Object Identification Using High Resolution SAS Imagery

Introduction

The classification of seabed features has traditionally been accomplished using side scan sonar in combination with multibeam echosounder (MBES) data (Hamouda, 2021). This process typically requires multiple passes over an area and is limited by resolution degradation toward the outer edges, limiting the ability to accurately identify targets (*IHO Manual*). Once located, a potential target is flagged for further investigation to identify the object. These site investigations are conducted prior to the installation of structures, remediation work, or for the detection of military mines and unexploded ordnance (UXO).

Synthetic aperture sonar (SAS) is gaining recognition in the industry for its higher resolution capabilities and faster data collection times. SAS imagery provides high-resolution images across wide swath coverages, significantly improving the ability to identify surface targets. Its versatility - being mountable on a range of platforms including remotely operated vehicles (ROVs), automatous underwater vehicles (AUVs), and towed systems - enables effective surveying across all water depths and seabed environments.

SAS allows for more accurate identification of debris and geological features. Metallic features, for example, typically display with higher intensity compared to soft or organic materials. Accurately characterising targets supports informed decisions regarding necessary remediation or removal efforts. SAS also aids in detecting and classifying seabed types such as distinguishing between boulder-covered areas and those consisting of fine sediment such as silt (Steele, 2023).

The Technology

SAS is a form of side scan sonar that emits a pulse of sound perpendicular to direction of travel and uses the returning signal to generate an image. Aperture refers to the array length; longer apertures yield narrower beamwidths and increased range capabilities. Figure 1 demonstrates the relationship between increasing aperture or array length and decreasing beamwidth or resolution. Sonar resolution refers to the size of the smallest detectable object within the sonar image (Dillon & Charron, 2019).

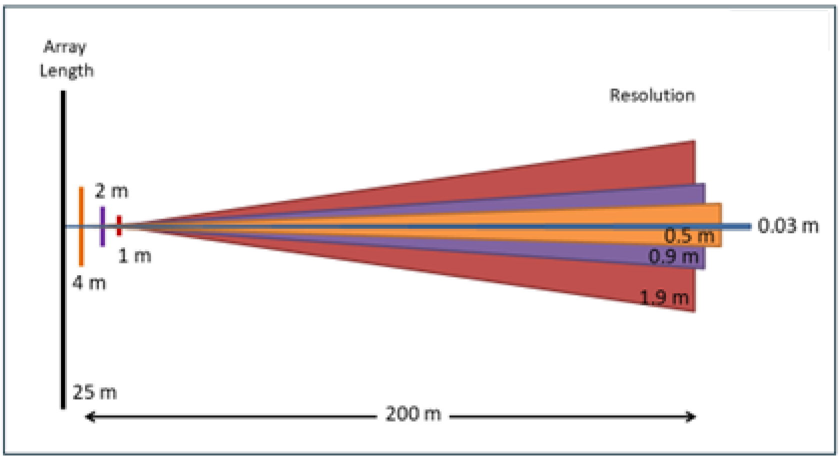

Figure 1 *Variation in array length and effects on resolution*

The SAS aperture length is adjusted by combining numerous pings as the vehicle travels forward to maintain a constant along-track resolution of 3.33 cm. Kraken Robotics MINSAS technology maintains the 3 cm across-track resolution using a modulated chirp transmission. The bandwidth of the chirp is 40 kHz; advanced signal filtering of the returning pings is used to achieve the resolution independently from the pulse length (Dillon & Charron, 2019).

MINSAS systems use a transmitter array with an operational frequency of 337 kHz. The number and configuration of receiver arrays is based on several factors including the survey application and the vehicle/tow-body on which the sensor is being integrated. As shown in Figure 2, each receiver array contains 32 elements - 16 each on the top and bottom rows - which can be assembled in a configuration of 1-3 arrays per side. The energy of the pulse emitted back to the receiver arrays is referred to as backscatter (Steele & Lyons, 2024). The intensity of the backscatter is measured against the travel time required to receive the transmitted pulse. The transmission time and speed of sound in water is used to compute the distance travelled. The backscatter is mapped to a colour pallet, and through the colormap and distance travelled, a horizontal row of across-track pixels is generated. As the sensor travels forward and collects consecutive rows of data, this forms the along-track part of the image.

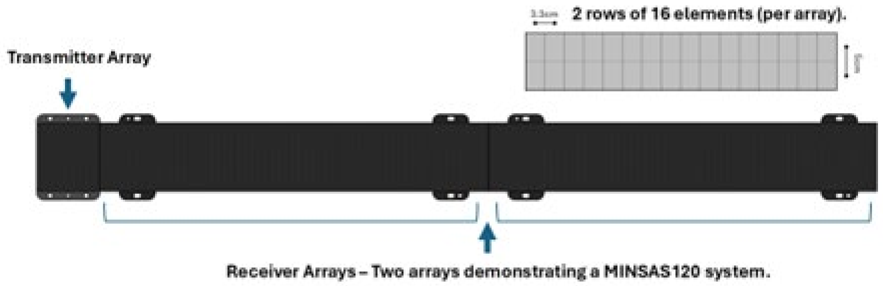

Figure 2 *Plan View of Kraken Robotics MINSAS 120; One of two identical sensors mounted on either side of a vehicle.*

Seabed Object Identification

Object detection is present in many applications such as route surveys, mine countermeasures, geohazard detection, and geological surveys. Most of these applications require precise resolutions to yield a higher number of objects quantified while maintaining high confidence in object picks (Steele, 2023).

The high-resolution imagery provides the ability to accurately depict seabed objects, but the backscatter intensity also contributes significant information for object identification and classification. Seabed objects of various composition have different impedance values which affect how the signal pulse is reflected. For example, dense material such as metal will have a strong acoustic return. As illustrated in samples B, E, and H of Figure 3, the metallic frames of these objects reflect much more acoustic energy compared to the surrounding silt-based seabed. Softer materials, such as rope or wood, reflect lower acoustic energy back in comparison to metals, as illustrated in Figure 3, samples D and G. However, aside from object composition there are other factors that affect these intensity values, such as acoustic velocity, and the angle at which the signal is reflected (Steele & Lyons, 2024).

Side-looking SAS imagery provides the advantage of shadow information. Equivalent to a source of light, a sound signal will also cast a shadow when projecting onto objects. The shadow orientation and shape are altered based on the angle and height at which the object is imaged (Abu & Diamant 2022). In some situations, this can provide more information for object analysis than the top-down perspective alone. Sample E in Figure 3 displays a seabed object with a strong intensity value. From a top-down view the object appears linear and relatively small, however when utilising the shadow, the object can be easily identified as a bicycle.

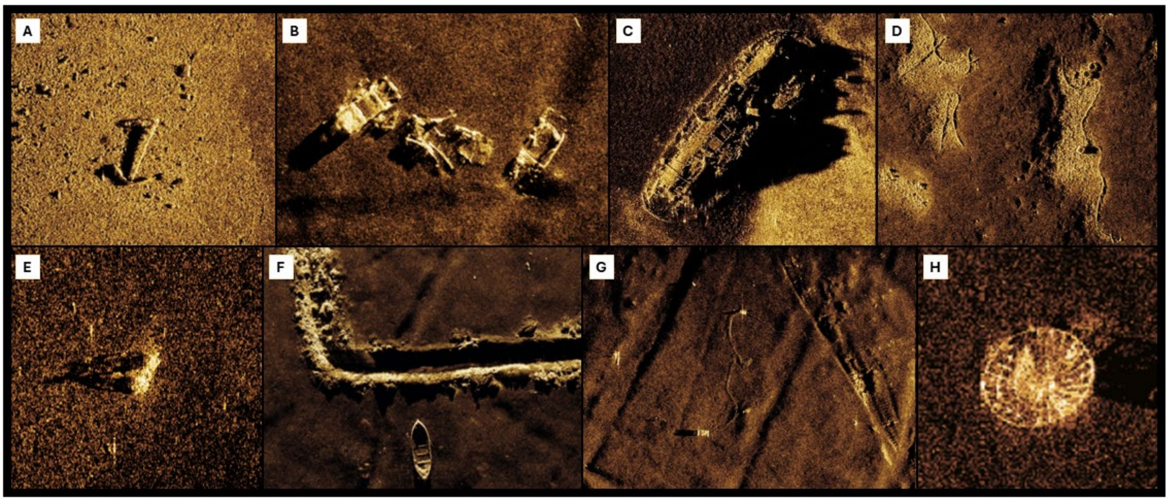

Figure 3 *Debris examples found during Harbour Surveys. A) Anchor, B) Car Frames, C) Shipwreck, D) Rope, E) Bicycle, F) Dorie with scour, G) Crab Pots and H) Satellite dish.*

Constant Resolution for Confidence in Classification

Kraken Robotics SAS data is broken down into blocks of data called tiles (.til). Each tile measures 50 m of length in the along track, and an across-track range of up to 200 m per side, which is determined by flying altitude, speed, and platform used for survey, maintaining a constant resolution of 3.0 x 3.33 cm. The range and frequency of the system has no effect on the resolution (Dillon & Charron, 2019). The constant resolution of SAS provides the ability to interpret data and identify man-made and natural objects with the same precision and confidence throughout the entire data block. Man-made objects are typically symmetrical in form and contain straight sides and 90° angled corners. These types of objects will typically provide high amplitude returns and allow for interpretation of shadows. Conversely, natural features are more typically rounded or irregular in shape and shadow.

Figures 4 and 5 display a sample resolution target. The resolution target is a cross feature with four 5 cm spheres attached to each arm of the cross. Figure 5 displays the port side tile; the red box indicates the area of the target. The closer samples of the target in Figure 4 demonstrate the difference between real aperture sonar (3 x 25 cm), real-time Synthetic Aperture Sonar (3.0 x 3.3cm), and Ultra High-Definition SAS of target (1.9 x 2.1 cm, note: this is a post-processing feature).

Object detection with centimetre scale resolution allows for accurate depictions and identification, which is crucial for high-risk operations such as Mine Counter Measures (MCM).

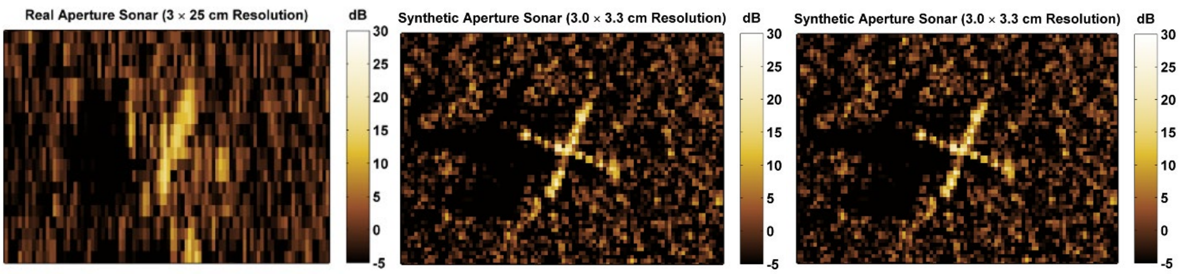

Figure 4 *Differences in Resolution of a resolution verification target*

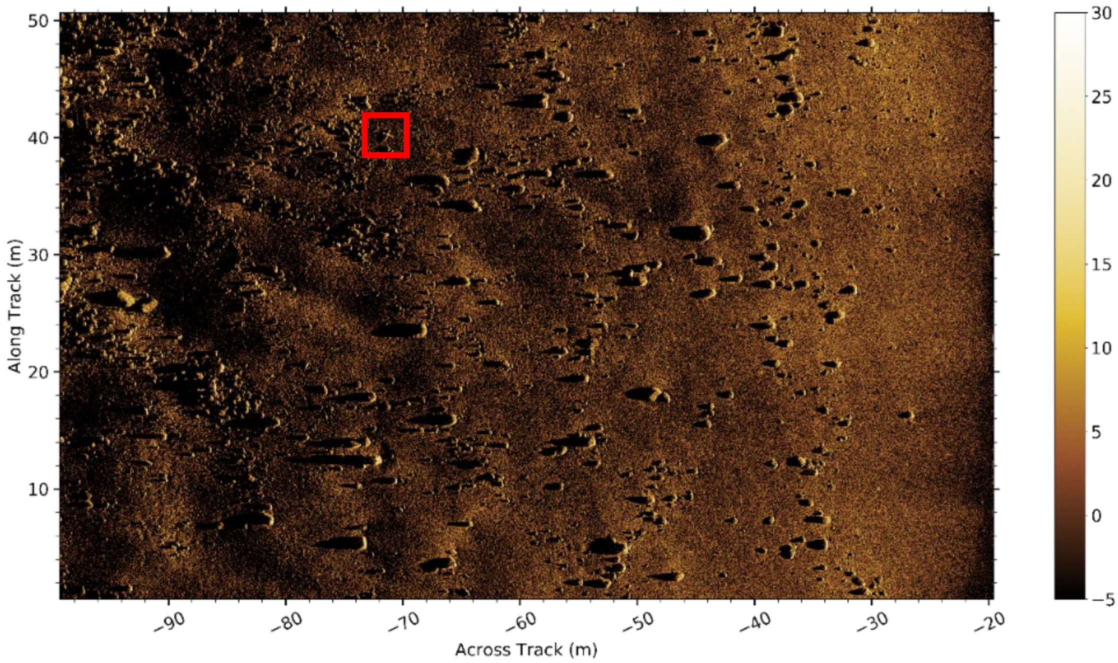

Figure 5 *Port side TIL of a resolution verification target*

Conclusions

The introduction of Synthetic Aperture Sonar (SAS) has marked an advancement in improving seabed target identification. Its ability to capture high-resolution imagery at faster speeds, over larger swath ranges not only reduces overall survey time but also minimises uncertainty in the interpretation. By accurately classifying debris and geological features, users can effectively plan for remediation or workarounds during operations. Moreover, the early detection of hazardous materials such as unexploded ordnance (UXOs), especially in high-traffic areas such as harbours, plays a critical role in safeguarding both vessels and personnel.

References

Abu, A., & Diamant, R. (2022). Underwater object classification combining SAS and transferred optical-to-SAS Imagery. *The Hatter Department of Marine Technologies, Haifa University, 199 Aba Koushy Ave., Mount Carmel, Haifa, 3498838,* Israel. https://arxiv.org/pdf/2304.11875

Amr Z. Hamouda (2021. Distinguish seabed objects utilizing different marine acoustic techniques. *National Institute of Oceanography and Fisheries. Egyptian Journal of Petroleum*

Dillon, J., & Charron, R. (2019). Resolution measurement for Synthetic Aperture Sonar. *OCEANS 2019 MTS/IEEE SEATTLE*, 1–6. https://doi.org/10.23919/oceans40490.2019.8962823

International Hydrographic Organization (IHO). n.d. *Manual on Hydrography (C-13)*. Accessed April 23, 2025. https://iho.int/uploads/user/pubs/cb/c-13/english/C-13_Chapter_4.pdf

Steele, S., & Lyons, A. P. (2024). An experimental test of end fire synthetic aperture sonar for sediment characterisation. *IET Radar, Sonar & Navigation*, *18*(11), 2057–2065. https://doi.org/10.1049/rsn2.12615

Steele, S.-M. (2023). "A Unified Semantic Segmentation and Object Detection Framework for Synthetic Aperture Sonar Imagery," *2023 IEEE International Conference on Acoustics, Speech, and Signal Processing Workshops (ICASSPW)*, Rhodes Island, Greece, 2023, pp. 1-5, doi: 10.1109/ICASSPW59220.2023.10193155.