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Geoscience Research
GSI
Suirbhéireacht Gheolaíochta Éireann
Geological Survey of Ireland

Geological Survey of Ireland Research Programme
- Short Call 2015, Final Report -

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Organisation name	University of Limerick
Organisation type:	☒HEI ☐Public Sector (other) ☐Private Sector
Department/section	Mobile and Marine Robotics Research Centre, Electronic & Computer Engineering Department

Project Title	Unmanned Surface Vehicle for Inshore Bathymetric Survey
Contract No.	2015-sc-053

INFOMAR
Integrated Mapping for the Sustainable Development of Ireland's Marine Resource

Tellus
Understanding Underground

Marine Institute
Foras na Mara

2. **Project information:**

Title of project	
Did you make any formal amendment to the project workplan / budget?	☒ Yes ☐ no If yes, please specify: Under direction from INFOMAR, this project was changed from a hand on engineering project to a desk-based study. Associated costs changed accordingly, however total spend is under the budgeted amount

Project Report (*max 1500 words, excluding figures and headings*):

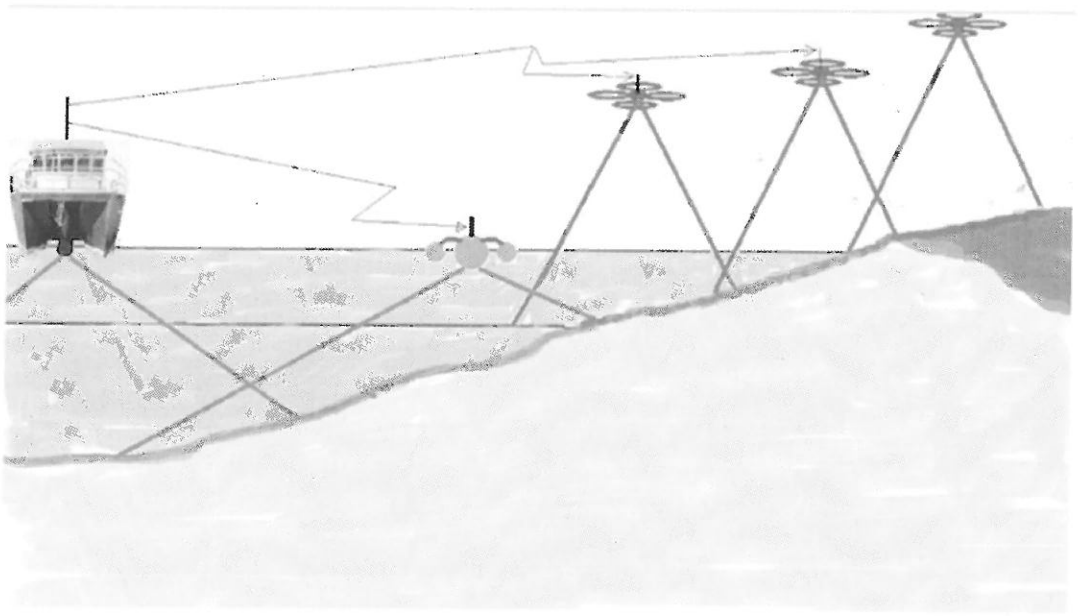
(i) Objectives and scientific/engineering targets beyond the state of the art

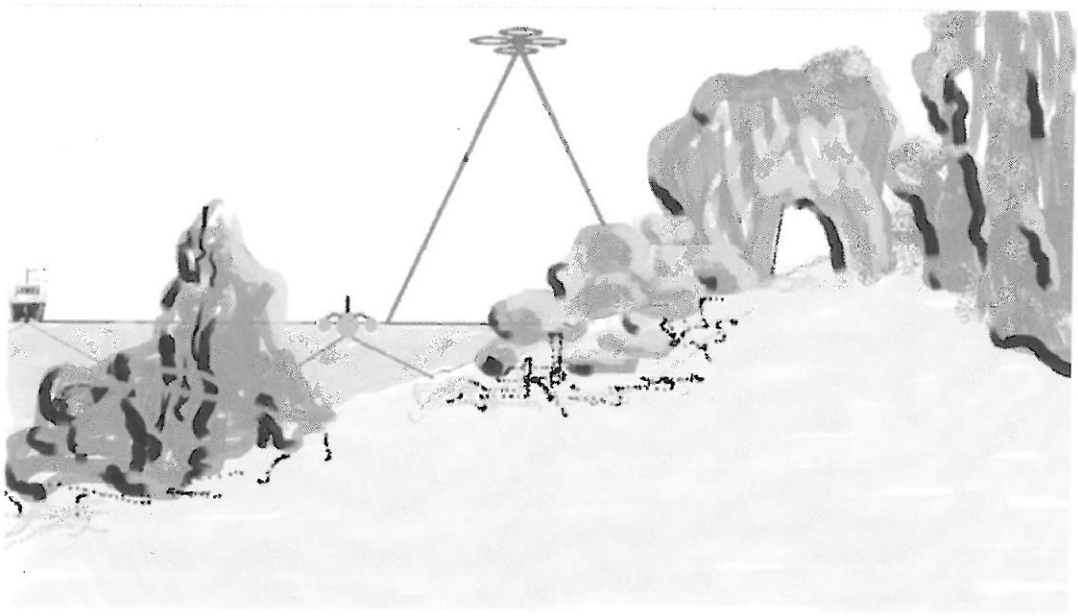
The project as per submitted proposal involved the development of an experimental control system that allows an operator to perform surveys in the near shore regions using a USV (Unmanned Surface Vehicle) piloted remotely from another vessel. The initial aim of the project was to study, develop and built a USV for very shallow water bathymetric survey e.g. in the inter-tidal zone.
During the initial project meeting INFOMAR personal suggested that we investigate the use of RV Keary as target vehicle/platform to be used in remote control, using the instrumentation and autopilot hardware controllers already installed on the Keary rather than develop a new USV within this small budget project. This decision caused significant changes in objectives and scopes of the project. The aims were changed to address the study of semi-automatic control systems to assist in inshore survey operations. In particular, the focus was on developing auto-pilot survey functionality on board RV Keary using existing equipment as much as possible.
The study and development of the trial system on board RV Keary is a good first opportunity for the seed project towards development of larger scale inshore USVs.
The project has been focused on the development of the components necessary to upgrade the standard function available on The Autopilot SIMRAD AP 35 aboard RV Keary to enable trajectory

tracking and path following in order to achieve 1-click survey functionality.

Next two figures show examples of blended survey approach involving:

- In-shore survey vessels: Keary & Geo,
- USV,
- UAV,
- Both USV & UAV with auto-nav & remote supervisory pilot control via radio link from pilot aboard vessel or off road vehicle ashore.



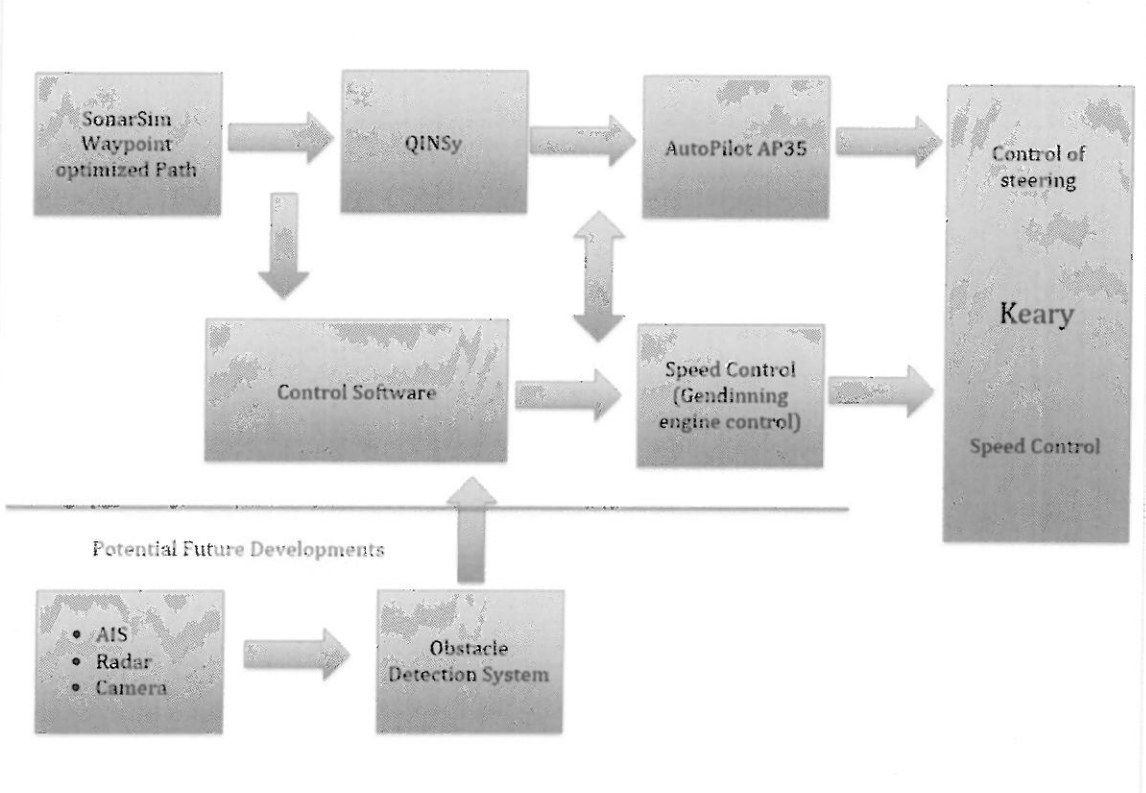


(ii) Implementation (including reference to timelines, milestones, management)

The first part of the project was dedicated to the study of the characteristics and functionality of the equipment of RV Keary relevant to the project, in particular:

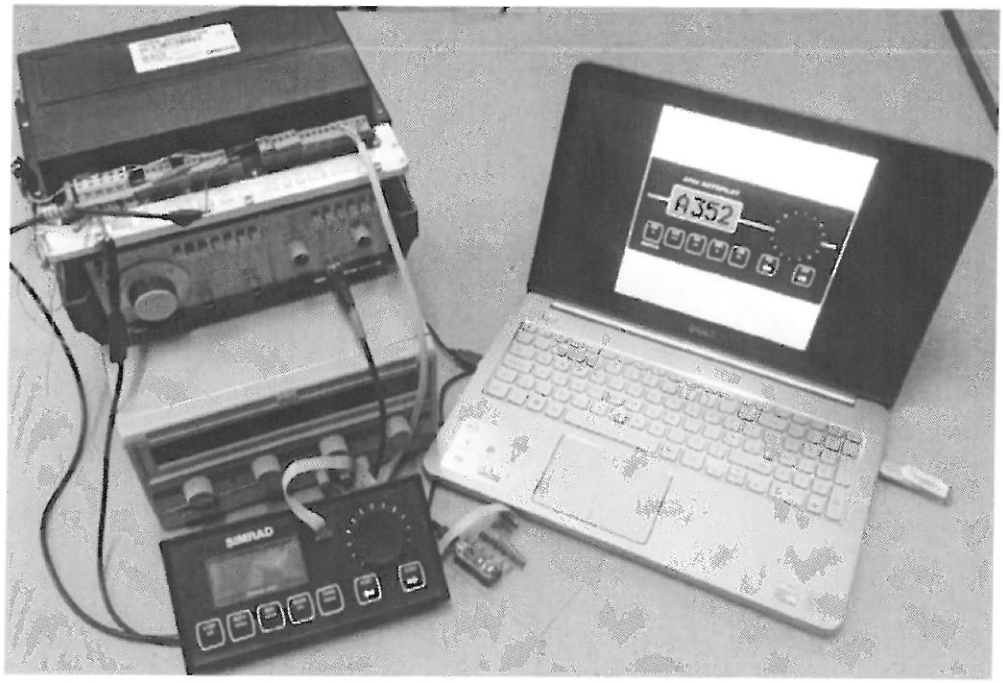
- Inertially-Aided Real-Time Kinematic System (IARTK) POS MV,
- Autopilot System SIMRAD A35,
- Power Control System Glendinning EEC4,
- Integrated navigation system software QINSy ,
- Run line optimization software Map by SonarSim.

In June 2016 MMRRC Engineer (Pierantozzi) and SonarSim engineer (Flannery) spent a full day on board of Keary during survey operations, (SonarSim is involved in a separate related GSI Short Call project). This provided an in depth understanding of how the automated system should work and the specification of the control system.
The next step was to develop and study the best way to integrate the entire suite of components in a single control system. The architecture of the proposed solution is shown in the following block diagram:



The main limit of the Autopilot SIMRAD AP35 is that it is not equipped with speed sensor and speed control. The auto pilot receives a list of one or more waypoint from the QINSy software and the Line of Sight algorithm is used to generate heading set points. Without speed control it is impossible to achieve full automatic control of the boat. The AP35 is developed to control the boat in trajectories with small course changes. For higher course changes the AP35 requires the approval by the operator via interaction with physical controls interface. This problem has been resolved in this project through the study and development of a software/hardware interface capable of controlling these manual functions in an automatic way.

The GSI provided MMRRC with an identical AP35 System (the same model as aboard Keary) for development and testing. The following pictures show the electronic and software interface developed:

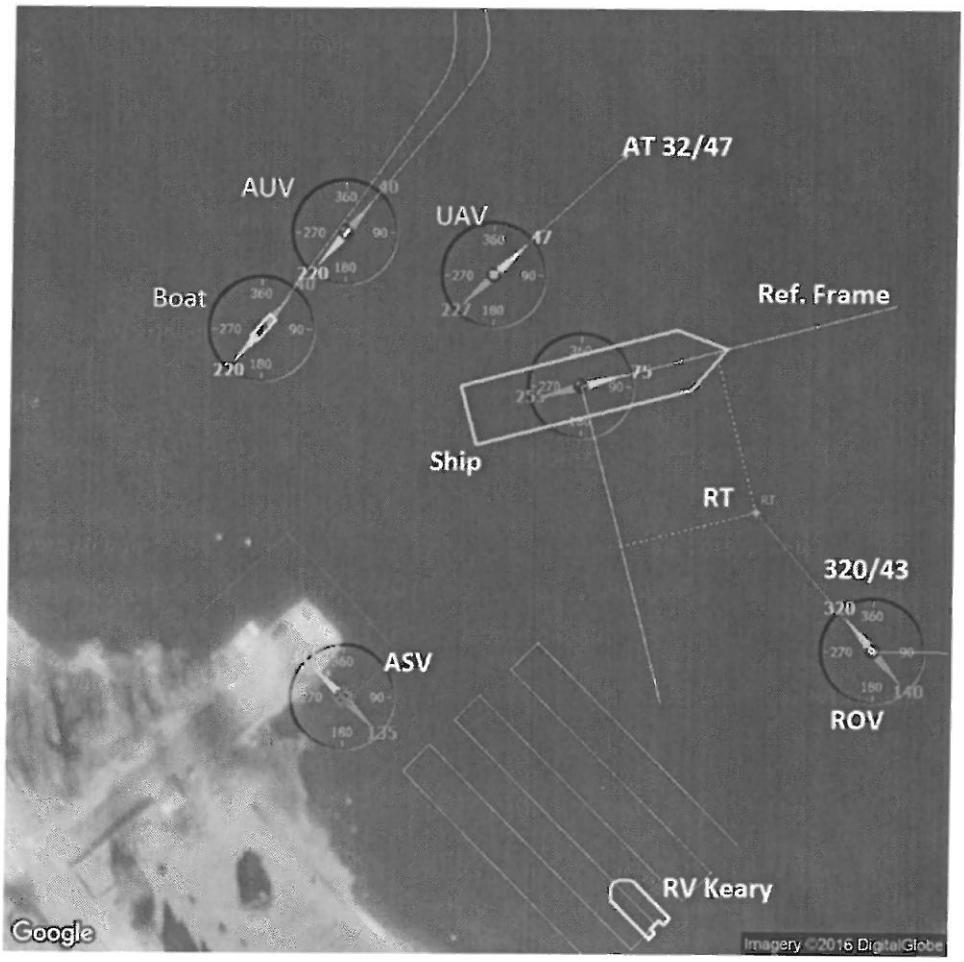


We have also developed a test rig to validate control algorithms using hardware-in-the-loop setup, which include the following components: laptop, junction box, rudder feedback sensor simulator and autopilot HMI.

NMEA 1083 simulator running on laptop has been used to generate messages (telegrams), which are send to the junction unit via USB-RS485 interface.

Signal for simulation of the rudder feedback sensor has been generated by wave signal generator and feed to junction box (Centre: 3400 Hz, 20 Hz/degree of change). HMI display shows received data (input data). The output control signal from the autopilot to the actuators can be monitored via oscilloscope. This setup provides a framework for system testing in near real-world conditions.

Over the last twelve years, the research team at Mobile & Marine Robotics Research Centre (MMRRC), University of Limerick has been focused on the development of OceanRINGS – a suite of smart technologies for marine and subsea operations. The MMRRC research incorporates development of support technologies for subsea operations, including fault-tolerant ROV control systems, enhanced operator interface, survey planning and system integration tools, real-time side-scan, multi-beam and marine vessels simulators, and the development and integration of sensors for environmental sensing. Recent research activities focus toward development of user interfaces for interaction with heterogeneous vehicles in smart Cyber-Physical Systems. For this GSI Short Call Project "Unmanned Surface Vehicle for Inshore Bathymetric Survey" Edin Omerdic, Senior Research Fellow, has worked to interface the developed RV Keary autopilot systems of this Short Calls project with the existing visualisation tools of Ocean Rings.
An example of 2D mission visualization is shown in the following figure.



There are seven vehicles performing various tasks: (i) an ASV – performing wall inspection; an AUV and Boat – with synchronized motion; a UAV – moving to an Absolute Target (AT); a support Ship – holding position in Dynamic Positioning (DP) mode; an ROV – moving to a Relative Target (RT), defined relative to Ref. Frame attached to the Ship; the RV Keary performing survey operations. The I/O interfaces with each vehicle and adjusts offsets (lever arms). The sensor fusion module provides real-world sensor information for the purpose of updating the pose of each vehicle on the 2D display with geo-referenced background maps. Floating heading indicators (showing true and inverse heading of each vehicle) move together with the associated vehicle represented with 2D contour top view. Distance D and bearing B from a vehicle to a target are shown as a pair D/B next to the connecting line (for example, the indicator 32/47 next to the line connecting UAV and AT means that the distance between them is 32m and the bearing from UAV to AT is 47°).

Some limitations of the proposed approach, learned over the project lifetime, are:

- Use of the boat AP35 as part of the main control system has imposed significant constraints on the performance of the overall control system: for example, the lack of direct speed control significantly reduces vessel's manoeuvrability required during survey in shallow water (e.g. frequent change of direction, U Turn, quick change of course, etc all require speed change capability)

- Existing actuators configuration on RV Keary with two rear propellers and a rudder belongs to the class of under-actuated systems, since the lateral motion (sway DoF) is not directly controllable. For high precision navigation in shallow water in the presence of external disturbances (waves, wind, current) direct control of lateral motion is highly desirable.

(iii) Project Outputs (please use bullet points)

- Development of a deep understanding of the problems connected with high quality survey in shallow water using a USV.

- Study and Development of control system components required for the semi autonomous use of the Keary or Geo using the Autopilot System Simrad AP35 already on board of these vessels.

- Development of a simulation station in our lab to test the autopilot system, including an interface for communication (NMEA 1083) and a simulator for the system components present on the Keary; heading sensor; rudder feedback sensor; engine power control.

- Study, design and development of an interface hardware/software solution (Arduino Nano based) for the control of the physical pilot interface of the AP35.

Impact/value of the project (*Max 500 words*):

The study has provided a recommendation and path to implementation of autonomous control of offshore survey boat. This solution can be used as a reference point when similar implementations need to be realised. The offshore survey industry is moving towards more automated systems with the realisation of software packages such as the SonarSim MAP. The implantation of hardware solutions, similar to the output of this project, goes hand in hand with the rollout of these automated systems and future impacts include significant reductions in survey time and costs.
Furthermore, the project has provided the opportunity to develop collaborations between Mobile & Marine Robotic Research Centre, INFOMAR and SonarSim.

While this Short Calls project has facilitated the initiation of technology development for inshore bathymetric survey with autopilot aboard RV Keary, a larger future collaborative project is recommended to take the project to a more developed operational survey stage including USV systems development complete with in-shore field trials.