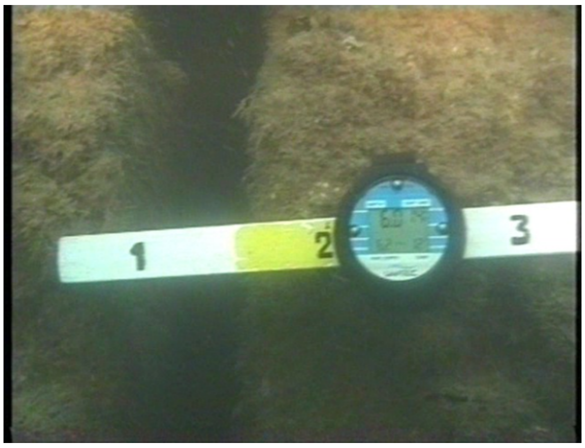

Figure 2. Crack in the wall of a wharf.

3. Conclusions

The use of a teleopereded vehicle, equipped with umbilical cable, avoids the problem to have own energy and to have a data line and images of high capacity, but it entails some difficulties of access and manoeuvrability, due to the presence of the umbilical cable.
Parallel dead-reckoning navigation to the wharf to different depths will be made to catch the images of the walls and foundations of the wharf, being processed itself the images to determine if anomalies or faults exist and later if degradation of the wharf takes place, locating each image in the digital cartography of the postulant. The use of diffuse techniques [4] for the analysis of the submarine images of the walls and foundations of the wharves of the port, will allow carrying out a more effective maintenance automatic/half-automatically.

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AIRSUB: Autonomous Robot For Dam Inspection

P. Ridao (1), M. Carreras (2), J. Batlle (3)

Campus de Montilivi Edificio P4 - Girona
972 419871 pere@eia.udg.es

1. Introduction

AIRSUB is a research project funded by the Spanish Ministry of Science and Technology with aim to explore the industrial applications of underwater robots. To achieve this goal AIRSUB, with the help of industrial agents, will study different application scenarios for this technology. Then, the project will focus on three specific domains: (1) dam inspection, (2) cable/pipe inspection and (3) harbour inspection. This is a join project where the University of Girona will focus on dam inspection, the University of the Balearic Islands will work on cable/pipe inspection, and the Politechnical University Of Catalonia will deal with harbour inspection tasks. The aim of this paper is to present the goals corresponding to the subproject of the University of Girona entitled “Autonomous Robot for Dam Inspection”.

2. Dam Inspection

Although there are several companies claiming to provide underwater robots for Dam inspection (Seabotix, VideoRay, FrugoSurvey, InuktunServices,...) often none of them is providing an integral solution to the dam inspection problem. Normally they propose the use of small class ROVs, working as teleoperated cameras for video recording, to replace the professional diver WHO traditionally occupied this place. There exist very few research precedents providing an added value solution. One of the most relevant works is the ROV3 system developed by the researchers of the Institut de recherche HydroQuébec (Canada) [1]. It is a small ROV, localized through a LBL system, which makes use of a multibeam sonar for collision avoidance. The system is able to control the distance to the wall and includes several video cameras as well as a laser system for 2D and 3D measurements.

The COMEX and the Electricité De France companies (France) developed a similar project [2]. In this case, a ROV manufactured by COMEX was localized using a 5 transponders LBL. Again, several video cameras together with 2D (double spot) laser system was used to take measurements. The Soniworks Company is selling a very accurate wired LBL navigation system to localize an ROV with centimetre accuracy. The system is combined with a GPS to geo-reference the imagery gathered with the ROV. Nevertheless, the system is not able to register the images to provide a big image mosaic of the surveyed area. Moreover, in all the previous systems the use of LBL makes the operation tedious due to calibration. During the year 2002, in collaboration with the Research Development and Technological Transfer Centre (CIFATT) IPA-Cluj, our team used the URIS robot [3] working as an ROV to build an image mosaic [4] of a small area of the wall of the Tartina Dam in the surroundings of Cluj (Romania). This work is the precedent of the current project and was our first contact with this application domain. To the best of the author's knowledge, this is the first time that image mosaicking techniques have been applied for dam inspection. This solution gives an important added value since they provide the civil engineers with a global view of the inspection area. Moreover, when conveniently geo-referenced, they allow carrying out temporal studies of particular areas of interest.

3. Inspection tasks
In order to focus on real problems, our team contacted with FECSA-ENDESA Spanish hydroelectric company to identify the tasks of interest. This meeting, together with our previous experience, allowed us to identify 3 mission scenarios that are described in the following sections.

3.1. Inspection of the Concrete of the Dam
Civil engineers of the hydroelectric companies, carry out periodic visual inspections of the state of the concrete. Until now this is commonly achieved through a careful visualization of a video recorded by a professional diver. Our approach to this problem will consist on the use of an AUV which will follow a pre-programmed path in face of the wall while snapping images.

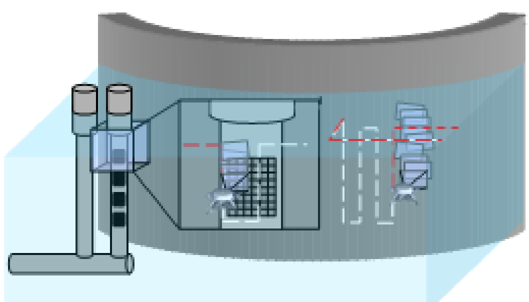

Fig. 1 Sketch of the inspection task of the concrete and the grille of the inlet.

For the localization, two systems will be studied:

1.a dead recknoning system based on the integration of velocities measured with respect the wall using a DVL in ground tracking mode (ground is now the wall).
2.An USBL system connected to a DGPS in order to be able to geo-reference the AUV and hence, the imagery taken by the robot.
After the mission, the set of gathered images will be used to setup an image mosaic of the wall of the dam. We plan to use Galadriel image mosaicking system which has been developed in our lab.

3.2. Inspection of the grille of the inlet
With the time, the grille of the water inlet gets obstructed with the vegetal residuals (Fig.2)

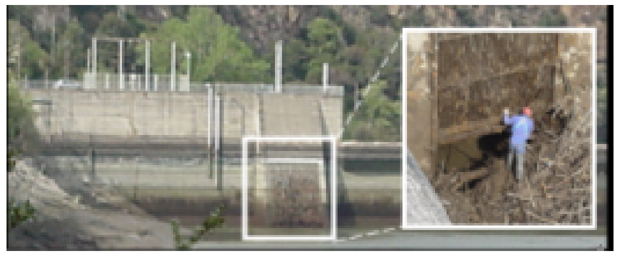

Fig. 2 Vegetal residuals obstructing the water inlet of Pasteral Dam in Girona.

normally transported by the rivers. The result is a loss of power during the generation process. Hence, this grille should be regularly inspected in order to schedule cleaning campaigns commonly carried out by professional divers. From the inspection point of view, this is the same problem faced in the previous section an therefore, we plan to address the task in the terms explained before.

3.3. Inspection of the penstock gallery
With time, small collapse problems can appear in the penstock gallery and it is necessary to assess their risk to ensure the safety of the installation. The penstock gallery is a big pipe (~ 4 m diameter, up to 4 Km long) which connects the water inlet with the power generator (Fig.3)

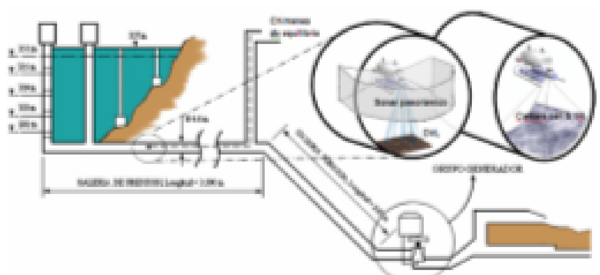

Fig. 3 Sketch of the inspection task of the penstock gallery.

For the inspection of this gallery, we plan to launch an AUV, from the equilibrium chimney, which will navigate through the pipe while taking images of the state of the gallery. The plan is to navigate based on DVL and a gyrocompass measurements, using an Imaging sonar to keep the robot in the centre of the pipe during the operation.

4. Equipment
For this project, we plan to use GARBI^{AUV} equipped with a DVL, a gyrocompass, an USBL for absolute navigation, an acoustic modem for supervision and imaging sonar. Visual inspection will be based on computer vision including image mosaicking techniques.

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Pipe and cable inspection in the AIRSUB project context

G. Oliver, J. Antich, A. Ortiz

Dep. de Matemàtiques i Informàtica, Universitat de les Illes Balears
Cra. Valldemossa km. 7,5 07122-Palma (SPAIN)
(+34) 971.173.201 goliver@uib.es

1. Introduction

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. To achieve this goal, AIRSUB, with the help of industrial agents, will study different application scenarios for this technology. Then, the project will focus on three specific domains: (1) dam inspection (the University of Girona); (2) cable/pipeline inspection (the University of the Balearic Islands), and finally, (3) harbour inspection tasks (the Polytechnic University of Catalonia). The aim of this paper is to present the goals corresponding to the subproject of the University of the Balearic Islands (UIB).

Since 1997, the Systems, Robotics and Vision Group (SRV) at the UIB has focused its attention on the development of image sequence processing systems for the detection and tracking of underwater power cables. At the same time, the design and development of an AUV (Autonomous Underwater Vehicle) has been carried out. The prototype, called RAO [1], has been extensively used by the group to experiment on navigation systems and strategies in structured and controlled environments. The AIRSUB project is the next natural stage for the above-mentioned research line; that is to say, the design of an autonomous video-based cable tracker able to work in a real environment. As a natural extension, the vehicle could also be tested, with minor changes, to track any other object similar in appearance to a cable such as oil, gas or waste water pipes. Moreover, the plans for the cable tracking system include the automatic detection of the more frequent defects and anomalous situations of those equipments, including cable coverage loss and free-span. It is essential for the project to have a vehicle with a structure robust enough to reach and work at depths of almost 100 meters. To this end, the SRV group acquired a unit of the low-cost commercial ROV (Remotely Operated Vehicle) SeaLion prepared to work at 150 m depth.

Fig 1. RAO II hull, based on a SeaLion ROV.

In this project, the vehicle will be mechanically and electronically modified to transform it into a new AUV prototype which will be called RAO II (see fig 1). To succeed, the project requires a big and specialized human team working on many different tasks at very different levels, ranging from research and development to field testing and mechanical engineering. As far as research in robotics is concerned, new algorithms of control architectures, computer vision, navigation strategies, behaviours, and learning, among others, will be studied and developed.

2. Underwater cable inspection at the UIB

Underwater power cables need to be periodically inspected to prevent failure caused by the loss of their external cover. On the one hand, marine stream, waves or even seismic activity can cause important changes in the seabed where a cable lays. As a result, the cable can become hanged between two rocks, giving rise to an anomalous situation known as free-span. Free-span is not desirable since can lead to a cable failure due to both the cover rigidity and a larger likelihood of an anchor hooking the cable. On the other hand, the corrosion affecting the cable due to the loss of the cover caused by the impact of anchors, fishing nets trawling, marine flora growth or shark attacks accelerate the ageing of the cable. Figure 2 shows both free-span and cover loss. Nowadays, the preventive inspection