Advanced PMA Capabilities for MCM

Shorten the sensor-to-shooter timeline

New sensor technology deployed on off-board underwater systems provides navies with improved imagery and data for the purposes of Mine Countermeasures (MCM). However, the cost has been a loss of situational awareness to the operator due to data overload, and an increase in the requirement to train a growing number of expert operators. These operators must be capable of interpreting complex sensor data with a high degree of confidence and in a repeatable manner. When performing Post-Mission Analysis (PMA) of underwater data collections, a highly trained team of operators must analyze large volumes of data over time. It is easy (and human nature) for performance to wane over time; thus, navies have adapted procedures to deal with known human performance shortfalls. SeeByte, a world leader in underwater sensor data management and fusion, has been developing tools that are not meant to replace the operator, but assist him, with little supervision, allowing for more repeatable PMA performance, as well as more complete underwater situational awareness. These solutions reduce processing time and provide a consistent, measurable level of performance. The solutions have a direct impact in helping to shorten the sensor-to-shooter timeline.

The suite of underwater data management and sensor fusion tools, developed by SeeByte, is called SeeTrack Military (or COIN within the US Navy). For Side Scan Sonar (SSS) equipped systems, the software suite includes an Automated Target Detection (ATR) product that is trained by the operator to look for specific targets in the data and to consistently call those targets in the geographic information system map; a Seafloor Classification product that provides the operator with another layer consisting of a geo-referenced map of the survey area, highlighting different areas of seafloor terrain; a bathymetry map layer, presented as a color image depicting the depth of the water, as well as a temperature map layer and water current, if that specific data is collected. These map layers are then used for towed SSS and Autonomous Underwater Vehicle (AUV) mission planning and will highlight differing areas of sea floor to distinguish which areas are more huntable, and those that are more difficult to fix, locate, and destroy mine targets.

Once the “huntable” regions are identified, the operator may further assess the amount of clutter by using the SeeByte Clutter Density product. Clutter density maps allow an operator to highlight regions where the seafloor is complex and problematic for an ATR system or an operator to process. Within these areas, an ATR system is likely to provide a higher false alarm rate and would benefit from different sensor settings, different sensors, and possibly human intervention.
The most relevant tool for the purposes of MCM is the ATR. SeeByte has developed an ATR model responsible for detecting mine-like targets that processes data looking for specific object shapes within the SSS imagery. Examples include cylindrical and truncated cone mine shapes. The algorithms analyze the data hundreds of times quicker than it took to gather, and the results are obtained more quickly and repeatedly than any human operator. By analyzing the performance of the ATR for each of these targets in relation to the sensor settings and the underwater environment, the user may extract Probability of Detection and Probability of False Alarm measurements, which are statistically consistent and operationally relevant. The operator can then focus on the targets identified by the ATR, initially disregarding volumes of non-relevant data, and therefore improve the sensor-to-shooter timeline. To improve the overall performance of the system over time, the operator provides feedback to the ATR regarding missed targets and distracting non-interesting targets.

The advantages of carefully managing the PMA process and performance through SeeTrack Military (and COIN) is that comparisons of results across multiple platforms and sensors, carried out over time, may be done at the meta-data level. That is to say the user may directly compare results from surveys carried out over the same section of seabed at different times with different equipment. SeeByte’s Change Detection module automates this process by automatically comparing previous mission PMA and highlighting the differences in another layer with data that can be grouped, queried, highlighted, and correlated to further reduce processing times.

The following paper explores some of the functionality offered by SeeTrack Military (US Navy COIN).

**Seafloor Classification**

The Seafloor Classification module has been designed by leading, published experts in the field and uses the latest image processing techniques. The algorithms extract information from the pixels to define features. Different seabed types are made up of different feature bundles and advanced statistical classifiers are used to group the seabeds according to the measured features. The process has been rigorously developed, ground-truthed and tested with real and simulated data to ensure that the result is an accurate picture of the seabed. The user may define and classify any number of seabed types.

**Geo-reference results**

Creating mosaics from classified data is a complex process requiring accurate classification results and accurate navigation information to fuse the resulting geometry into different seabed types. This is because a side-scan sonar survey may contain sections were the data from one run overlaps the data from previous single or multiple runs. As the classification results and navigation are never perfectly accurate, a single point in the world might be assigned more than one single seabed type. This problem is resolved by assigning more than one type of seabed to those regions. The user can visually display each seabed type as a layer on a GIS system. The layers can be turned on or off to suit the analysis.
The result provided by the Seafloor Classification module is a very accurate geo-referenced mosaic of seabed type which can be used to assist the MCM Commander. This mosaic can also highlight regions of the seabed that have not been measured by the survey.

**Clutter Density**

Logically an ATR system, as well as a human operator, will see more potential targets of interest in cluttered environments, therefore, providing more false alarms in these areas. Unless these areas are flagged to the operator, the false alarm rate will seriously reduce performance and the operator’s trust in the system. SeeByte has developed a methodology for estimating clutter density using wavelet features to provide an estimate of complexity and anisotropy of the seafloor regions within the sidescan sonar imagery. Complex areas, such as rock beds and sea grass, are typically complex but not anisotropic (directional). Textured seafloors with varying heights of sand ripples are often complex and anisotropic. The SeeByte approach allows regions of high clutter density to be automatically identified at the same time – during the ATR processing of the imagery. This capability allows the operator to view the regions of high clutter in a very rapid, automated manner. In these areas, a more considered PMA process and possibly a different data collection may be required. The system allows the operator to quickly decide if he is interested in the ATR output from these specifically highlighted regions.

The SeeByte ATR feedback in regions of high clutter may be tailored to meet the needs of the operator. One possible response is that the ATR will output no contacts at all within high clutter areas, highlighting the need for a more focused inspection. This would seriously reduce overall mission false alarm rate, providing ATR contacts in only the easier to search areas where the Probability of False Alarm is low. SeeByte’s tools will still output all ATR contacts, but will super-impose the clutter areas on top of the results so that the operator has an increased situational awareness of why these contacts are being flagged. Through the careful use of seafloor and clutter information, the user is assured a more rigorous understanding of performance.

The ATR has detected possible contacts in 2 different images (shown by boxes). Regions of high clutter are also shown as a transparent blue layer.
Automatic Target Recognition

Automatic Target Recognition (ATR) systems are generally comprised of a Computer Aided Detection (CAD) and a Computer Aided Classification (CAC) component. The aim of these models is to highlight possible targets within the sensor data to the operator. The CAD component is designed to detect all mine-like objects (MILOC’s) from the sidescan sonar data. The CAC component then provides further analysis, and is tasked with providing a measure of how ‘mine-like’ each of the MILOC’s, produced by the CAD module, are. Based on this information, the user may decide whether the MILOC is a mine or a false alarm. SeeByte ATR is integrated into SeeTrack Military (or COIN) and allows the user to browse, QA, modify, and add/subtract to the output produced by the ATR. The ATR can also be provided as a real-time embedded module running on a small form factor PC (PC-104).

Sonar and environmental factors

The most recently enhanced SeeByte ATR uses fast, supervised classification techniques to classify typical cylinder and truncated cone shapes, which provide a step-up improvement in processing speeds and results. When the sonar resolution remains high enough to resolve an object from the background, the ATR module is often able to provide a high probability of detection, regardless of the particularities of these factors. However, as the conditions move away from the ideal, this high probability of detection may only be achievable if the false positive rate is also increased. For instance, typically on flat seabed the user may expect over 90% of mine like objects (MLO’s) to be identified with negligible false alarms. In cluttered environments, a detection rate of over 90% of MLO’s results in approximately 1 false alarm in an area of roughly 160 m². Processing times vary according to the PC platform used, the resolution of the sonar and the complexity of the object. For reference, a 1000x512 pixel image typical of short range SSS is processed in 0.1 to 0.4 seconds on an Intel I7 1.60 GHz CPU.

Operate at the contact level

The SeeTrack Military Change Detection module can be used to compare side-scan sonar data and other sensor data in order to highlight any significant changes to PMA datasets (specific regions). The key to the Change Detection module is that it operates at the contact level. In contrast, the standard approach...
of utilizing only the raw sonar image, requires running the same vehicle and sonar setup through exactly the same mission plan, so one sees the same targets, in the same manner, from the same aspect angle and compares images. This is highly susceptible to any change in the environment and requires a level of navigational accuracy which is difficult to guarantee in today’s SSS and AUV systems. SeeTrack Military Change Detection, instead, compares the contact meta data, considering the imagery as well as the location and spatial distribution of the contacts within the surveyed region, to flag possible new threats (or, conversely, those that are now missing). Operator or ATR selected contacts and ground truth may also be used in the process.

**Different asset, different sensor**

By carrying out the change detection at the contact meta data level, it is possible to compare data sets that have been collected with different assets over time. Any sensor or vehicle which is compatible with SeeTrack Military or SeeTrack Professional can contribute to the change detection process. Fusing data in this manner removes the need for the same vehicles to swim in exactly the same manner with the same sensor, because data is not being compared from the raw sonar image. This provides the operator with greater flexibility, allowing him to use a wide range of assets and to plan missions based on the Commander’s daily intent as opposed to being forced to adapt operations to fit the Change Detect capabilities.

**In operation**

The software automatically compares the data sets from two PMA’d surveys and highlights changes to the contact layer in its own layer. It highlights new contacts and also contacts that are no longer visible. The user can then observe the relevant information for each of the changed contacts.

**Further details**

The Change Detection module requires SeeTrack Military or SeeTrack Professional. Further technical details and specifications are available on request. www.seebyte.com