Rapid-prototyping and field deployment of a USV for the Metropolitan Police

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I. Background

The Metropolitan Police have a nationally deployable team of specialised divers capable of carrying out a variety of underwater missions. These range from search and recovery of missing persons to the collection of evidence. Typically, the divers are required to operate in confined shallow-water environments with low visibility (canals, lakes, water reservoirs, etc.) and they must deploy and complete their tasks within very short time frames. Due to their unique training for these difficult conditions and their limited numbers (84 in England and Wales and 34 in Scotland), they are a valuable resource that is in extremely heavy demand.

Researchers at the University of Bath are assisting the Metropolitan Police by developing autonomous robotic systems to aid and complement the capabilities of their divers. The aim is to develop an ultra-portable and fully autonomous robot equipped with sensors that can inspect the underwater environment for objects of interest (e.g. evidence, weapons, and improvised explosive devices) as well as potential hazards to the divers. This enhanced situational awareness will contribute to greater effectiveness, efficiency, and safety of the team.

II. Rapid prototyping

A series of unmanned surface vehicles (USVs) have been created via a "rapid prototyping" approach using a combination of laser-cutting, 3D printing, and off-the-shelf components. This design methodology has facilitated the rapid construction of light weight and configurable prototypes, using a highly modular approach. The ability to dynamically configure both the vehicle chassis and the electronic payload is vital in the design of a USV family that can operate in a wide range of environments and mission profiles. Depending on the required payload the hull configuration may be either catamaran or trimaran. An example is illustrated in Figure 1 for a trimaran with multiple sonar payloads.

III. Autonomous Navigation

The USV prototypes are propelled by two thrusters in a differential drive fashion. They can be operated by remote-control or by autonomous GPS way-point following. The GPS way-points can be defined at the start of an excursion or may be added dynamically based on data received from the sensing payloads. A long range point-to-point communications link is maintained to a shore based control station. Real-time data from all USV systems are transmitted using this link and the operator may take control at any time. Data from on-board GPS and inertial sensors are aggregated to provide a reliable heading. An automated guidance system then provides thruster commands in order to travel from one way-point to another.

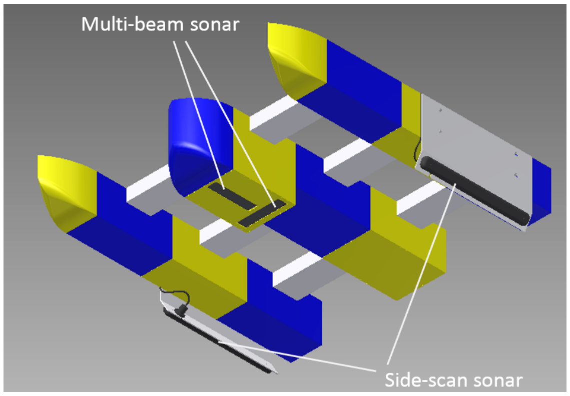

Fig. 1: Rendering of a trimaran hull structure with locations of the side-scan and multi-beam echo-sounder labelled. All structural components are either 3D printed or laser cut.

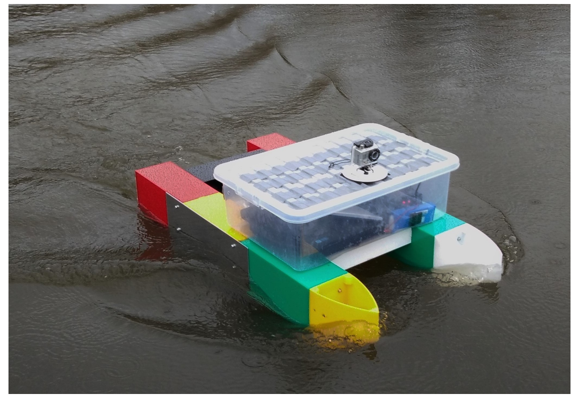

Fig. 2: A catamaran configuration in operation performing autonomous navigation and side-scan sonar mapping of the Kennet and Avon Canal in Bath, UK.

IV. Remote Sensing

A. Above water

Two high resolution cameras are fitted to the platform. One is fitted to the top of the platform, as illustrated for a catamaran hull in Figure 2. This camera is used for remote inspection of the vehicle path. Future iterations of the autonomous control system will use this camera as the basis for obstacle avoidance.

B. Below water

The other camera is mounted below the water level and is designed to closely inspect features in shallow water. Investigations are being undertaken to assess the possible improvement in image quality attained by using underwater illumination.

In addition, the platform is equipped with a side-scan sonar, providing wide-area surveillance in the order tens of metres either side of the platform. This allows large swaths of terrain to be mapped rapidly, picking up features of potential interest. A multi-beam echo-sounder is also used, which is able to produce a high-resolution three dimensional map directly beneath the platform. This imaging system may be used to interrogate features detected by the side-scan sonar at much higher resolution. By fusing the data collected by these systems and the platform's GPS location, it is possible to localise these features and display them for human or autonomous classification.

The side-scan system has a maximum range of 100m, a minimum across-track resolution of 5cm and a horizontal beamwidth of $0.5°$. The multi-beam echo-sounder has a total beamwidth of $42°$ consisting of 64 individual $1°$ beams. An example side-scan image formed by fusion with co-registered GPS data is illustrated in Figure 3, where the canal wall may be seen just to the left of the platform's path. This test site is relatively flat expanse with few features of interest as can be seen on the right side of the image. Future testing will be performed using known test targets to assess the true capability of the system.

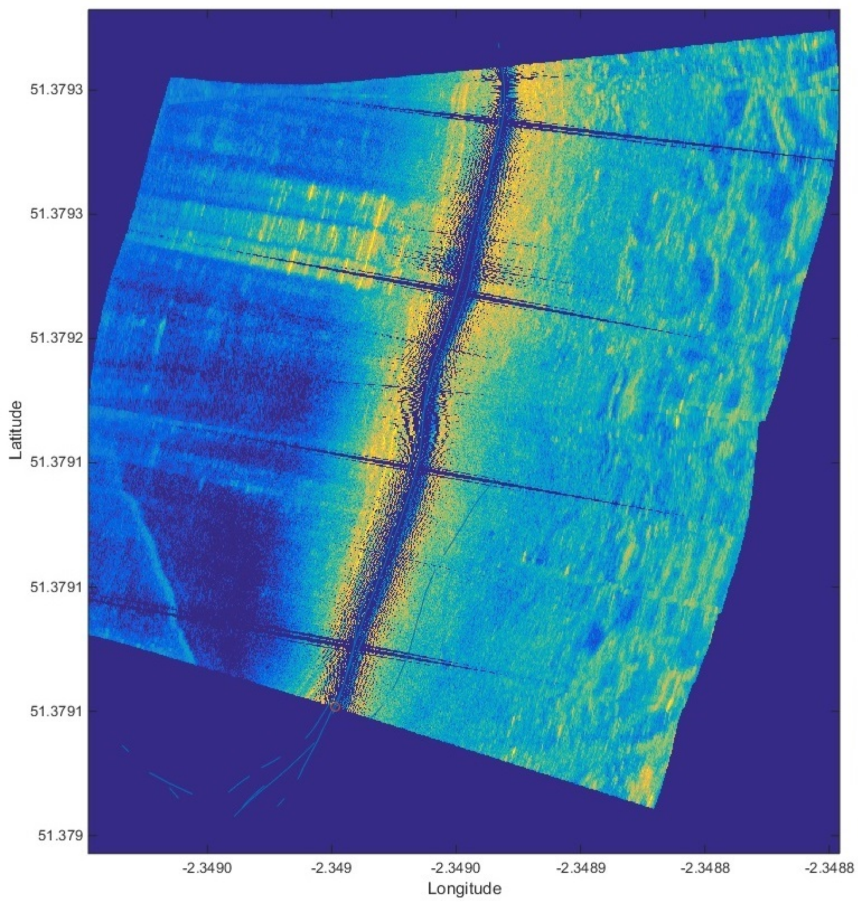

Fig. 3: Co-registered GPS and side-scan sonar data, collected by the catamaran vessel of Figure 2 in the Kennet and Avon Canal in Bath, UK

V. Future work

The prototype is being delivered to the Metropolitan Police presently. The next phase of work will focus on the specific application of evidence detection in water and aims to transition from a proof-of-concept towards a commercial product. To this end, further developments are required to deal with automated data interpretation and object recognition, intelligent path planning and obstacle avoidance, and human interfacing. It will also be crucial to test, demonstrate, and evaluate the performance of the system with relevant experimental trials.

VI. Acknowledgements

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