Marine Robotics Research at the ACFR

The ACFR, as operator of a major national Autonomous Underwater Vehicle (AUV) Facility, conducts AUV-based surveys at sites around Australia and overseas in collaboration with institutions including the University of Tasmania, the University of Western Australia, the University of New South Wales, James Cook University, AIMS, CSIRO, the Woods Hole Oceanographic Institution, the University of Rhode Island and the University of Nottingham. These AUV surveys are designed to collect high-resolution stereo imagery and oceanographic data to support studies in the fields of engineering science, ecology, biology, geoscience, archaeology and industrial applications.

One of the major challenges with this program is managing, searching through and visualizing the resulting data streams. Our recent research has focused on generating high-fidelity, three-dimensional models of the seafloor; precisely matching survey locations across years to allow scientists to understand variability in these environments; and identifying patterns in the data that facilitate automated classification of the resulting image sets.

Providing precise navigation and high-resolution imagery lends itself to novel methods for data discovery and visualization. As a result, we have a strong focus on methods for interacting with and discovering patterns in the data using machine learning techniques. We also have a strong record of engagement with end users in a variety of domains interested in understanding marine environments. We have a number of opportunities for postgraduate students to join our team and make significant research contributions in the area of marine robotics. Prospective students will work closely with research staff in the group to develop an engaging study topic. Recent examples of studies facilitated by our research include the following.

IMOS AUV Facility

The ACFR leads Australia’s Integrated Marine Observing System (IMOS) AUV Facility. IMOS is a nationally coordinated program designed to establish and maintain the research infrastructure required to support Australia’s marine science research. It has, and will maintain, a strategic focus on the impact of major boundary currents on continental shelf environments, ecosystems and biodiversity. The IMOS AUV facility generates physical and biological observations of benthic variables that cannot be cost-effectively obtained by other means and this project will provide support for its fifth year of operation and into the future. We have established an Australia-wide observing program that exploits recent developments in AUV systems to deliver precisely navigated time series benthic imagery at selected reference sites on Australia’s continental shelf. These AUV-based observations are providing a critical link between oceanographic and benthic processes for Australia’s IMOS program.

IMOS scientific end users have defined the location, extent and frequency of surveying of the sites that are being visited by the Facility’s AUVs. Over the course of four years we have conducted hundreds of dives at sites located around Australia, resulting in millions of high-resolution, geo-referenced images. Figure 1 shows a summary of the dive locations visited during this period. The
focus of the sustained observing program has been on the establishment of benthic reference sites on both the east and west coasts along the full latitudinal range of the continent. The symbols on the figure designate the location of the survey sites and are colour coded by dominant habitat and sized proportional to the number of images currently available in the IMOS AUV Facility image archive.

Figure 1 - Survey locations around the Australian coast for AUV imagery. The circles are coloured by dominant habitat type and scaled based on the number of images currently available in the IMOS AUV Facility image archive. The dashed circles at the Solitary Islands and the Southern Great Barrier Reef represent sites to be established in 2012.

Clustering in Large Image Archives
The use of robots for scientific mapping and exploration can result in large, rapidly growing data sets that make complete analysis by humans infeasible. This situation highlights the need for automated means of converting raw data into scientifically relevant information. We have developed Bayesian clustering models for the labeling of large quantities of seafloor imagery in an unsupervised manner. This approach has the attractive property that it does not require knowledge of the number of clusters a-priori, which enables truly autonomous sensor data abstraction. The underlying data representation is also learned using unsupervised feature learning techniques. This approach consistently produces easily recognisable clusters that approximately correspond to different habitat types. These clusters are useful in observing spatial patterns, focusing expert analysis on subsets of seafloor imagery, aiding mission planning, and potentially informing real time adaptive sampling. Figure 2 shows an example of these techniques applied to coral reef data collected at Scott Reef on the North West shelf in Western Australia.
Figure 2 – Bayesian clustering of large volumes of data collected by an AUV operating over a coral reef at Scott Reef in Western Australia. The middle top figure shows an overview of an area surveyed by the AUV. The objective was to target the interface between coral and sand. Below this is a figure showing the cluster label assigned to each image based on colour, texture and structural cues extracted from stereo imagery. Corresponding examples from each cluster are shown in the thumbnails in the columns on the side, with the border corresponding to the cluster labels. There is clear spatial correlation in this data suggesting that the clustering algorithm is identifying examples corresponding to distinct habitats – in this case sand, rubble and various species of coral.

Marine Archaeological Studies
Recent work in collaboration with our partners has focused on collecting imagery to support the study or marine archaeological sites. Examples include the survey of a Neolithic settlement site off the coast of Greece, the site of a naval battle from the first Punic war that took place off the coast of Sicily in 241BC and numerous shipwrecks and hydrothermal sites around the Black Sea and Mediterranean. These surveys have all exploited our developments of advanced AUV survey techniques together with the ability to combine the resulting imagery to yield detailed three-dimensional models of the seafloor to provide archaeologists with a unique view of these sites. Visualisation of the resulting models can provide new insights into the layout of artefacts.
Figure 3 – Examples of archaeological surveys conducted using high-resolution stereo imagery. (a) and (b) show examples of data collected by the University of Rhode Island using a Remotely Operated Vehicle. Visualisation of the resulting texture-mapped surface models shows the layout of the amphorae surveyed. (c) shows an example of the foundations of a neolithic settlement site surveyed off the coast of Greece. The top image shows the texture-mapped model while the lower image shows the 3D structure. Overlaid on top of the structure is an archaeological survey of the same structure created using a laser based surveying tool.