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# The Autonomous Mediterranean submarine “SAM”

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**Abstract--** In this paper we shall present a new autonomous underwater vehicle designed to operate in the Mediterranean Sea. The aim of the robot is the substitution of human researchers performing scientific measurements in long and repetitive missions together with the possibility to operate jobs up to 3000m depths fully autonomously. Innovative issues will be implemented with respect to the available AUV. Particularly we shall use composite materials to obtain higher performance/weight ratio pressure vessel with an alveolar design as in aeronautical applications. A bi-directional acoustical communication to a ship to transfer the collected data quickly will be installed together with a sonar safety system. Moreover we are developing a safety system, based on a supervisor, able to learn from simulation tests how to react in forecast and, hopefully, quite unpredictable situations

**Index Terms**—AUV, Mediterranean, intelligent system.

## I. INTRODUCTION

THIS paper is dealing with a new autonomous underwater vehicle (AUV) designed to operate in the Mediterranean Sea. The Autonomous Mediterranean Submarine (SAM) project is carried out according to an agreement between the Italian National Agency for New Technology, Energy and Environment (ENEA) and the Italian Ministry of Education, University, Scientific and Technological Research (MIUR); the program of the agreement is dealing with oceanology and environmental problems in the Mediterranean area. The project, according to the MIUR’s programme, is carried out by Tecnomare of Venice, supported by DUNE of Rome and ENEA itself; ENEA is charged of the project responsibility.

In recent years a strong increase was observed in the demand, both by the scientific and the commercial community, for AUV able to perform automatically scientific measurements or survey job. The aim of the robot SAM is the substitution of human researchers in long and repetitive missions together with the

possibility to operate jobs up to 3000m depths fully autonomously.

Innovative issues will be implemented with respect to the available AUV. Particularly we shall use composite materials to obtain higher performance/weight ratio pressure vessel using also an alveolar design. A bi-directional acoustical communication to a ship to transfer the collected data quickly will be installed. A sonar system will be installed to avoid AUV-ship collision owing to the sea traffic in Mediterranean area. Moreover we are developing a safety system, based on a supervisor, able to learn from simulation tests how to react in forecast and, hopefully, quite unpredictable situations.

The development of SAM is the upgrading the SARA Project (Antarctic Autonomous Robotic Submarine), [1] aimed at scientific surveys in the Ross Sea, in support of the Italian Scientific Program for Antarctica, and based on the Italian settlement of Terranova Bay. Their missions are quite similar, performing measurements in hydrology, chemical, biological and geological oceanography. However it must be stressed some peculiarities to distinguish the needs for an AUV operating in the Mediterranean area. The main differences, with respect to the ocean exploration, is the higher variability of the sea bottom and of the coast pattern, producing vortex (that has the mean of differences between water mass movements) leading to a higher density of the grid measurements. Some important reasons to design a dedicated AUV for the Mediterranean Sea are the following:

- Long time for water exchange with the Atlantic Ocean, enhancing needs for studies and measurements on pollution phenomena in the Mediterranean Sea.
- Higher relevance of the coast pattern.
- Fine structure of water circulation useful to understand climate variation.

In a typical SAM scientific mission the following class of measurements must be carried out:

- Hydrologic (conductivity, temperature, depth, water speed, etc...).
- Chemical (Ph, oxygen content, light transmission, etc...).

- Biologic (chlorophyll content, food content, etc...).
- Geological (sea floor morphology, topography, etc...).

By these needs the following feature are required:

- Max depth 3000m.
- Speed cruise 2 m/sec.
- Autonomies 250 Km.
- Max duration 35 h.
- Hovering capability

This paper gives an overview about the Sam project that is starting.

SAM will be a torpedo shaped vehicle at least 5.5m long and with a diameter of 0.75m. It is composed of three main sections: a pressure vessel in the middle and two free flooding fairings of composite material fore and aft.

The pressure vessel houses the batteries, the computer and other electronic equipments. As relevant task it also guarantees a neutrally buoyant condition by compensating the weight into water of the items located in the flooded sections.

Bow main thrusters compose the propulsion system.

In the cruise mode two pairs of aft fins in a cruciform configuration control the vehicle.

## II. QUALIFYING ELEMENTS OF THE PROJECT

The innovative elements in the SAM project are essentially three.

The first is a bi-directional acoustical communication to a ship to transfer the collected data quickly and to increase the flexibility of the operation and emergency interventions. Moreover a system for safe surfacing: due to the naval traffic of Mediterranean Sea, a sensorial system, based on Hydrophone and a suitable data analysis and decision making system is developing. The need of such system was dramatically confirmed by the Haway Islands accident.

The second is in the use of reinforced thermosetting resins, to realize the pressure vessel, able to support the compressive and buckling strength at high depth. An alveolar structural tube design is employed as used in aeronautical application to obtain a high ratio performance/weight.

The third, that is the main feature of SAM, is the possibility to change the parameters of the mission in the meanwhile of the performance because of an "intelligent supervisor" system. In case of failure of some instruments, as example, the full mission will be re-planned to carry out a reduced mission optimising the performance, using the remaining resources.

## III. THE ACOUSTIC COMMUNICATION SYSTEM

The first innovative feature in the SAM project is a bi-directional acoustical communication to a ship used in short time missions. Because of the Antarctic Environment, acoustic communication to SARA is quite unfeasible. In a Mediterranean situation the exploitation of the acoustic channel may add flexibility (capability of parameter modification, or mission reprogramming), as well as some debugging of the vehicle status and intervention capability in case of emergency situation; anyway, the control system is designed in order to allow a non-continuous information transfer.

Actually, the physical acoustic channel is a Datasonics system, and main features were already tested.

So far the collected data quickly are transferred to the ship, processed and a new mission can be transmitted to the AUV soon.

## IV. THE PRESSURE VESSEL

The vessel has the task to preserve all the apparatus that cannot operate under high pressure and to guarantee a neutral buoyant behaviour. The innovative pressure vessel will be realized by a tetrafunctional epoxy resin cured with particular care to avoid imperfections. AS4 carbon fibre will be used as continuous reinforcement. Some experiments on the materials are in progress to tests the mechanical characteristics of the vessel. The structure of the cylinder will be optimising with respect to the critical buckling strength. We can outline the use of the sectors and alveolar structure, like used in aeronautical applications, to increase the inertial moment of the structure saving weight. In our dimension the critical pressure will be 35 MPa, corresponding to a safe activity of 3000 m. depth.

## V. THE CONTROL SYSTEM

The functional architecture of the control system is thought as a hierarchical structure (NASREM). This has the mean that the basic idea is the logical decomposition of the mission that the system must execute. The mission program is acquired and decomposed in a sequence of tasks. The tasks are executed by the single competence unit. For the submarine navigation a navigation system is installed to follow the pattern described in the mission plan. A monitor system has a coordination function. A supervisor system has the task to manage all the

emergency events and to check the general state of the apparatus. This last is separate from the other for modularity reasons and to allow- the robot to work also without the supervision system. A simple scheme of the control system is shown in Fig.1. Particularly, from the figure, we can distinguish the logical units of scheduling, monitor, navigation and supervisor.

The scheduling task is to divide the received mission in simple tasks sequence and pass them to the monitor. It can receive from the monitor the new planned mission.

The monitor receives the scheduled mission and sends the commands to the scientific sensors and the navigation plan to the navigator system, which sends it the navigation state. It also receives the data to transmit.

The navigation system receives from the monitor the navigation task and informs it on the navigation state. It sends the elementary tasks to navigate to the actuators receiving the feedback.

The aim of the supervisor system is to increase the safety and the adaptability of SAM during the mission. Generally supervision activity can be described as the control of automatic process to note malfunction that are not corrected by the feedback information of the automatic system [2]. This can imply new configuration of the whole automatic process. Our supervision system must be able to react to circumstances not explicitly previewed. Moreover it must be able to program a new mission if the events make impossible the current mission, and in the extreme case it must put SAM on the surface to be recovered by humans. Most common emergency that belongs to the supervisor competence is the lack of power (It can reacts, as example, activating the "economy mode"), malfunction of one sensor unit (isolate the unit), obstacle avoidance and the excessive mismatching between the programmed pattern and the realized one.

This can be obtained trying to make "intelligent" our robot. It is well known that the research for an efficient intelligent system can be based on methods like rule-based approaches, on heuristics methods, on the generation of best behaviors following genetically selected solutions, on the application of minimization functions (like in the case of neural networks or fuzzy logic) to address simple solutions to specific problems. In fact, different methodologies have been developed in order to face different problems, or, in other words, whenever a consolidated theory is failing as a new class of problem, or of new "point of view" is raising in relevance.

For a real machine, operating in a real word, we have to make the assumption that any class of problem is possible. It follows that, at the present status, any

possible "intelligent method" may be useful, operating in cooperation or in competition with the whole system. Practically, the development of such "intelligent" system is starting by the simplest of these methods, the rule based solutions and will increase progressively in complexity. Actually this is performed by the building of a rule table like "If...Then" and giving the AUV the possibility to increase both the number of the rules and their weight in the table. This aim could be pursuit defining appropriate "state variables" and working about their interactions. The state variables will contribute to the data structure, to increase the "knowledge" finalized to the aims of the mission. The "experience of the system" which is the most difficult task, will be simulate by the massive use of computers.

One of the most difficult processes in an automatic system is to convert data into knowledge, where knowledge has the mean of structured information to pursuit aims [3]. An intelligent system is able to manage and modified its knowledge, in the direction of the aims. Data organization is, therefore, one of the most important task. A simple proposed scheme of the supervisor system is showed in Fig.2. Here we can outline six modules and their connections between them and the NASREM levels of the controls system. In particular it should be noted the simulation module whose task is to generate an expected state from the initial condition (actual state). The diagnostic module evaluates if the actual state is similar to the expected one. The decisions are taken by the supervisor which can activate the re-programming module. The supervisor always is connected with the global memory to obtain all the measured data.

Let us come back to our simple supervisor system model based on a rule table just programmed like "If ...Then". A fixed number of events are previewed. Of course a fixed number cannot be flexible and to include all the possibility is out of our aim. We allow an expert system to enlarge the table and the weight of the rules with the "experience". The experience should be acquired by massive use of computers. To this aim we can define some "state variable" indicative of the system status and able to describe the perceptual reached goal to decide the new weight and the new rules. This new variable (or class of variables) can be sketched as an "efficiency state" of the robot with respect to the aims of the mission. In case of the lowest efficiency level the emergency solution (emersion and emission of help signal or, alternatively, back tracking to home) can be authorized. As example an excessive variability by the navigator on the rudder could be mean as failure by building some stability parameters.

Practically the following steps need to be performed:

- Data collection.

- Data structured (knowledge).
- “State variable” evaluation. Stability analysis.
- “Efficiency state” evaluation, using fixed rule algorithm.
- Change of the rules by expert system.
- New structured preferences based on the new rules.
- Choose of the task to do in the decisions space.

## VI. CONCLUSION

The Sam project, which is the based on the SARA project, is in progress with the aim to build a new advanced AUV robot. Four features distinguish SAM from the preceding AUV. They are a more interactive data exchange system, a sonar system to avoid collision in emersion, a new composite vessel and an “intelligent” supervisor to manage emergencies.

## VII. GLOSSARY

AUV	Autonomous Underwater Vehicle.
ENEA	Italian National Agency for New Technology, Energy and Environment;
MIUR	Ministry of Education, University and Scientific, Technological Research.
SAM	Autonomous Mediterranean Submarine.
SARA	Antarctic Autonomous Robotic Submarine.

## VIII. REFERENCES

- [1]. PapaliaB. et al., 1998, 17th Int. Offshore Mechanics and Artic Engineering Symposium, Lisbon.
- [2]. Lambert M., 1999, Conception centrée sur l’homme d’un system de supervision avancè. Laboratoire d’Automatique et de Mecanique industrielle, Valenciennes France.
- [3]. Antsaklis, P.J., 1997, Enciclopedia of Electrical and Electronics Engineering, J. Wiley &sons.

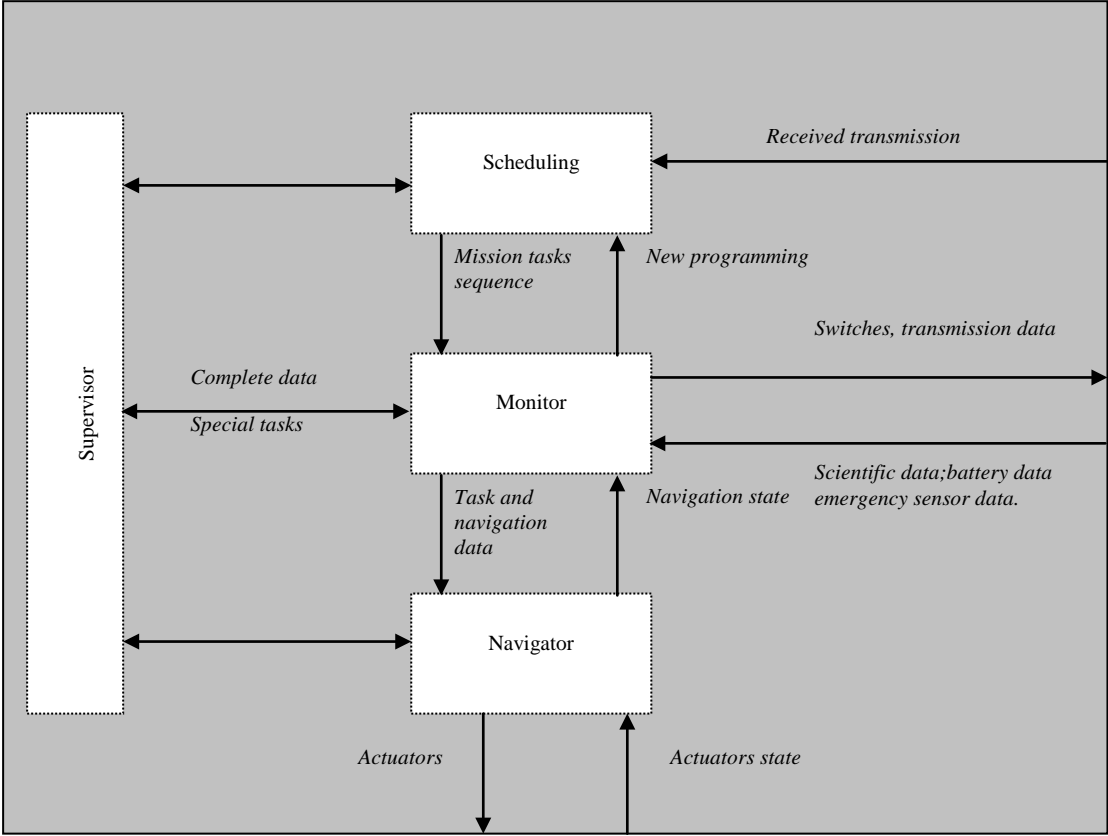


Fig. 1 Logical scheme of the control system and its connections

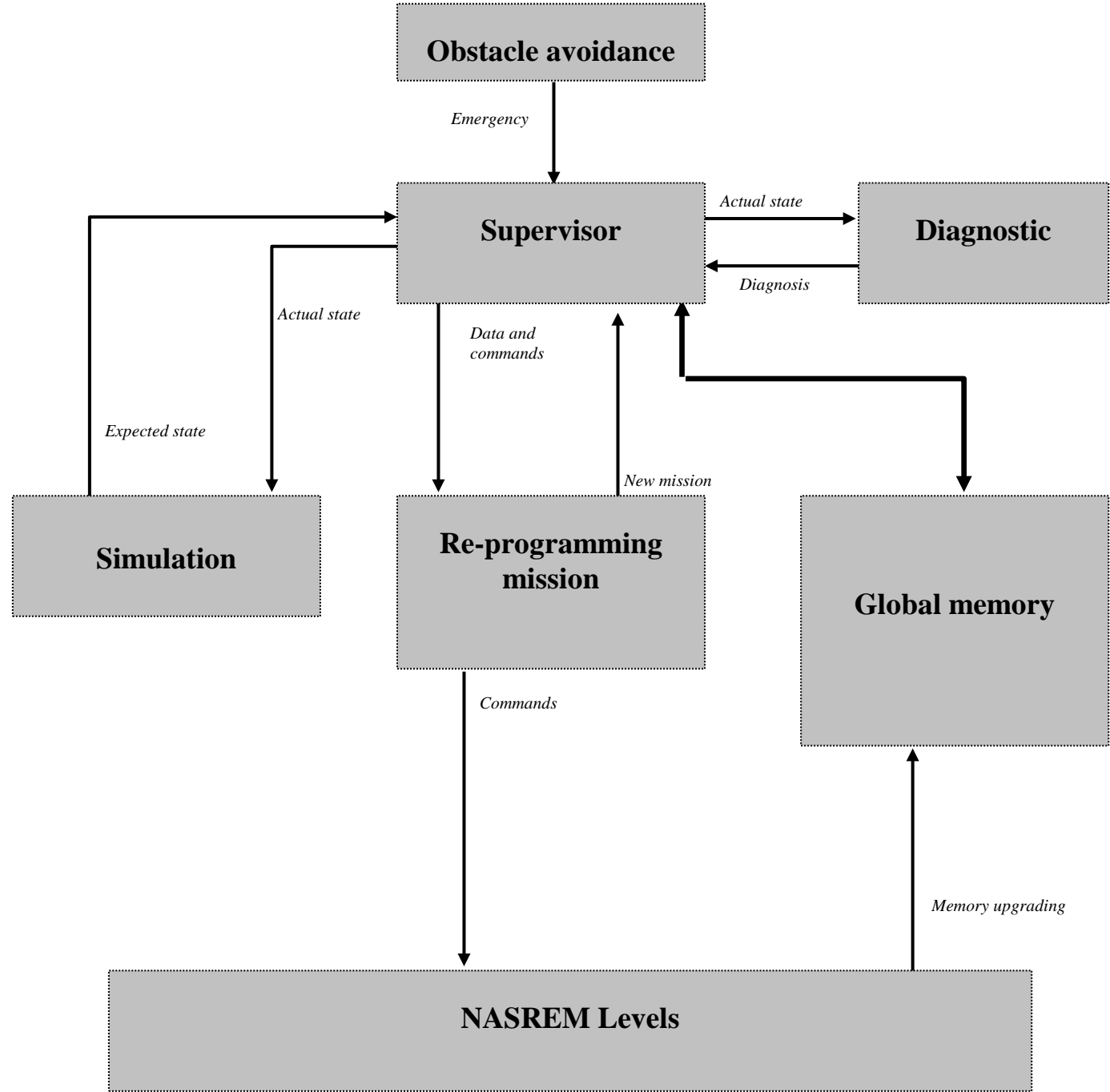


Fig. 2 Logical scheme of the architecture of the supervision system