The ASEMAR Project

J. Le Gall, N. Mandelert
Thales Underwater Systems SAS
Site Amiral Henry Nomy, Route de Ste Anne du Portzic
29238 BREST Cedex 3 France

Abstract- Aware of the new trends in Surveillance Operations, THALES Underwater Systems has been developing AUV based sonar systems since the late 1990's. At present, THALES and ECA are developing an AUV system, within the frame of the French Poles of Competitiveness (Pôle Mer Bretagne). This project is called ASEMAR, for “Auv de Sécurité MARitime”.

In this development, THALES and ECA work together in a strong partnership, THALES being the System Design Authority and ECA being the expert in vehicle design. The objective is clearly to develop, experiment and industrialize an autonomous AUV based Surveillance System.

The main components of the AUV are the embedded intelligence, the sonar payload, the navigation function and the vehicle. The AUV may communicate with the surface ship through an acoustic link; sonar and navigation data are recorded on board the AUV. To secure its main capabilities, the AUV takes benefit of efficient functions and sub-systems. For instance, THALES is developing a challenging on board processing that will perform automatic target recognition and determine adaptive behaviour as part of the mission management. The system is open and modular, which means that, as future growth potentials, it may include more efficient or additional functions or equipments. Academic partners are also involved in the project, to investigate new innovative functions to be integrated in the system.

The presentation will give details about the functions and performance of the AUV and will give some results from sea trials.

I. INTRODUCTION

The ASEMAR project objective is to develop an autonomous underwater vehicle (AUV) for maritime security dedicated to the monitoring of sea bed. This 1-ton class AUV is equipped with the best technologies in imaging and in autonomy of navigation. Its cost will be competitive on the emerging market of the maritime security.

The mission of this vehicle is the detection of the immersed dangers. Its spectrum of use is very wide: from the search of sunk ships or cargoes of hazardous or polluting materials lost offshore, to the observation of seismic faults or geologic movements.

The ASEMAR project has been carried out by THALES and ECA, THALES being the System Design Authority and ECA being the expert in vehicle design, within the frame of the French Poles of Competitiveness (Pôle Mer Bretagne). Academic partners (ENSIETA, Ecole Navale, ISEN, UBO in Brest) are also involved, in a coherent policy of development of the technologies linked to underwater robotics and acoustics. The industrial partnerships bring them an opportunity to strengthen their technical positioning.

- ENSIETA has studied obstacle avoidance, multi-sensor data fusion and multi-view fusion of sonar images.
- ISEN has been in charge of acoustical optimization and sonar receiver electronics study.
- IRENAV (Ecole Navale) has developed a Geographic Information System for the management of campaigns data, and has studied the hydrodynamics of the vehicle.
- UBO (AMURE) has been in charge of studying the legal aspects connected to the use of AUVs.

This project has been an opportunity to develop innovative solutions and to demonstrate ASEMAR performances during sea trials of spring 2010.

II. ASEMAR MISSIONS AND GLOBAL PERFORMANCES

A. Missions

The objective of the ASEMAR project is clearly to develop and experiment fully autonomous AUV based MCM systems [1][2], dedicated to exploration and survey missions.

These AUV systems must have the capacity to operate in an unknown area and to autonomously detect, classify and localize suspicious objects laying on the sea-bed.

Such missions require high degree of autonomy, real time onboard sonar processing, transmission of tactical data towards the sea surface ship, high accuracy of target positioning to make easy later identification and intervention operations.

B. Global performances

High level of operational performances (about coverage rate, probability of target classification, target location, endurance) are required to satisfy the missions.

Autonomy is essential to reach these performances: decision can be taken automatically to improve coverage rate, localization and automatic classification by planning re-visit trajectories after initial mission plan.

III. ASEMAR KEY TECHNOLOGIES

The main components of the AUV are the embedded intelligence, the sonar payload and the vehicle with enhanced positioning. The AUV may communicate with the surface ship through acoustic links when immersed, or radio links when at surface. Sonar data, vehicle status, navigation data and all sensors data are recorded on board the AUV.
The system is open, which means that, as future growth potentials, it may include higher performance or additional functions or equipments (eg: bathymetric sonar, multi-aspects sonar, vision camera).

A. Embedded Intelligence

This function produces on board decision capabilities and mainly aims at:

- planning the mission,
- managing the events from the different components embedded in the AUV,
- updating the mission plan from the unforeseen events.

Mission planning elaborates the detailed plan of the mission and insures its re-planning further to an unforeseen event during its progress.

It takes into account:

- the objectives of performances of the mission (in terms of coverage rate, tracking, localization),
- some elements introduced by the operator (mission area, position of the surface ship, time slots, restricted areas),
- some criteria concerning the mission (localization accuracy of the vehicle, margin on the available energy, margin on the duration, ...),
- some constraints concerning the capacities of the vehicle (energy, maneuverability, ...) and of the sonar (range, speed, altitude, ...),
- the environmental constraints (sea current, seabed marks, ...).

Supervision, using Petri nets, oversees the progress of the mission according to its plan and defines the suited reactions against the events detected by the system.

Various levels of reactions are possible, according to the detected events:

- Global re-planning,
- Local re-planning,
- Interruption of the mission,
- Emergency stop of the mission.

Safeties of low level are directly activated by adhoc subsets; however, in any case, the supervisor is informed about their activation.

B. Sonar payload

The main design considerations are the following ones:

- Synthetic Aperture Sonar processing, using the Thales Underwater Systems TSM 2054 SAS technology:
  - high acoustic frequency,
  - long antenna to allow high coverage rate,
  - high acoustic frequency bandwidth, sufficient to obtain the required cross-track resolution, but extendable to improve it, by simply replacing the current COTS processors by more powerful ones when available,
- Hybrid Ping to Ping Cross-Correlation (Thales patent) to compensate for antenna movements and to produce data for the positioning function
- Automatic Target Recognition, using on board AuDC (Automatic Detection and Classification)

- Real time sonar performance assessment, in order to adjust SAS and ATR parameters, to optimize the global planning and to plan re-visit at the end of the mission.
- Seabed marks recognition, useful for the positioning function.

Taking into account the required lateral resolution of the sonar, a synthetic aperture processing is to be used to form the sonar image. The along track resolution is the same whatever the range and is achieved through coherent integration of the received signals on several successive pings. The SAS configuration is processed in real-time and takes the benefit of a THALES patented and sea proven self calibration algorithm to estimate the translation and rotation motions of the arrays during the integration. A lot of precautions were taken in the design of the system, to avoid acoustic interference with other equipments (obstacle avoidance sonar, Doppler log, acoustic link).

Additional arrays are used to obtain a multi-aspects sonar in three directions (broadside and broadside +- 30 degrees). This function allows improved shadow classification by providing the system with three quasi-simultaneous different views of a target.

The Automatic Target Recognition function contains 2 sub-functions:

- target detection uses techniques in order to isolate shadows corresponding to suspicious targets (from the size); attributes are then computed and sent to the next sub-function,
- target classification uses fine segmentation of the observed shadow, and makes decision by comparing the current shadow shape to a data base of masks, corresponding to known targets shadows; the data base of masks may be adapted to the type of targets to be found.

The sonar performances indication is computed in real time on board the AUV; these data are taken into account by the embedded intelligence to adjust the system configuration and to optimize its performances (sonar range, speed of advance, tracks spacing).

The produced and monitored data are the bottom backscattering strength, the ping to ping cross-correlation coefficient, the signal to noise ratio, the shadows rate, the echo rate, the holes of cover rate.

C. Vehicle

The vehicle has a cylindrical shape, a single propeller for an optimized autonomy. The energy is provided by a lithium-Ion embedded battery.
Positioning function is fully autonomous. The positioning uses a complex Kalman filter with inputs from an accurate Inertial Navigation System, a depth sensor, a Döppler log, the SAS processing (cross-correlation micro-navigation) and sonar data processing (seabed landmarks).

The stability of the vehicle is in accordance with the SAS induced requirements. The maneuverability of the vehicle typically allows for specific short-radius patterns in order to investigate more accurately detected targets, and for obstacles avoidance.

As the AUV performs fully autonomous missions, the acoustic links are not functionally required for operation. However, 2 links are available in real-time:

- A bi-directional, low data rate link for transmission of AUV status and position as well as possible commands from the surface,
- A mono-directional, high data rate link for real-time transmission of sonar images extract of interests. While the classification is autonomously performed in the AUV, this link allows a real-time, redundant classification at surface by the operator.

Two radio links are available:

- One high data rate Ethernet link (Wi-Fi), allowing distant uploading of the acquired data and downloading of new parameters.
- One low data rate link, to keep track of the AUV when at surface, even at very long distance.

In addition to the acoustic and radio link, the vehicle can be fitted with an optional fiber-optic link. This is convenient for testing and real-time tuning of the various embedded algorithms.

The AUV ensures autonomously its own safety, should an unexpected event or a dysfunction occur. While rapid response actions are taken at a low level (reflex actions), the embedded intelligence can anticipate and accommodate for more global measures, such as re-planning of the mission, immediate return to recovery point or mission abort.

In addition, the AUV is fitted with an obstacle avoidance system, allowing for both lateral and vertical avoidances.

IV. SEA TRIALS RESULTS

Sea trials have been conducted from beginning of 2010 until end of April 2010, at first in the South of France, near Toulon, to validate the behavior of the vehicle and its components in various conditions, and then in the West of France, near Brest, to validate the sonar performance when integrated in the vehicle and the global system performances.

During these sea trials, the AUV has demonstrated its capacity to perform large missions in full autonomy.

As an example, results from such a typical mission is given below.

This mission, which was successful, was performed to explore a 1x2km area in which some manufactured objects were laid down (3 cylinders with a length 2m and a diameter 0.5m, 1 sphere with a diameter 0.75m)

The preparation of the mission consists in defining the area to be covered by the AUV. Then automatic planning is performed by the system, as illustrated on the screen capture below.

The full plan is composed of eight horizontal lines, covering the whole area, including filling of the coverage gaps under the vehicle. After the launch, the vehicle reaches the centre of the area for a GPS fix. Then the mission begins, with a diagonal to the Southwest corner. The eight lines are then covered. If the sonar range, measured in real time, is not as long as expected due to environmental conditions, the embedded intelligence of the vehicle is able to re-compute a planning with narrower lines to allow the best sonar performance over the whole area.
During the mission, the vehicle sends data to surface through the low data rate acoustic link. Its position and other vehicle parameters are monitored on the surface display, as well as the sonar performance map, that is regularly updated as illustrated below:

Figure 4: ASEMAR monitoring, beginning of mission plan

Figure 5: ASEMAR monitoring, half mission plan

Figure 6: ASEMAR monitoring, end of initial plan

At the end of the initial mission plan, the sonar performance map shows that almost all the area has been covered with good performance (in green on the display). Automatic re-visits are then planned by the vehicle, to fill the coverage holes and to get several views of suspect objects detected and classified during the initial plan. The trajectory followed by the vehicle is shown in yellow on the next image.

Figure 7: ASEMAR monitoring, end of re-visit

Figure 8: sonar data mosaic of the whole area

Depending on the estimated interest computed for each performance hole and each contact, a re-visit will be decided if the available electrical power is sufficient to perform the re-planning trajectories. If the remaining energy is too low, the system will optimise its trajectories to re-visit the most interesting holes and contacts.

At the end of the re-visit phase, the vehicle returns to its recovery area. As soon as it is in surface, the download of the data can begin through the wireless Ethernet link. The data available for the operator are then a mosaic of the sonar data over the whole area, a waterfall of each sonar line, and a list of contacts. The contacts may be composed of several observations, that have been associated by the automatic detection and classification function. Each observation has been automatically detected according to the dimensions of typical searched objects, and classified by comparison to a database of known objects. The operator has access to the contacts, their positions, their dimensions, their classes and the sonar images of the observations that are associated to the same object. For example, the mosaic obtained over the area is given below.

The 3 cylinders and the sphere have been found by the system, with an absolute positioning error of less than 10m. On each object, several views are available to the operator. The cylinder showed below has been observed 3 times. Two observations come from the initial mission plan, and the third one from a re-visit trajectory. Thanks to these observations from different
The system has automatically classified this object as a cylinder, and this can be confirmed by the operator with a good confidence level.

![Three views of a cylinder](image)

**Figure 9: Three views of a cylinder**

### V. CONCLUSIONS

The advanced technologies developed in this ASEMAR project have allowed to perform at sea the demonstration of an autonomous underwater vehicle able to perform surveillance missions over large areas, with a high level of performance thanks to its high level of autonomy.

Vehicle endurance, navigation, positioning, embedded sonar SAS processing, real time sonar performance evaluation and seabed estimation, automatic detection and classification, multiple views fusion are essential capacities of this system, developed for ASEMAR and demonstrated at sea in operational conditions.

![At sea with an unexpected visitor](image)

**Figure 10: At sea with an unexpected visitor.**

### ACKNOWLEDGMENT

The ASEMAR project has been carried out by Thales Underwater Systems in co-operation with ECA, in the frame of the French Poles of Competitiveness (Pôle Mer Bretagne), with the contribution of academic partners: ENSIETA, Ecole Navale, ISEN and UBO in Brest.

### REFERENCES
