International Journal of Engineering Inventions
e-ISSN: 2278-7461, p-ISSN: 2319-6491
Volume 2, Issue 7 (May 2013) PP: 34-40

Underwater Object Recognition

Hatem Awad Khater[1], Ahmed A. Megahed[2], A. Baith Mohamed[3]
[1]*Chief of Naval Research and Development Department, Alexandria, Egypt*
[2]*Arab Academy for Science, Technology & Maritime Transport College of Engineering, Alexandria, Egypt*
[3]*Arab Academy for Science, Technology & Maritime Transport College of Engineering and Technology, Computer Engineering Department, Alexandria, Egypt*

Abstract: *Underwater object detection is very essential issue for many civilian and military applications such as hydrographic survey for the purpose of securing navigation and anchorage areas and planning underwater communication cables, pipelines and mine detection. The aim of this work is to provide a flexible, fast and accurate underwater object recognition system for use in a variety of underwater low level images captured from underwater imaging devices, these imaging devices include (Multibeam Echo Sounder "MBES" and Side Scan Sonar "SSS") are used in different times and under varying weather and bathymetric conditions. Experiments have been done in front of Alexandria coast (between Sidi Krir and Agamy area) contains noticeable features such as pipelines which were utilized and processed. An approach was developed with the use of different software packages and applied on the prepared real data to detect objects to assure gathering of object details during the processing procedures. Results proved that our system is capable of recognizing different underwater objects such as pipelines, rocks and shipwrecks.*
Keywords: *Underwater object, Recognition, Multibeam Echo Sounder (MBES), and Side Scan Sonar (SSS).*

I. Introduction

Underwater (Hydrographic) objects are the objects that rise above the bottom surface more than a specific amount as defined by IHO survey standards [1]. Object detection normally acquires long time processing and analysis by human experts. Side scan automatic processing software packages in object recognition field (which is one of the main functions of hydrographic survey) yield obvious discrepancies [7]. This can be referred to the differences in shapes and sizes of submerged and buried objects (such as pipelines, rocks, and ship's wreck). Physical samples should be gathered at spacing dependent on the seabed geology and as required to ground truth any inference technique.

The main objective of any hydrographic survey equipment is to represent the details of the seabed, and to find its features. The nature of the seabed should be determined in potential anchorage areas; it may be determined by physical sampling or inferred from other sensors (e.g. single beam echo sounders, side scan sonar (SSS), sub-bottom profiler, video, etc.). Manual surveyor method is the base for traditional method for processing side scan data that is still in use today by many software applications. This approach means each line of side scan data is loaded and then a section of that line is examined for man-made objects and outliers, which are manually edited out accordingly. Then comes the role of simple automatic data cleaning algorithms for MBES data.

Despite the fact that manual processing techniques became impractical to deal with massive amount of collected data and having a fatal time consuming disadvantage, they may lead to the loss of undefined important objects during automatic cleaning process [3].

II. Underwater Object Recognition

Many challenges faced the attempts of creating underwater object recognition tools such as: underwater objects Identification which is subject to their surface characteristics and irregular geometric shapes which are also affected by underwater currents and silting, a huge target library is needed due to different shapes, scales and sizes.

Real time object recognition is very important especially when dealing with special purpose hydrographic survey operations such as dredging operations (for the purpose of deepening harbors, navigation lines and underwater mining) which is a cost effective and time constraint operation that needs a precise and fast surveyor decision to determine the presence of any objects or obstacles in the dredging zone.

Many object recognition techniques have been developed. In 2005, Vasile and Marino presented a pose-independent automatic target detection and recognition system that uses data from an airborne three-dimensional imaging laser radar (LADAR) sensor. The automatic target recognition system uses size signatures from target models to detect and recognize targets under heavy camouflage cover in extended terrain scenes. But this technique requires predefined target dimensions and characteristics (target library) which is impractical to be applied in seabed features [3].

Bonnlander et al. (2006) illustrated that the target criterion articulated by the experts which can be informally described by selecting an area and then computing the average of all depth measurements within this selected area, and comparing this average to the depth of the shallowest point in the area. This method can be applied in remote sensing recognition but needs predefined objects to check its accuracy which is also difficult to apply on seabed objects[5]. In 2007, Vásquez stated that available automatic cleaning software have a leakage in target recognition field and they may require professional users to deal with them, so it might easily happen to lose an important target (ex: pipeline, rock, ships' wreck) during cleaning process with no indication about losing important objects[6]. Quintal et al. developed an automated system that eliminates the need for the initial manual sidescan review process, which is currently performed by junior hydrographic surveyors. The aim was to enable the experienced surveyor to review the sidescan record for data quality and to provide quality assurance of the bottom tracking and digitized contacts generated by the Automatic Target Detection software which is still time consuming and specialized on sidescan contacts only [7].

Available automatic cleaning software has a leakage in target recognition field and they may require professional users to deal with them, so it might easily happen to lose an important target (ex: pipeline, rock, ship wreck) during cleaning process with no indication about losing important objects [5]. An automated system was developed that eliminates the need for the initial manual Side Scan Sonar review process. The aim was to enable the experienced surveyor to review the side scan record for data quality and to provide quality assurance of the bottom tracking and digitized contacts generated by the Automatic Target Detection software. The latest technique is still time consuming [6].

III. Areas of Investigation and Data Acquisition

Our experiments were carried out on two phases in two different areas as follows:

3.1 Phase I

MBES images were acquired at Sidi Kerir west of Alexandria which contained underwater pipelines (on the seabed) as shown in figure(1); the depth of the area varies from 10 to 30 meters.

Figure 1: First investigation area location map

3.2 Phase II

Side Scan sonar images were acquired from the area near Alexandria port, the depth of the second investigation area is about 30 meters. The area of interest contained underwater objects on the seabed such as (pipe, and a sunken ship wreck and a boat wreck). The study area was scanned according to IHO standard S-44 [1].

Figure 2: Second investigation area location map

IV. Real Data Preparation and Processing

The collected data was corrected for tide, sound velocity and offset adjustment during the period of the survey to produce edited data. Processing of our case study hydrographic real data containing obvious features (pipelines) was done using manual procedures so it can be used as a reference for verification which was time consuming.

At last, a scanned surface was created by the sonar device and was exported as XYZ data to be ready for using it easily in other processing software.

V. Object Analysis and Recognition

Our object recognition approach was applied in order to speed up the object recognition process by simplifying these objects to the nearest geometrical shape. Acquired MBES Real data contained three pipelines, which was used for testing the proposed approach, and then artificial data was generated and processed using the prementioned approach to check the validity of this approach. Artificial objects represented a sample of the most common underwater objects were tested; objects included a pipe, partial ship wreck and a rock. The proposed approach can be summarized in the following steps:

- Sonar data acquisition.
- Format Conversion :
    - Conversion of the acquired XYZ data to 3D image by creating triangles (TIN surface) to join these points and represent them as a three dimensional surface.
    - Converting 3D image to 2D image.
- Feature extraction by representing with shape vector.
- Object recognition using nearest geometrical shape.
- Validation phase using simulation data.

Applying the above steps to the MBES output as follows:

5.1 Sonar Data Acquisition:

Data is acquired from the MBES as XYZ data file format which identifies the location of all shape points, hence defines the sea bottom objects.

5.2 Format Conversion

Selected real data exported from MBES system as XYZ data, and then triangles were plotted using Triangulated Irregular Network technique (TIN surface) to join these data and represent it as a three dimensional surface. The Triangulated Irregular Network connects each three soundings to make a (triangle face) as shown in figure 3.

These forces can be used to represent an interpolated surface. Selected area has been rotated to horizontal view in MATLAB® (to facilitate the recognition process and comparison) as shown in Figure (4).

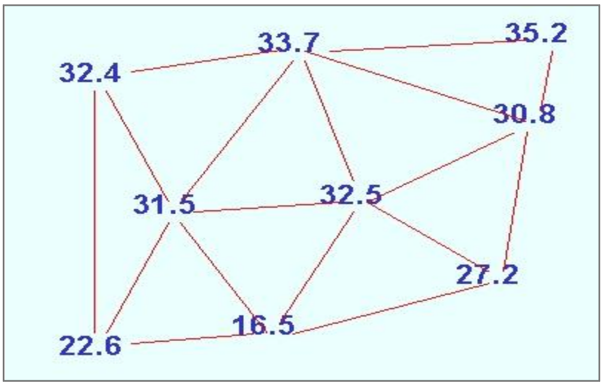

Figure 3: Triangle "face" formed by three soundings

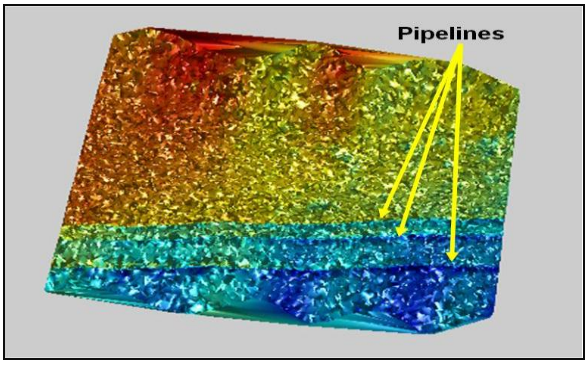

Figure 4: Pipelines shown in 3D surfaces

5.3 Feature extraction

Triangulated 3D recording points (X,Y,Z data) were transformed to (dat) file format which was then converted to a 2D image using ERDAS 8.4®, by checking the output 2D image as seen in figure (5), we recognize the presence of three pipelines in the chosen data. 2D images were then exported to MATLAB® for feature extraction via MATLAB code.

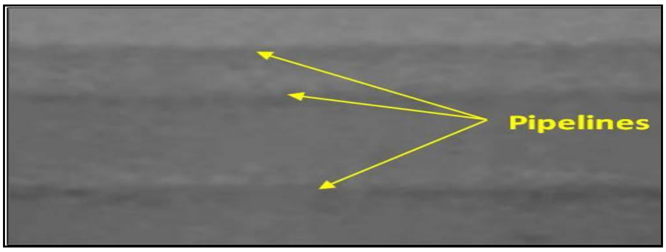

Figure 5: 2D images showing three pipelines

5.4 Object Recognition Using Nearest Geometrical Shape

The generated images (shown in figure (6)) are then recognized via MATLAB® code generated for object recognition using nearest geometrical shape. The figure shows that objects (pipelines) were recognized via the developed MATLAB® recognition code the three pipelines were all recognized (100% detection).

Figure 6: Recognition results illustrating obvious pipelines

5.5 Side Scan Sonar Object Recognition

The approach was applied to side scan sonar survey data which contained three underwater objects as stated before, the data acquired from area near Alexandria port contained underwater objects on the seabed which included (pipe, and a sunk ship wreck and a boat wreck).

The side scan sonar is a successful tool for object detection. Side-scan sonar has been for a long period the only available instrument for mapping seabed features on a broad scale.

- Pipeline: The pipeline image shown in figure (6) obtained from the side scan sonar was processed for feature extraction code in MATLAB ®, the generated segment was then applied to the recognition code which recognized the shape as a rectangular shape and hence it represents pipeline.

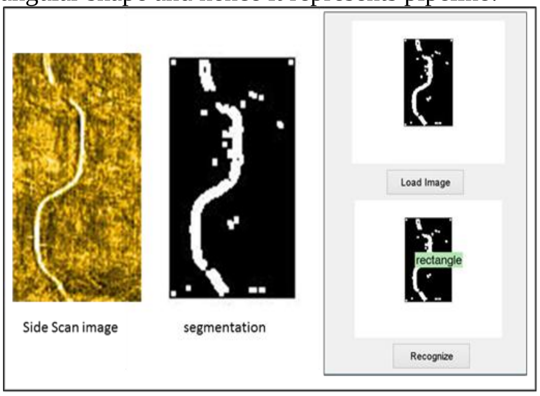

Figure 7: Side scan object recognized as pipeline

- Shipwreck : two ship wrecks were detected by side scan sonar that are shown in figures (8) and (9) consecutively, objects were processed for feature extraction code in MATLAB ®, the generated segments were then applied to the recognition code which recognized the shapes as ellipsoidal and hence they represent shipwrecks.

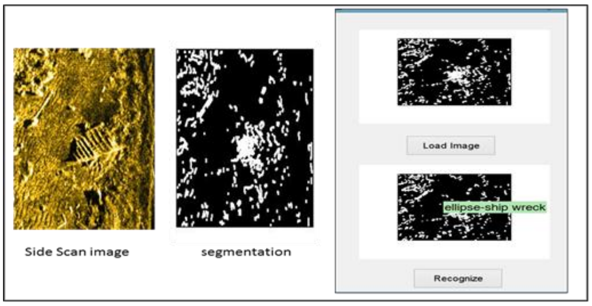

Figure 8: Side scan object recognized as shipwreck

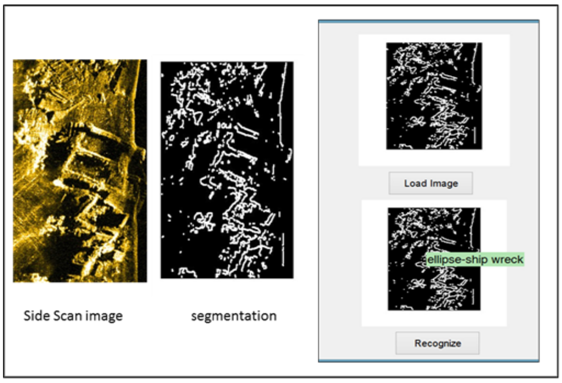

Figure 9: Object recognized as shipwreck(small boat)

VI. Validation of the Object Recognition Approach Using Generated Objects

6.1 Object Generation

Artificial objects were generated which represent a sample of the most common underwater objects which included a pipe, partial ship wreck and a rock . Objects were generated Using Autocad® software package; artificial surfaces were created in 3D space simulating a depth of 30m with 0.25m cell size and containing three objects. These sample objects are as follows:

- Pipe (representing pipeline with 0.5m radius).
- Ship wreck (6.5m Length, 1.3m width).
- Rock (1.75m Length, 2m width).
-

The surface containing sample objects was exported from AutoCAD® file as XYZ data in order to resemble the MBES output data, then this XYZ data was imported in Hypackmax® software using Triangulated Irregular Network (TIN) program to be surfaced and viewed as the surface as shown in Figure (10).

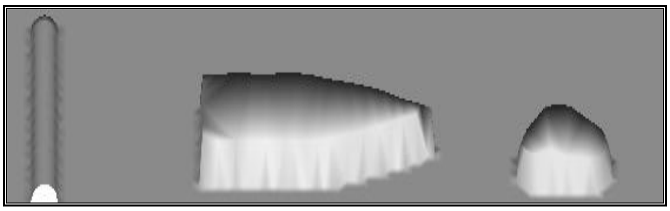

Figure 10: Artificial objects surface

6.2 Data Preparation

The generated artificial data was loaded as XYZ data with cell size 10 cm into three variables (X, Y and Z). Using special MATLAB® code, triangles were created (TIN surface) to join these data and represent them as 3D surface as shown in Figure (11).

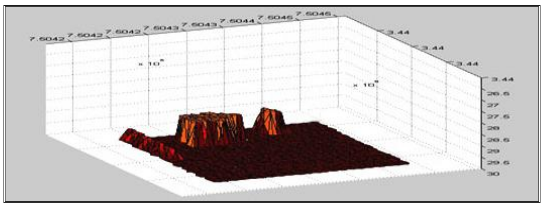

Figure 11: 3D surface including the three artificial objects

The triangulated surface including the three artificial objects (from right to left as shown in Figure (11): pipe, shipwreck and a rock) was cleaned from both axis and triangles as shown in Figure (12) to be ready for 2D image conversion.

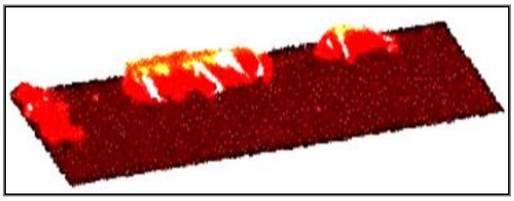

Figure 12: Cleaned 3D surface

6.3 Image Processing

The triangulated X, Y, Z data exported to Surfer 8® software to transform it from XYZ file format to Dat file format. Figure (13) illustrates the data file after converted to 2D image using ERDAS 8.4® software .The 2D image shows the objects in one layer regardless of the depth variation. The next step was representing the 2D image into vectors using MATLAB® software package.

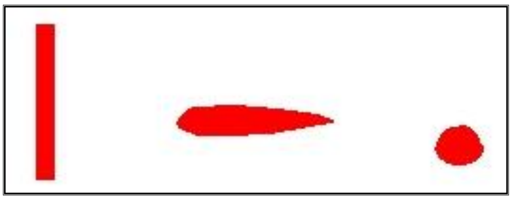

Figure 13: 2D surface with three objects

6.4 Object Recognition

The vectorized image was loaded in the object recognition model using nearest geometrical shape via MATLAB® code (Trieu, 2010) as shown in figure (14).

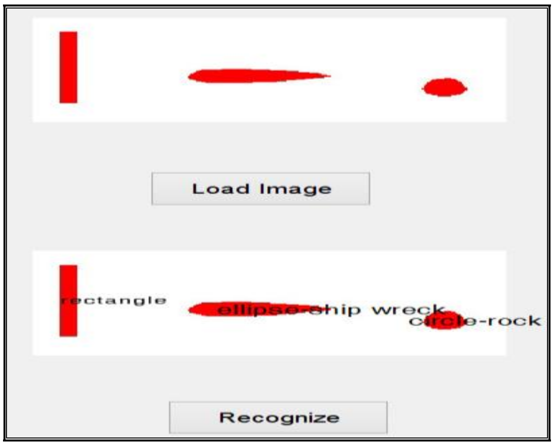

Figure 14: artificial objects recognition

Objects recognized from left to right as follows:

- Rectangle: object is recognized as a pipe (a pipeline).
- Ellipse: object is recognized as ship wreck.
- Circle: object is recognized as a rock.

The advantages of the proposed approach are as follows :

- Less processing time as it is considered a fast approach can be used for fast and instantaneous check.
- It can deal with a large amount of data and target library is not needed.

VII. Conclusion

This research applies a quick underwater object recognition approach which is capable of recognizing underwater objects obtained from imaging devices (Multibeam Echo Sounder (MBES), and Side Scan Sonar(SSS)) to aid the hydrographic surveyor to analyze the MBES output and SSS images in the cost effective and time constraint operations that need a precise and fast surveyor decision to determine the presence of any objects or obstacles in a certain area.

References

[1] International Hydrographic Bureau , IHO standards for hydrographic surveys , international hydrographic organization , MONACO, Special Publication No. 44, 5th Edition, February 2008

[2] Calder & Mayer, Automatic processing of high-rate, high-density multibeam echo sounder data, Center for Coastal and Ocean Mapping and Joint Hydrographic Center, University of New Hampshire, United States of America, geochemistry geophysics Geo systems, VOL. 4, NO. 6, 1048, 2003.

[3] Vasile & Marino, Pose-Independent Automatic Target Detection & Recognition Using 3D Laser Radar Imagery, Lincoln Laboratory Journal, Vol. 15, 2005.

[4] Mallace & Gee, Multibeam processing – the end to manual editing, The Hydrographic Society of America Conference Proceedings, San Diego, USA, 2005.

[5] Bonnlander, Glymour & Teng, Automated Target Detection and Grouping from Remotely Sensed Data, Institute for Human & Machine Cognition, USA, 2006.

[6] Miguel E. Vásquez, Tuning the CARIS implementation of CUBE for Patagonian Waters, University Of New Brunswick, September, 2007.

[7] Quintal, Infantino & Byrne. Automated Side-Scan Target Detection: New Tools for Hydrography, Proceedings of the Canadian Hydrographic Conference and National Surveyors Conference, 2008.

[8] NOS hydrographic surveys specifications and deliverables, U.S. Department of Commerce, National Oceanic and Atmospheric Administration, Recognition to nearest geometrical shape code, 2009.

[9] Di Maida & Tomasello, Discriminating between Posidonia oceanica meadows and sand substratum using multibeam sonar, Department of Ecology, University of Palermo, ICES Journal of Marine Science, 2011.

[10] B.H. Houston et al, Wide Area Detection and Identification of Underwater UXO Using Structural Acoustic Sensors , Naval Research Laboratory, USA, NRL/MR/7130-11-9337, 2011

[11] A Elbergui , model based classification of mine-like objects in Side Scan sonar using the highlight information, Proceedings of the 11th European Conference on Underwater Acoustics, United Kingdom 2012.

[12] Lim, Sonar Detection and Classification of Underwater UXO and Environmental Parameters, Naval Surface Warfare Center Panama City Division, SERDP PROJECT MR-1666, 2012.

Acknowledgment

It is a pleasure to thank everyone who has assisted us during the writing of this paper. First of all, we are grateful to Almighty God for enabling us to complete this research. And we are grateful to the Arab Academy for Science, Tech. & Maritime Transport staff who has helped us to finish our work.

Biography

Hatem Awad Khater received a BSc. In Electrical Engineering, MSc.In Electronic and Communication Engineering and Ph.D. in Computer Engineering, Kent University, United Kingdom, in 2008. He holds the position of Chief of Naval Research and Development Department. His research interests include Software Engineering, Cryptography, Image Feature Detection, Matching Technique,, Geometric Transformation, Image Registration, Pattern Recognition, Computer Graphics, Web Programming, Automatic Controls, Modern Electronics communication, Acoustics, Voice Identifications, GIS, International and European Business, conomics & Management information Systems. Member and Reviewer at IET. Also Member of Image and Information Engineering Research Group, University of Kent, U.K.

Ahmed Megahed received BSc. degree in Computer Engineering in 1999. He is a Master student at Computer Engineering Department in the Arab Academy for Science, Technology& Maritime Transport, and Alexandria, Egypt.

Dr. A. Baith Mohamed, received the BSc. In Computer Science, Vienna University, MSc. And Ph.D. in Computer Science (computer system security), Vienna University, in 1992. He is a Professor at the Arab Academy for Science, Technology and Maritime Transport (AASTMT), Computer Engineering Department. In addition, he holds the position of Vice Dean for Training and Community Services, College of Engineering and Technology. His research interests include computer and Network Security, Bioinformatics, Steganography, Cryptography, and Genetic Algorithms. He was also a member of International projects teams in Europe, for design, implementation and maintenance of subsystems in the environment of peripheral processor controls as part of a larger Public Switched Systems (EWSD) in SIEMENS, AG. Austria. Also, he was a scientific researcher in the department of Information Engineering, Seibersdorf Research Institute (Atomic Energy Agency) in Austria for design and implementation of security software systems in the domain of railway automation project (VAX/VMS, DEC systems), Austria. He was also a member of software testing for distribution points in an international project in AEG, Vienna, Austria. He is a senior member of IEEE Computer Society, USA since 2001.