AUVs as Integrated Acoustic Sensors for Concurrent Detection, Localization and Classification in Littoral Mine Countermeasures

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Summary

Autonomous Underwater Vehicles (AUV) are rapidly being transitioned into operational systems for national defense, offshore exploration, and ocean science. AUVs provide excellent sensor platform control, allowing for e.g. accurate acoustic mapping of seabeds not easily reached by conventional platforms, such as the deep ocean. However, the full potential of the robotic platforms is far from exhausted by such applications. Thus, for example, most seabed mapping applications use imaging sonar technology, the data volume of which cannot be transmitted back to the operators in real time due to the severe bandwidth limitation of the acoustic communication. The sampling patterns are therefore pre-programmed and the data is stored for post-mission analysis, with indiscriminate distribution of the sampling throughout the area of interest, irrespective of whether features of interest are present or not. However, todays computing technology allows for a significant amount of signal processing and analysis to be performed on the platforms. For example new approches for concurrent detection and mapping in unknown environments may be implemented on the platforms, the results of which may subsequently be used autonomously for real-time, adaptive sampling to optimally concentrate the sampling in area of interest, and compress the results to a few parameters which may be transmitted back to the operators. Such new autonomous and adaptive sensing concepts for concurrent detection, localization and classification of proud and buried objects, combining environmental acoustics, signal processing state-of-the-art robotics, are being developed under the SACLANTCEN-MIT GOATS Joint Research Program [1-6]. [Work supported by ONR and SACLANTCEN].

GOATS'2002 Experiment

Figure 1 GOATS'2002 Odyssey III acoustic payload. (a) Twin line array mounted in nose of the AUV. (b) Pressure vessel with 16 channel DSP-based acquisition system, and Edgetech sub-bottom profiler source configured for insonifying the seabed at 30 degrees grazing angle.

In the GOATS'2002 experiment in May-June 2002, a new state-of-the-art Odyssey III AUV from Bluefin Robotics was equipped with a 16-channel acoustic array in a nose-configuration, and a DSP-based data acquisition system. This vehicle was also equipped with an Edgetech sub-bottom profiler source in a low grazing angle configuration for insonifying the seabed. This monostatic system was used for exploring concurrent mapping and localization of proud and buried targets using mono-static, focused synthetic aperture processing. Figure 1 shows the AUV with a 2x8 element twin array, and the acoustic payload section with the source in a 30 degree grazing angle configuration. As in the previous GOATS'98 and '2000 experiments [1] a number of proud and buried targets, such as spheres and cylinders, were deployed. In addition, the Framura area NW of La Spezia, Italy, where the experiment was carried out contained a field of concrete blocks, deployed to protect a sea cable. This target area was particularly useful for the feature-based navigation and mapping component of this experiment, the results of which are described below.

Results

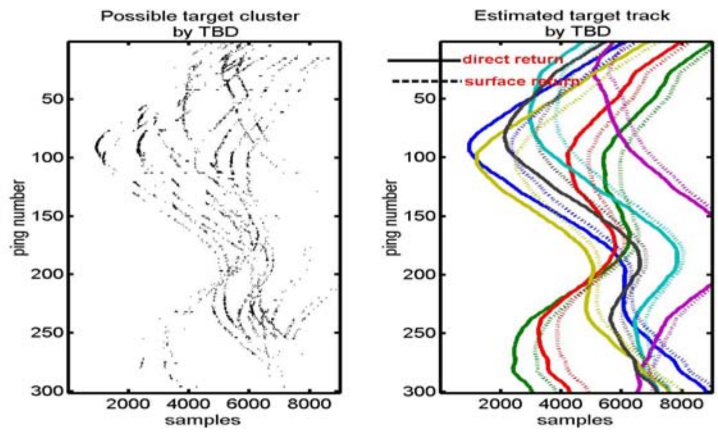

Fig. 2. Detections (left) and estimated target tracks using the Track-Before-Detect algorithm (right).

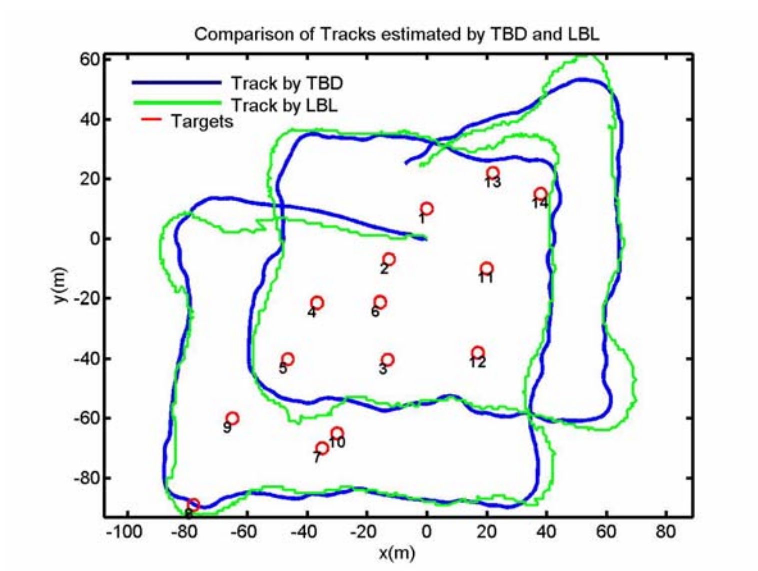

Fig. 3 Map of target locations corresponding to TBD tracks in Fig. 2.

The most recent result of the GOATS research program is the development and demonstration of a new Track-Before-Detect algorithm for concurrent target detection and localization, and platform navigation. In contrast to traditional methods based an detection followed by tracking, this technique uses successive pings to track the possible AUV trajectory and targets, and declares a target detection once the integrated detection metric exceeds a threshold, dynamically adjusted according to the background reverberation. The two major advantages of the TBD for adaptive target detection are: (i). The AUV can navigate by itself in the target field while detecting targets without using any external navigation instruments. This brings a higher level of autonomy to the AUV and less hardware constraints. As will be demonstrated below the TBD can track the AUV trajectory with comparable accuracy to an LBL system, (ii). By coherently summing the time signals over the estimated AUV path, dim targets may be more readily detected. The effect of this method is to provide a synthetic aperture sonar (SAS) signal gain without the strict constraints on the sonar platform motion that are typical of SAS processing. The TBD algorithm therefore provides more information on potential targets while the AUV adaptively searches for targets of interest.

The new TBD algorithm has been applied and demonstrated for the GOATS'2002 data collected in the cable area containing dozens of partially buried concrete blocks. Figure 2 shows the possible target tracks fitted to the AUV track without any predefined threshold and the corresponding estimated tracks of the targets relative to the AUV. The instrumentation tones are eliminated due to their ping-to-ping lack of coherence. The bathymetry returns and multi-path returns from targets are identified as such using the planar beamforming capability of the AUV array, and used for AUV navigation and target detection, respectively. In a traditional scheme, these multi-paths could be treated incorrectly as targets or be filtered out by the constraint of the known AUV dynamics. Thus, the TBD has the ability to eliminate clutter and detect the target tracks without eliminating dim targets and to distinguish the target multi-paths using the estimated AUV tracks. The target map created by the TBD algorithm is shown together with the estimated AUV track in Fig. 3, with green and blue tracks showing the AUV path as determined by the long baseline navigation system and the TBD algorithm, respectively.

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