II include: a panoramic sonar, a Doppler velocity logger (DVL), a depth sensor and a CCD camera.
The panoramic sonar has been placed at the upper place on bow. The sonar, a Miniking from Tritech, can scan 360º with a 40º vertical 3º width acoustic beam. This sensor is mainly devoted to the forward detection of obstacles up to 100 m (see fig 1).

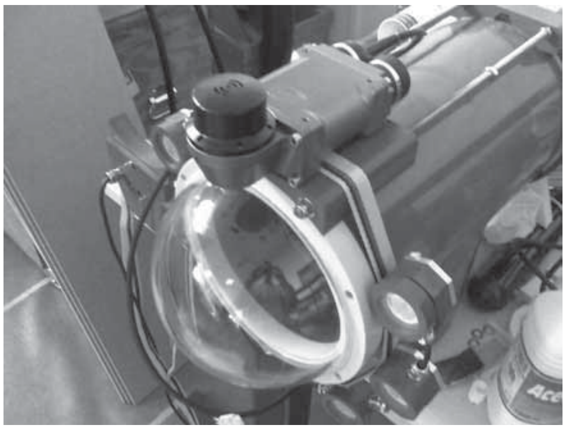

Figure 1. Panoramic sonar and lighting system.

Based on the frequency shift of the echoes of four bottom-looking acoustic beams, the DVL measures the displacement of the vehicle with high precission. Thus, integrating this information, the DVL provides motion data on the XY plane. Z information is measured by a pressure sensor. Additionally, the DVL is used to obtain the height of the vehicle. Our AUV carries the Explorer DVL from Teledyne RDI, the precission of which is ±1 cm/s. As can be observed from figure 2, the Explorer DVL comes in two separated modules, one containing the sensing unit and the other one for the associated electronics. This singular solution makes easier the adaptation of the sensor to the vehicle structure. Despite of the high quality of this sensor and because of its intrinsic drift error, it is under study the use of an Inertial Measurement Unit (IMU), which integrates 6D pose information thanks to the use of gyroscopes, accelerometers and absolute heading sensors.

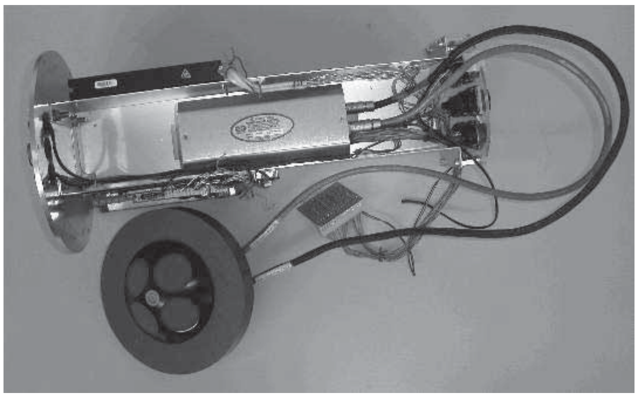

Figure 2. DVL sensing head and electronic unit.

The former CCD camera of the vehicle has been substituted by a Firewire unit to improve the quality of the images and to speed up the interface with the processing unit onboard.
Self diagnostic sensors, which supervise the structural safety of the vehicle, have been deployed in critical parts of RAO-II. Leak sensors are distributed in all the watertight hulls of the vehicle, including the battery enclosure, and temperature sensors are placed close to the processing unit.

3. Processing unit
The central processing unit of the vehicle is based on a P-IV (@ 800MHz) board. An I/O card with several digital and analog ports is needed to connect the CPU with some of the sensors and to the thrusters' servocontrollers. Finally, a Wi-Fi port allows the communication of the main station with the vehicle when on surface.

4. Lighting and structural modifications
Figure 3 shows a schematic representation of the new structure of the RAO-II. Yellow parts correspond to the original structure, while the grey part is the extension added to room the sonar, the DVL and the light sources.

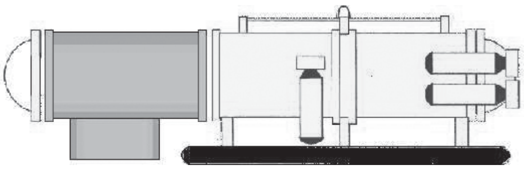

Figure 3. Modified structure of the RAO-II vehicle.

The new lighting system, which can be partially seen in figure 1, is composed by six spotlights based on LED technology. Thanks to this change, the power consumption has been dramatically reduced from 400W of the original halogen lamps system to 18W without loss of lighting quality.
Another important change concerns the internal structure containing the processing unit and all the additional electronic components (see figure 4). This new structure has been built in aluminium to ensure proper heat dissipation thanks to the direct contact of one of its faces with water. Furthermore, all the heating parts of the system are in direct contact with this structure.

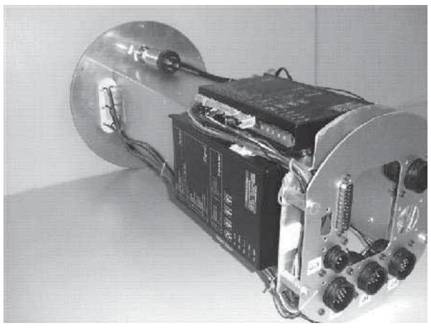

Figure 4. Aluminium based electronics enclosure

5. Power system
The power system is based on lead battery cells. The whole pack provides 48V and has a capacity of 8A/h, providing an estimate autonomy of almost 1h in normal operation. All the additional voltages needed in the vehicle are obtained from DC/DC modules.

6. Future work
Future work includes extensive testing in pool and open waters to adjust system and algorithm parameters and to evaluate the need for more navigation and mission sensors like a GPS and the abovementioned IMU.

7. References

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REACTIVE NAVIGATION IN TROUBLESOME ENVIRONMENTS: T² STRATEGIES

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1. Introduction
Reactive mobile robot navigation based on potential field methods (PFM) [1] has shown to be a good solution for dealing with unknown and dynamic scenarios, such as, for instance, in undersea environments, where timely responses are required. Unfortunately, the complexity of the tasks which can successfully be carried out is limited by the inherent shortcomings of the approach, being the trapping situations due to local minima the most often cited [2]. This work proposes a solution to the local minima problem by introducing the traversability and tenacity (T2) principles. As a result, navigation is achieved in troublesome scenarios such as the typical U-shaped canyon or even in maze-like environments. A set of up to three variants of T2 are also put forward to ensure, whenever possible, the completion of any navigation task.

2. Fundamentals of the T2 Approach
The classic potential field approach [1] is the basic framework for the application of the T2 family of navigation strategies. It computes the motion of the robot on the basis of two simple behaviours: GoTo and AvoidObstacles. More precisely, the former generates an attractive force in direction to the goal, while the latter considers obstacles as repulsive surfaces. The robot follows the negative gradient of the resulting potential field towards its minimum, whose position coincides with the goal point.

The inability to move the robot away from the goal direction in a non-momentary and strategic way is the main cause of the undesirable trapping situations suffered by PFM. Figure 1(a) shows an example where a robot controlled by PFM is unable to escape from a U-shaped obstacle. A solution to this problem is given next by applying the T2 principles in the context of the so-called navigation filter.

The main function of the navigation filter is the appropriate alteration of the direction of the motion vector generated by the GoTo behaviour in order to overcome any obstacle irrespective of its size and shape (figure 1(b)). Such change is carried out according to the traversability and tenacity principles.

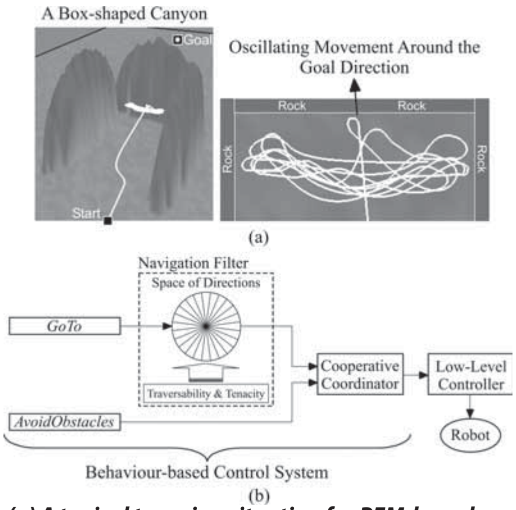

Figure 1. (a) A typical trapping situation for PFM-based control systems. (b) Integration of the navigation filter into the classic potential field approach.

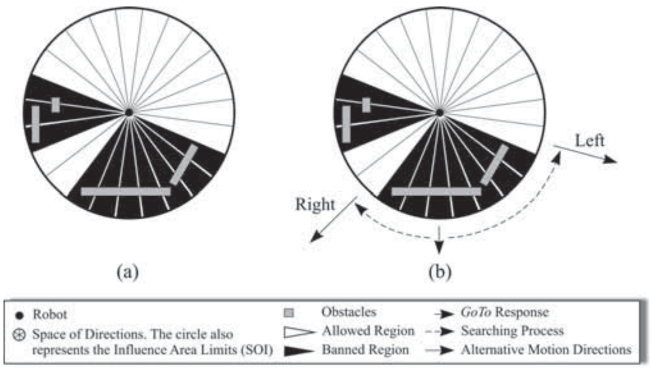

Figure 2. (a) Division of the space of directions into regions, labelling them as allowed or banned. (b) Alternative obstacle-free motion directions.