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EURODOCKER – a universal docking – downloading – recharging system for AUVs

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Abstract

The EURODOCKER project has the objective of developing an unmanned support system for autonomous underwater vehicles (AUVs), to permit docking, data downloading and battery recharging activities to be carried out underwater. This system shall overcome two of the principal current restrictions to the use of AUVs, tied to their limited independence from expensive surface support, and the risks of loss or damage inherent to continuous surface launch and recovery operations.

The solution developed entails a submerged docking station for AUVs, that may be deployed either as part of an unmanned underwater platform on the seabed or lowered from a support ship from the surface. The system developed shall be suited to various AUVs that are now under successful development and aims at becoming a standard subsystem of any AUV support spread.

This project, supported by the EC MAST programme, is a joint RTD venture by five Partners: Maridan AS (DK); The Institute of Automation IAU at the Technical University of Denmark (DK); Studio Tre Ingegneria (IT); Orca Instrumentation (FR); and the Underwater Technology Centre of the Institute of Materials Science at Hannover University (DE) which is also the Co-ordinator. The project started in December 1997, and is due to end in May 2001.

Following an extensive market analysis to determine both the state of the art and specific AUV docking requirements, the solution selection, design and prototype construction activities have been completed. These covered the docking garage concept, launch and recovery, the homing procedure in term of both localisation and guidance, dynamics and control, and connector aligning and latching.

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1 Introduction

The EURODOCKER concept provides a universal autonomous Docking - Downloading - Recharging System for AUVs.

This system overcomes the current restrictions of AUV's, namely operative range due to limited energy storage capacity, and the repeated launch and recovery operations necessary to get the vehicle onboard the support ship. A submerged docking station for AUVs, either as part of an unmanned underwater platform on the seabed or lowered from a support ship from the surface, is a suitable means to solve these two problems.

The main objective of the EURODOCKER project is to develop and demonstrate in water the technologies necessary to automatically dock an AUV to an underwater station, whether it is ship-supported or based on an unmanned underwater platform. In addition the system shall be suited to various AUVs that are already on the market or under successful development, and thus aims at becoming a standard subsystem of the AUV support spread.

2 Operative Scenarios

The following operative scenarios have been identified in which the EURODOCKER is envisaged to be used.

2.1 Operative Scenario 1 - Ship support at any water depth

The first Operative Scenario is based on the manner in which AUV's are currently operated, and therefore foresees the use of the EURODOCKER as a support to AUV's that are deployed and recovered from dedicated or chartered ships. It shall have the advantage of not requiring a launch and recovery operation for each mission, and thus the AUV may perform repeat missions without the requirement to be recovered on board the ship.

2.2 Operative Scenario 2 - Open water missions from Coastal waters

In the second scenario identified the EURODOCKER shall be placed on the ocean floor and not be deployed from a ship. The AUV shall treat the EURODOCKER as a subsea home base from whence it shall emerge to perform its mission, and to which it shall redock at the end of the mission for data downloading and recharging. This scenario shall permit the AUV's to perform repeat missions over a significant period of time without the necessity to recuperate to the surface or to have a costly vessel in support.

2.3 Operative Scenario 3 - Ice infested waters

The development of AUV's and their docking systems are considered essential 'technological packages' for the exploration and exploitation of Arctic and Antarctic waters. Within this scenario therefore the EURODOCKER would be placed on the seabed much as in scenario 2, however in this case in an area with periodic or permanent ice pack above it. The main advantages shall clearly be obtained from the cost saving tied to the use of expensive icebreaker vessels, and the vastly lengthened time that the AUV's can operate.

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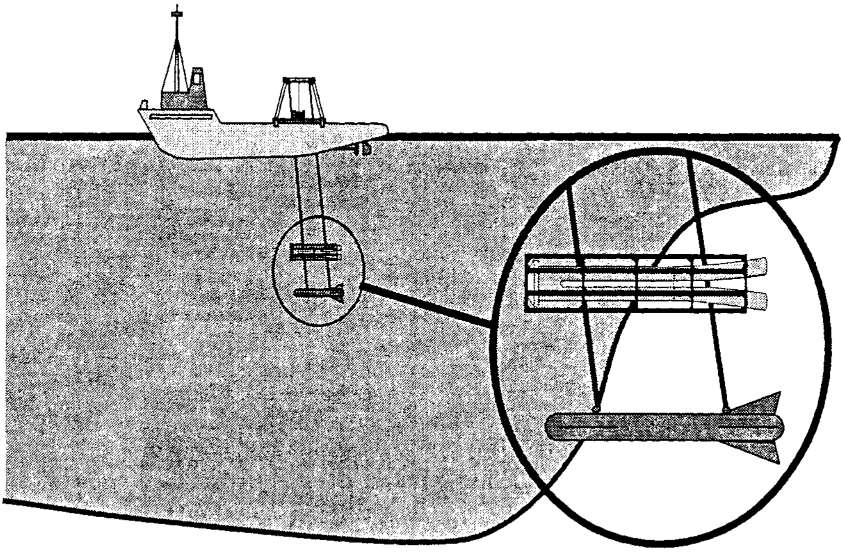

Figure 1: Operative Scenario 1 – ship supported version

3 EURODOCKER System Description

Homing System:
The long distance tracking of the AUV's, as assistance to or in back up to the on board navigation and positioning system, is performed utilising four GPS-LBL (Global Positioning System - Long Base Line) buoys for first circle re-entry. For scenarios in which the homing shall be performed under the ice, the buoys shall not be available and therefore a LBL (Long Base Line) system with a set of repeater stations shall be placed on the sea floor in the area of the EURODOCKER system.

Once the AUV is within 50 metres from the EURODOCKER an acoustics system for close range tracking is utilised to assist in guiding the AUV into the EURODOCKER. The acoustics solution consists of an USBL (Ultra Short Base Line) system, which is suitable for the close range approach. This narrows the position accuracy typically to 20 cm, at a rate of 2-4 fixes per second. The USBL may be that of the AUV if it is already part of its equipment or may be on board the EURODOCKER. In this latter case the AUV shall carry only the transponder part of the system.

The navigation of the AUV into the EURODOCKER is based on a passive role for the EURODOCKER system. This means that the AUV shall maintain navigation control but shall receive information on its position relative to the docking component from the EURODOCKER system.

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AUV Mating and Release System

The mating and release system is characterised by the following operative functions:

- fine guidance during docking;
- the manner in which the AUV is protected during docking and launch and recovery;
- the system for connecting the electrical connector to the AUV;
- and the manner in which the AUV is released for its next mission.

These aspects have led to the selection for a garage system as described below.

Garaging System

The release and expulsion of the vehicle from the garage is performed by permitting the garage structure to open up or down (respectively when sea bottom or ship supported) so that the AUV can swim away under its own power.

The Launch and Recovery System

The Launch and recovery system is characterised by the use of guide wires and a dead weight, in order to reduce the horizontal motions of the EURODOCKER while crossing the splash zone. In this way the L & R system is compatible with sea state 4 without active systems.

The launch and recovery system satisfies the following operative requirements:

- Deployment of the garage to sea level on the lift wire, following which the garage is stopped via a variable buoyancy system and the lift wire made slack.
- The garage then continues its decent autonomously (in a negative configuration controlled by the variable buoyancy) down to the established depth.
- The lift wire shall be shackled to one of the guidelines every 10 meters to ensure it does not tangle.
- In order to return to the surface the variable buoyancy system will be activated.
- Once the garage is at its operative depth it can rest on suitable landing bumpers placed on the dead weight.
- When the AUV commences its homing procedure the garage can be brought up to a suitable distance above the dead weight, say 10 m, utilising the variable buoyancy system.

A more complete description of the EURODOCKER garage system is given below.

The **Support Structure** is characterised by the following:

- It is an open lattice structure.
- It is constructed in tubular members that are sealed to limit weight in water.
- Material for the structure is robust to ensure damage does not occur.
- A suitable corrosion protection system must be foreseen.

The **Bumper System** is characterised by the following:

- It is shaped so as to provide a conical entry point into the garage.
- It is lined with low friction material at the contact points.
- It is connected to the structure with elastomeric elements.
- It performs braking of the AUV within the garage.

Permanent Buoyancy System

The actual weight/net buoyancy of the garage in water is the minimum necessary to guarantee that the garage shall descend down the guidelines under the force of gravity at a moderate velocity of 0,2 m/s.
The EURODOCKER garage is composed of steel beam members that are sealed and therefore have a limited weight in water. The desired weight is achieved by use of suitably distributed permanent buoyancy elements and lead weights.

Variable Buoyancy System (required only for the ship-supported version)

- It ensures that the garage shall float during the first phase of the launch operations down to the level of the water.
- It permits the garage to descend under its own weight to the dead weight.
- It raises the garage to a height of about 10 m above the dead weight.
- It maintains a neutral position during the docking phase.
- It returns the garage to the surface for the recovery operations.

Mechanical Block

- It ensures that the AUV cannot accidentally be dislodged from the garage once it is docked.
- It provides the positive reference position that shall permit the Power and Signal connector to be actuated.
- It is an automatic system that is activated when the AUV enters the garage.
- It permits the AUV to be released easily by the release system utilised.

The solution selected is a pin and groove system, due to its simplicity and ease of construction. The pin is provided by a dedicated fin that is placed on the AUV.

The **Power & Signal Connector** is suitable for relocation along dedicated rails within the EURODOCKER structure. The connector mating system is able to bring the plug of the connector into contact with the receptacle placed on the AUV within the tolerances that the connector system itself can cope with (+/- 25 mm, +/- 2°).

The **Umbilical System** has been specified as a typical, integrated, dynamic umbilical. It contains all the power and signal lines that are required between the garage and the surface. These is contained within two polyurethane sheaths, interspersed by a two contra-helically wound armour wires.

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System Control

The developed low level control essentially regards the actuators of the different components of the docking station. For this both hardware and software have been developed.

A number of micro-controllers receive and interpret the data from the surface control unit using the CAN protocol, specified in co-operation with the development of the operator interface. The data will be transferred via DC-isolated power supply (DC/DC converter) and transceiver to a two-wire circuit (CAN bus).

Operator Interface

An operator control and monitoring unit was developed and constructed. It consists of a standard PC with monitor and three video monitors. The first one displays the video signal of a camera showing the entrance of the EURODOCKER. The second monitor displays the video signal of a camera showing the connector and receptacle. The third monitor is connected to a video camera that monitors the launch and recovery operations.

A software architecture with clear and user friendly user interface was developed to operate the EURODOCKER system safely.

Simulation Tool

The aim was to develop a simulation tool capable of simulating docking operations involving the underwater vehicle and the docking station. To achieve an accurate imitation of the AUV's behaviour an advanced hydrodynamic model was obtained and incorporated into the simulator. Similarly, to achieve a truthful appearance of the vehicle and the docking station, accurate CAD drawings were adapted to the simulator.

The simulator is designed in a spirit of modularity, allowing easy incorporation of new visual or dynamical models of the vehicle, the docking station and the environment. By using dedicated and widespread tools for both simulation and visualisation, modelling of the simulated entities is greatly facilitated. The result is a generic and modular simulation and visualisation environment that can easily be adapted to new scenarios involving different entities and surroundings.

The dynamical modelling is performed in Simulink for Matlab. As it is possible to communicate over a network (or the local computer) from Simulink using sockets, the model can be run in parallel and communicate with other programs on any other platform supporting sockets.

The selected visualisation tool, VRML, provides a similar modularity and generality (see Figure 2). Firstly, tools exist to convert almost any CAD format to VRML, enabling geometric models to be easily imported from whatever format they already exist in without having to redraw these. And, equally important, VRML 3D browsers can be installed as free plug-ins within common free 2D browsers, such as Netscape or Internet Explorer. Furthermore, as VRML can exchange messages with external programs written in Java, scenes can be enhanced with Java's powerful computational and network facilities.

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For instance, positional data can be received via sockets either from the web or from other programs on the local computer, interpreted and treated in Java and then finally routed to the VRML scene.

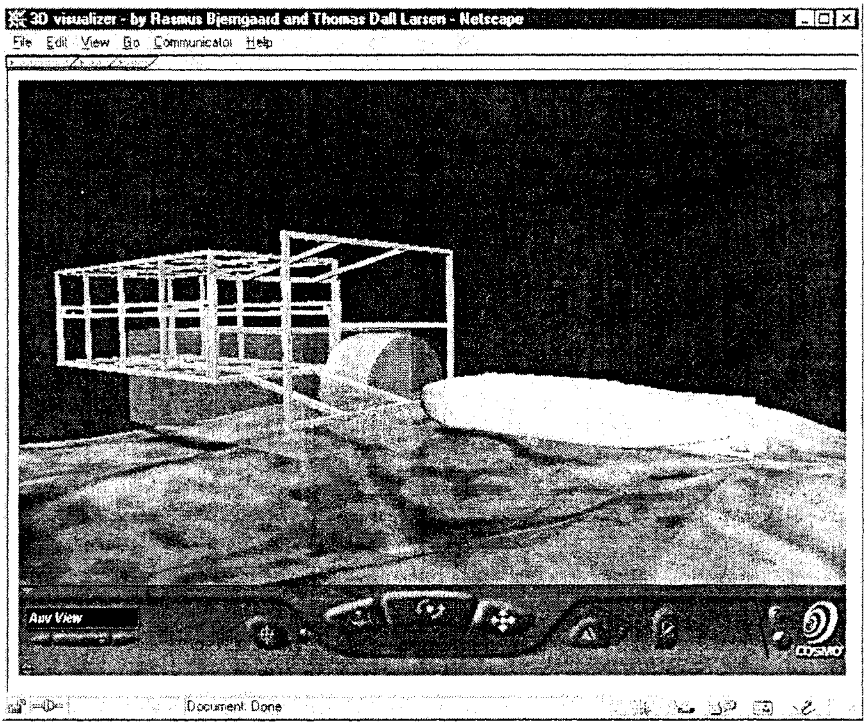

Figure 2: Simulation and visualisation of the homing and docking operation

All communication between different blocks in the simulation is performed according to the IEEE standard for Distributed Interactive Simulation, DIS. This standard is written for military simulations involving large number of entities distributed over a network. DIS defines standardised protocols to communicate simulation parameters and entity positions with a minimum of overhead. By complying with this standard, compatibility with other researchers in the fields of computer simulation and autonomous underwater vehicles is achieved.

4 Bottom supported version

For the bottom supported system the solution that has been identified is for the use of the same garage described for the ship supported version, turned upside down and anchored to the sea bed via an anchor line. The anchor line is attached to a structure placed on the seabed.

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5 The Prototype

The Construction of the EURODOCKER prototype is completed and the components have already illustrated their efficiency in dry and wet tests at the IW laboratories in Hanover, Germany. The system will finally be demonstrated under real environmental conditions in Kiel, Germany.

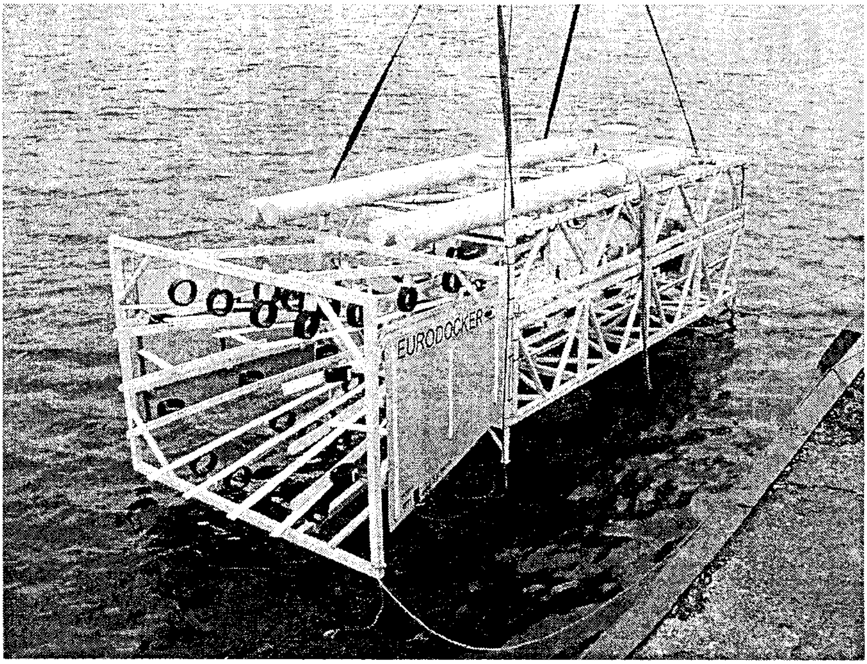

Figure 3: Sea trials with the EURODOCKER prototype

6 Conclusions

The EURODOCKER project aims at the design, manufacture and testing of an underwater docking system for AUV's. Its successful development will permit the exploitation of the enormous possibilities offered by AUV technology, ultimately resulting in cost effective underwater research, surveying and monitoring.

The EURODOCKER project is not tailored to a specific AUV, but shall be suited to the wide set of vehicles now under successful development, although Maridan's AUV has been taken as reference and shall be utilised for the tests. The end result of a viable Data Down Loading and Recharging system shall be obtained through the development of all the necessary technologies to permit the connection of the AUV underwater, including: homing, garaging, mating and launch and recovery.

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