MARTIN - an AUV for Offshore Surveys

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Abstract - The Unmanned, Untethered Vehicle MARTIN designed for offshore surveys is currently being tested at sea. The design is based on the prototype vehicle MARIUS developed under the European Community programme MAST (1992).

Being an untethered vehicle, it minimises the operational cost, as no cable-handling system onboard the mother ship is required. The vehicle can be instrumented for offshore pipeline and cable inspections, bathymetry surveys, and oceanographic surveys. The exchange of payload is facilitated by a modular design.

A Mission Management System including Obstacle Avoidance enables the vehicle to fly close to the seabed using its internal navigation system. The range capacity is 70 km powered by 5kWh lead-acid batteries. The onboard positioning system currently being tested is utilises DGPS and a tracking system onboard the mother ship. The accuracy is being improved by dead-reckoning based on data form an Inertial Platform and a Doppler Log.

1 Introduction

The AUV (Autonomous Underwater Vehicle) MARTIN was developed in 1995 for oceanographic and industrial surveys down to 100 metres. The hull and basic power and propulsion systems are based on the prototype vehicle MARIUS[1,2,3] developed in 1992 under the European Community programme MAST (Marine Science and Technology). Tank tests and sea trials with MARIUS and MARTIN have proven the excellent manoeuvrability of the flatfish shaped, low-drag hull[4] (Figure 1).

The design is primarily suited for cruising at 1-2.5 m/s (2-5 kn). Furthermore the six thrusters allow for hovering and precise manoeuvring, even at low speeds. Two bow-fins can lift the vehicle quickly enough to avoid obstacles even when flying close to the bottom.

Great effort has been put into the navigation and positioning system to meet industry requirements. An advanced Mission Management System (MMS)

Figure 1: MARTIN presented at the OMAE '95 Exhibition.

is under development. The MMS will guide the vehicle during the pre-programmed surveys and maintains vehicle integrity. The system is being developed in a collaboration among Maridan ApS, Institute for Automation, Technical University of Denmark, and Risø National Laboratory.

MARTIN is currently being operated in UUV-mode (Unmanned Untethered Vehicle), as operations require an operator onboard a mother ship nearby. Operations in UUV-mode with an on-line communication link to the operator represent an important milestone in the development of a fully autonomous mission control system for MARTIN. In the future, operations may be performed in AUV-mode, i.e. without on-line communication to the surface. This may be possible, as future versions of the MMS will focus on increasing autonomy. Operations in AUV-mode have particular interest for deep surveys and surveys under ice, but for many types of oceanographic and industrial surveys there is no demand for operating without a mother ship. In future systems, possible savings might be obtained by replacing the mother ship with communication buoys.

With its accurate positioning and precise attitude and azimuth control, MARTIN is expected to be a suitable carrier for all types of surveys requiring high density data collection equipment. Payload may include pipe-tracking equipment, video, multi-beam echo sounder, side-scan sonar, laser radar, sub-bottom profiler and any user-specified sensors as required for the survey. A typical application could be a pre-construction survey for sub-sea wellhead installations and associated pipelines and cables. Furthermore, MARTIN will be suitable for any type of surveys related to construction work, such as trenching, dredging, and rock-dumping surveys.

2 MARTIN Instrumentation

The control hierarchy for AUV's are commonly divided into three levels, Mission Control, Path Control and Servo Control[5]. The same three levels are found in MARTIN[6].

- The Mission Control Level generates way-points for the survey and takes care of surface communication and emergency situations.
- The Path Control Level includes Obstacle Detection, Path Planning, and Path Following.
- The Servo Control Level includes Sensor Fusion and an autopilot that controls heading, speed, and depth (or height).

The instrumentation of MARTIN is based on a decentralised computer structure to ensure integrity and to facilitate later extensions of the system (Figure 2). All sub-systems are connected by a CAN net[7], well known for its stability. Communication with the control panel and the operator is carried out through an acoustic modem or a radio link using an aerial on a surface buoy when applicable. Furthermore, the PC systems onboard are connected via an Ethernet for off-line communication and data transfer to the operator's PC, and for large on-line data transfers which are not timing-critical, e.g. path plans and passed obstacles.

The decentralised computer structure has several advantages:

- Low-level sensor and actuator interfaces - being very timing-critical - can be implemented on local, dedicated 80C552 microcontrollers (CIP boards[7]).
- High-level data processing and decision making is done on PC systems, because they are flexible and they have better developing environments. PC's are, however, not feasible for implementing timing-critical processes due to operating system overhead.

All PC-based sub-systems are equipped with a hard disk drive to maintain their own logs. The Payload

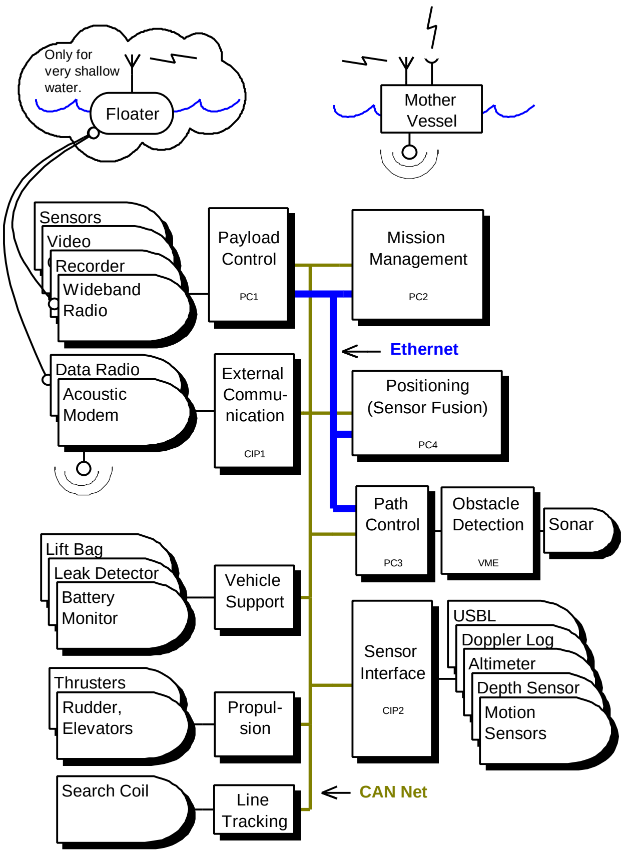

Figure 2: MARTIN Instrumentation includes four PC's and three CIP computers connected by two networks

Control hard disk may furthermore store payload survey data. All logs can be retrieved off-line after the survey, using the 10 Mb/s Ethernet. Furthermore, the operator's PC will log the survey, but as the communication link band width is limited (10 kb/s) only survey data will be included.

The electronics is placed in cylindrical pressure compartments (∅200 mm) made of a non-metallic low-weight GRP-based composite material with POM end covers. The compartments are tested to 100 metres; an upgrade to 1500 metres is planned.

2.1 Positioning

A positioning system calculates the global position and global velocity of the vehicle. The calculations are based on Sensor Fusion. Data sampling is performed by the Sensor Interface computer (CIP 2), and the data is transferred to the PC-based sensor fusion via the CAN-bus. The purposes of sensor fusion are:

- To validate sensor input and to detect excessive noise by, e.g. comparing redundant sensor systems and by analysing sensor input over time.
- To filter sensor input as required.
- To interpolate between sensor inputs from different sensors to get an improved navigation data package at the required time steps (5 milliseconds).

Some sensors provide redundant information; e.g. the doppler log and the inertial platform. Furthermore, the path calculated from these instruments, can be corrected with DGPS positions from the mother ship.

2.2 Path Control

The aim of Path Control is to navigate the vehicle from one way point to the next. Path Control includes Path Finding to calculate a safe path to the next way point, and Path Following to guide the vehicle along the path. Heading, speed and attitude are controlled by an autopilot.

Based on sonar images, Path Finding calculates a coarse path to the next way point, avoiding any known obstacles. In case of a late detected obstacle, a Reactive Obstacle Avoidance System sends emergency commands directly to the autopilot.

2.3 Mission Management

The Mission Management System (MMS) under development comprises the following subtasks: Vehicle Diagnostics, Mission Control, and Mission Management.

Vehicle Diagnostics monitors all sub systems of the vehicle and the environment. Should a problem emerge, Vehicle Diagnostics will attempt to classify it and analyse the cause of the problem using a ruled-based expert system based on experiences from sea tests.

Mission Control executes the survey plan downloaded from the operator by generating the input to Path Control and Payload Control. Mission Control also register the progress of the survey and decides when sub-goals of the survey plan have been reached.

At present, two cruising modes can be used:

- Cruising from way point to way point, or
- Following environmental parameters (e.g. tracking a pipeline or following an environmental gradient).

Input to Path Control from the MMS in the first case can be way points and accepted deviations from the points. In the second case, input can be maximum deviation from the tracked object, or gradient and maximum distance with no information.

Mission Control maintains a master map of the survey area. The master map is initially downloaded by the operator, and during the survey it is updated by onboard sensors. Stationary objects detected by the Obstacle Detection System and information about water currents is included on the master map. The map includes only data relevant for the survey and is not intended for hydrographic purposes.

If the survey plan cannot be continued due to environmental problems, such as strong current or many obstacles, Mission Control reports to Mission Management.

Mission Management controls the communication with the operator, informing about the vehicle and survey status, and receiving survey plan updates and operator commands.

In case of failures or unexpected events, Mission Management takes a decision based on reports from Vehicle Diagnostics and Mission Control. The list of possible failures includes internal problems, such as vehicle sub system failure, and external problems, such as incorrect seabed map or other survey information, strong current, entanglement with wires, etc.
Mission Management informs the operator about vehicle and survey status and asks for new instructions when required. Mission Management acts through an intelligent scheme assessing the risks of survey failure, vehicle damage or even loss of the AUV.

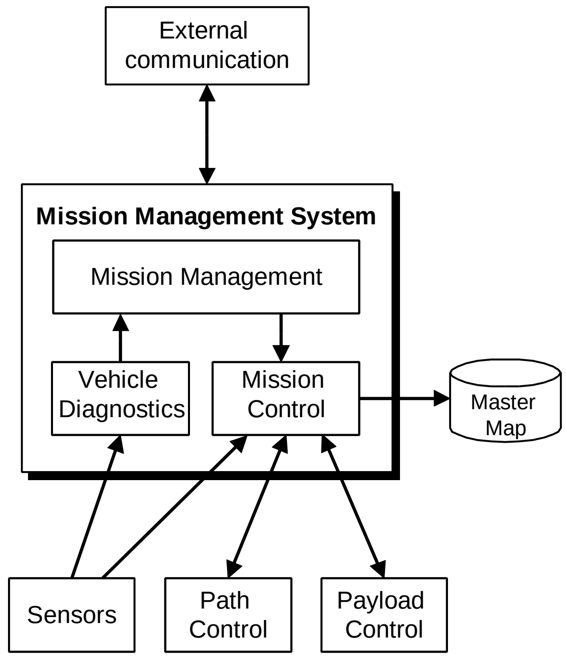

Figure 3: Structure of the Mission Management System and its interactions with other systems

Mission Management can initiate evasive actions when required if there is an immediate danger for the vehicle, or if the operator does not respond (e.g. if communication fails). Possible actions may include:

- Surface or return to the mother ship, possibly using the emergency liftbag.
- Re-plan the path or the complete survey to avoid problems. This can be done by the operator, but in future versions by Mission Management.
- Go to the bottom and moor, waiting for the situation to pass (e.g. tidal current), or waiting for manual recovery of the AUV by divers or an ROV (e.g. when entangled by wires).

2.4 Operator's Interface

The operator's interface consists of a control panel and a PC. The control panel (Figure 4) is equipped with joysticks, switches, displays and light indicators for test and for manual control of the vehicle at launch and recovery.

The operator's PC is used for survey planning, on-line monitoring, off-line data inspection, and survey re-play.

Figure 4: The control panel.

3 Status of development

Since the sea trials with MARIUS in 1993-1995, the hull and propulsion system have been thoroughly tested during the MAST project[8,9,10,11]. MARTIN, based on the same hull construction, is currently being tested at sea in Denmark. Manoeuvrability, radio link, manual control, and autopilot have been tested successfully. An Obstacle Detection System has been tested in the lab[12]. Planned sea tests in 1996 will include a positioning system, obstacle avoidance and a first version of a Mission Management System.

A pipeline inspection survey with MARTIN is planned in the summer of 1997[13].

4 Conclusion

An Unmanned Untethered Vehicle (UUV) for offshore surveys, MARTIN, is currently being tested at sea. A high-precision navigation system is under development. The wide range of payload instrumentation includes bathymetric sonar systems, video systems and pipe tracking equipment. A pipeline survey with MARTIN is planned in 1997.

Based on the experiences from MARTIN sea tests, a Mission Management System is under development. It includes intelligent control systems to ensure the safety of the AUV and the success of the survey with a minimum of operator action, even under unknown conditions.

5 Acknowledgements

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