Sonar Detection And Classification Of Buried Or Partially Buried Objects In Cluttered Environment Using UUVS

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LONG TERM GOALS

The long term goal of this program is to develop acoustic reflection methods and acoustic processing techniques for detecting, imaging and classifying objects buried in the seabed such that the methods can be eventually implemented on UUVs.

TECHOLOGICAL OBJECTIVES

- Develop acoustic and signal processing technologies for detecting and visualizing buried objects and objects lying on the seabed
- To determine the best image processing and visualization techniques for buried object imaging
- To generate databases of buried target strengths, volume and surface scattering coefficients and sediment acoustic properties over a wide frequency range that can be used for sonar prediction modeling
- To develop sonar models that predict the SNR of targets for various array geometries, sediment types, frequency bands, etc .
- Develop acoustic models of sound interacting with the seafloor to provide a theoretical basis for signal processing techniques and predicting the detection of buried objects

APPROACH

In order to develop a UUV sonar for detecting and imaging buried objects, the phenomenon of volume and surface scattering from the sediments, fluid / porous solid boundary-interacting acoustics, and the interaction of sound with elastic objects contained with a porous solid must be understood so that the signal levels and interference can be accurately calculated when estimating sonar performance of a particular design. An experimental approach is being taken to determine those acoustic processes. Two sonars have been constructed to measure the effects of sound interacting with the seabed and to measure the characteristics of target echoes. The sonars provide a direct measurement of the target echo strength and acoustic scattering levels as a function of frequency. The first sonar uses a 3m wide by 1m long towed vehicle containing a 0.75 m long line transmitter and 16 line hydrophones covering an aperture of 0.75 by 3 meters. A 16 channel sonar processor was used to collect the 16 channels of reflection data. The data was sent to a topside processor via a 100 Base T link for display and storage and merging with underwater video. The data from the first sonar, covering the frequency range of 1.5 to 10 kHz, was used for testing across track focusing. Experiments over mines in sand showed that the sonar could generate images of mine-like objects to a burial depth of 2 meters, but had difficulty

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detecting partially buried objects because of high sediment-water interface scattering near normal incidence. The experiments showed a clear need for a steerable transmission beam which required a planar receiver that could focus forward and aft in addition to across track focusing.

CEROS (DARPA) funded the hardware development for a compact imaging sonar. This sonar has the added features of a steerable transmit beam and a beamformer that provides across track and along track focusing. This sonar is much more compact and has a frequency range of 4-25 kHz. The 1 meter long by 1 meter wide towed vehicle contains a 6 element transmitting array and 8 line hydrophone arrays with 4 line segments each. The sonar processor on the fish steers the transmit beam forward or aft to any selected angle of incidence and acquires 32 channels of reflection data which is sent to the topside processor via 100 Base T for display and storage. The two sonars are designed to provide integrated video and acoustic data sets for measuring the impulse response of buried targets and the scattering interference from sediments in the vicinity of the targets. The compact sonar steers the transmission beam forward thereby substantially reducing the high scattering levels from the sediment water interface at near normal incidence that make it difficult to detect objects near the interface.

A 1.2 MHz chirp sonar was designed and constructed to provide AUVs with the capability of automatically detect mines lying on the seabed. The operating frequency of 1.2MHz was selected to ensure that the wavelength was short enough so that scattering of sloping target surfaces could be used to provide detailed target images. Automatic detection of mines is performed in real time using a 466 MHz Celeron processor that calculates the size of the acoustic shadow of the mine by detecting a drop in the scattering level behind the target. The length and height of the mine is measured and reported to the AUV host. An image of the mine is also provided so that the host AUV can transmit the image to shore or to a support ship. A block diagram of the system is shown below.

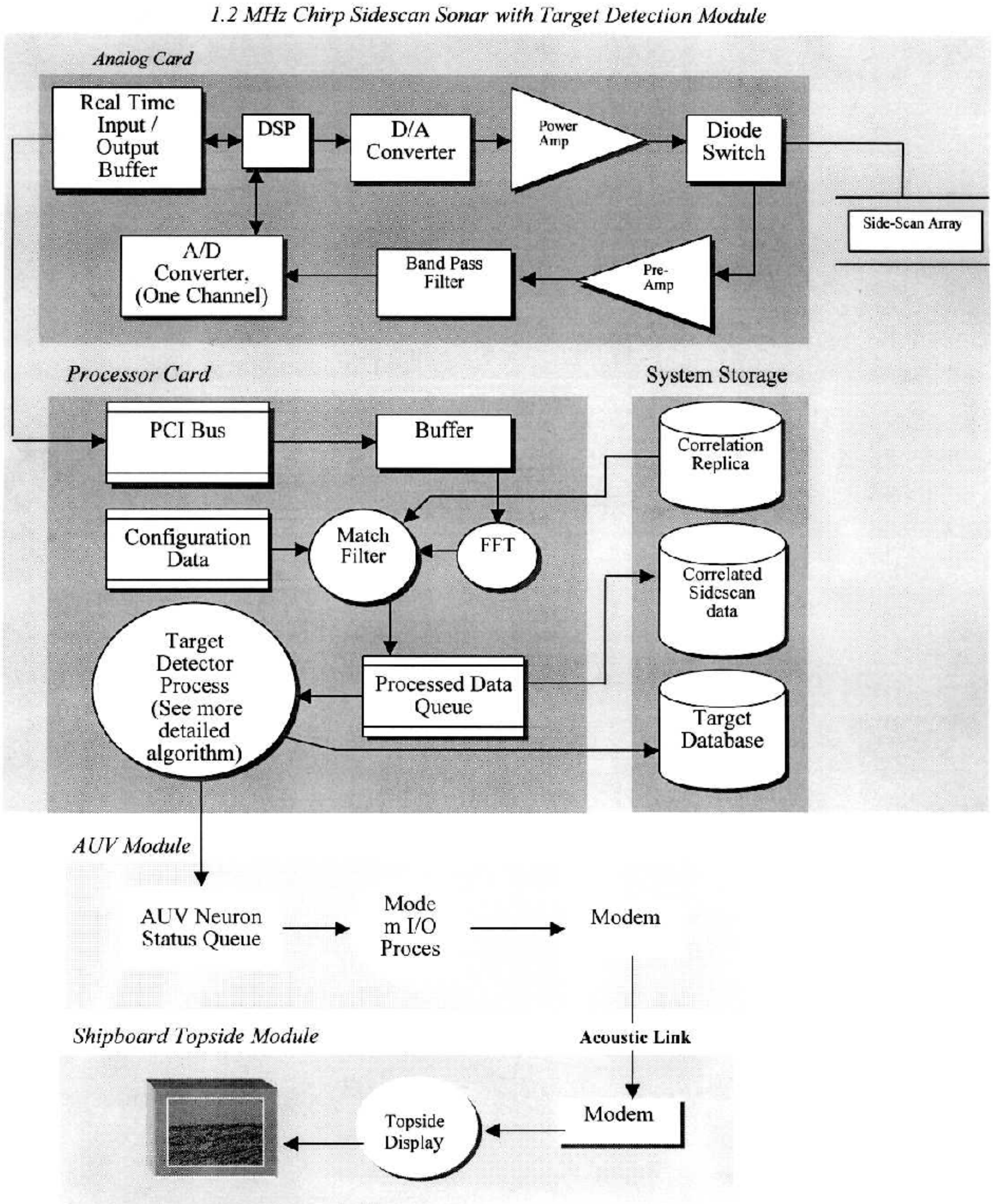
Dr. Schock and Jim Wulf supervise the research which is conducted by graduate and undergraduate students. Jim Wulf is a retired engineer from IBM who designed and tested the electronic components of the sonar processors. Arnaud Tellier, who completed his Master's of Science thesis in August 1999, developed a simulation that predicts the images generated by the imaging sonar for spherical elastic targets in a fluid. He also processed the data from the 32 channel sonar to generate images of ordnance buried in sand. Eric Bauer, graduate student, assists in conducting experiments and is responsible for testing procedures for the automatic real time detection of mines lying on the bottom.

WORK COMPLETED

During the past year, the development of the compact (1m x 1m) 32 channel sonar with along track and across track beam steering was completed and tested. The sonar was sea tested in Hawaii over along a test line containing buried ordnance. Underwater video provided good correlation between subsurface target images and actual target locations which had markers above the targets. Volume and surface visualization techniques have been developed and tested on synthetic data. The marching cubes method was selected as the surface rendering technique.

A 1.2 MHz chirp sidescan was constructed and tested. The sonar was designed so it could be towed or mounted in a AUV. If towed the sonar is connected to the topside via 100 Base T. If mounted in the AUV, the sonar is controlled via LonWorks. The Celeron sonar processor has sufficient computing power to perform the correlation processing and automatic target detection. The sonar was tested over a field of mines and concrete blocks. The sea trials of the 1.2 MHz chirp sidescan sonar showed that the sonar provided detailed size and shape information about targets lying on the seabed. Images of mines and a concrete block are shown below. A shadow detection algorithm was developed to detect all targets lying on seabed on the Navy range just south of Fort Lauderdale, without any false detections. The algorithm searched for a drop in scattering levels, an indication of a shadow. If the measured shadow length is higher than that produced by a sand wave, the target was detected. If the along track length of the target past a preset threshold, the target was reported to the AUV host and the image stored on disk. The algorithm was developed to run in real time. Extensive sea testing is planned for the target detection system at the AUV fest in November 1999.

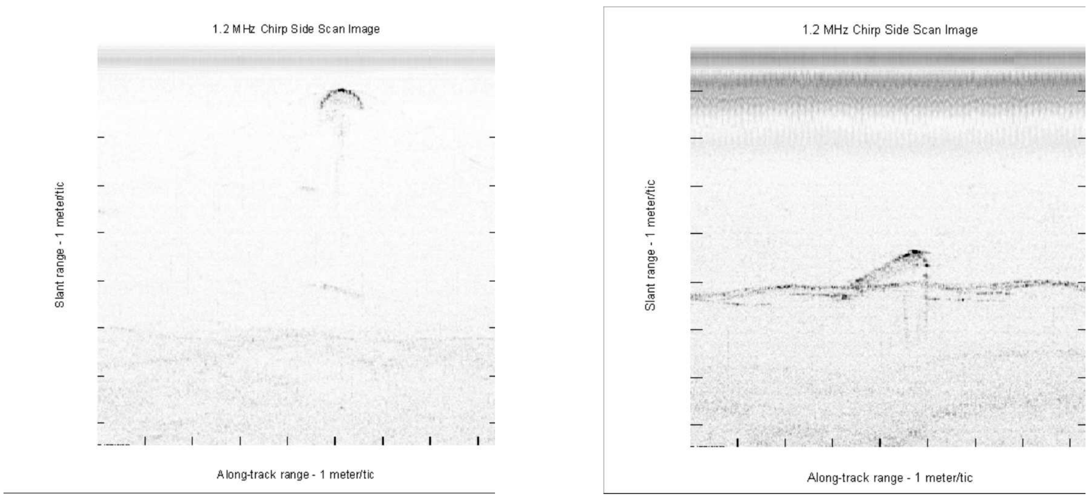
AUV Bottom Mine Detection System



1. Block diagram of AUV automatic detection system for bottom mines. Sidescan images of mines can be transferred to the ship from the AUV in real time via an acoustic modem.

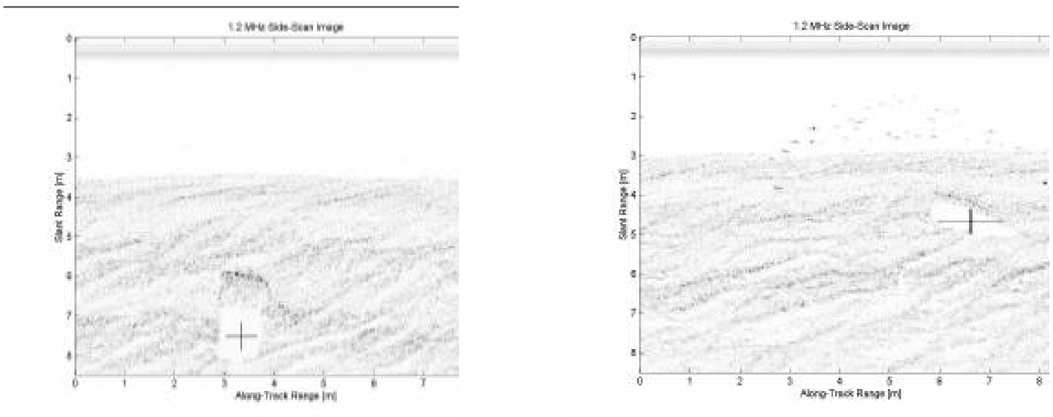
RESULTS

The 1.2 MHz chirp sidescan sonar was towed through a mine field at the Navy range just south of Fort Lauderdale to collect image date for testing a target detection algorithm that searches for acoustic shadows. Figure 2 shows images of mines in the water column. Mooring lines are barely visible in the images. The use of a 1.2 MHz signal allowed the detection of scattering off the target surfaces not normal to the sonar because many surface appear rough at acoustic wavelength on the order of 1mm. This scattering resulted in images that show the shape of the spherical and cylindrical mines. The diameter of the spherical mine and the length and diameter of the cylindrical mine can be measured from the images.



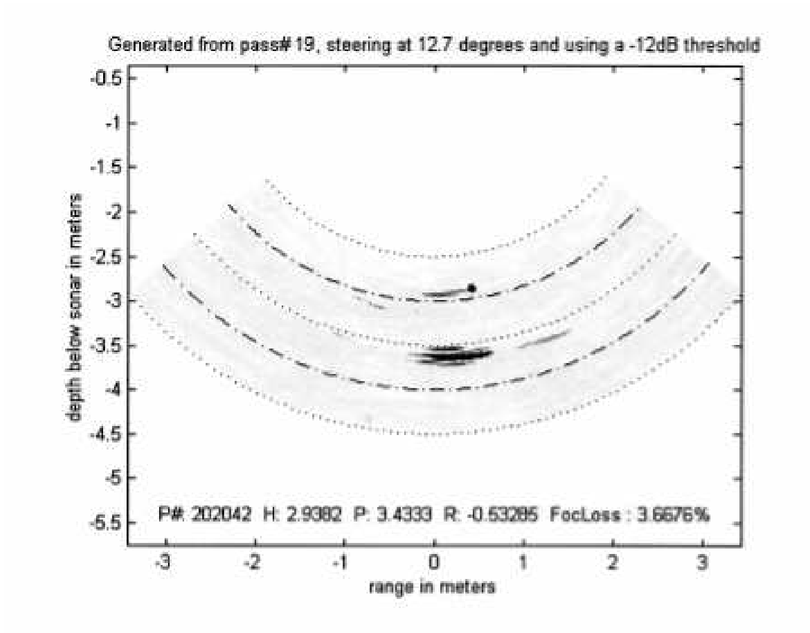
2. Images of spherical and cylindrical mines in the water column. The images were generated by a 1.2 MHz chirp sidescan. The short wavelength allows measurement of scattering off of sloping surfaces of the target and a clear picture of the shape of the target. The echo near the cylindrical mine is due to a surface reflection.

The target detection algorithm that searches for acoustic shadows was tested using sidescan images of bottom mines and a concrete block lying on the seabed of the Navy range. The algorithm detected all mines without any false alarms in the one field data set that was collected at the range. Figure 3 shows the location of detected shadows for two targets. Note that the targets were in a field of sandwaves and that the school of fish presented no problem for the shadow detection algorithm.

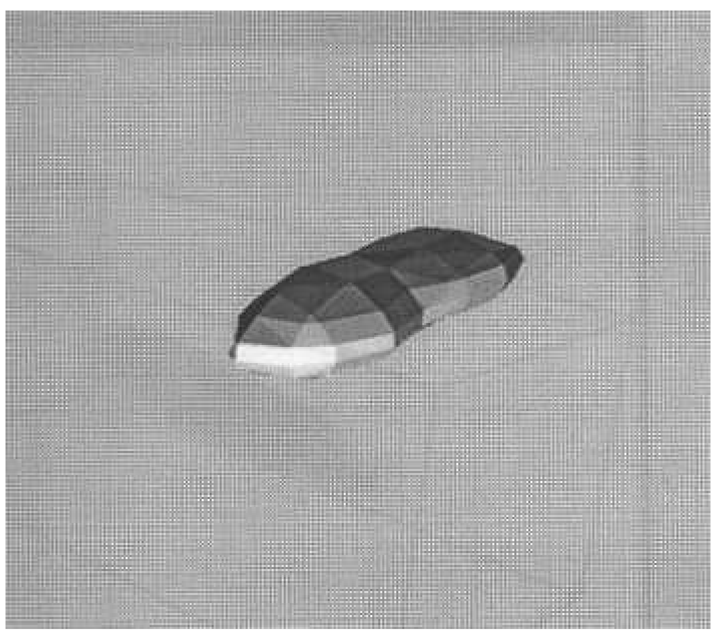


***3. Images of a concrete block and a mine lying on the seabed generated by a 1.2 MHz chirp sidescan. The cross indicates the center of the acoustic shadow detected by the target detection algorithm. The targets were detected reliably without any false alarms*.**

The 32 channel buried object imaging sonar (partially funded by DARPA/CEROS) was calibrated and tested at FAU. Subsequent field tests in Hawaii along a line containing buried ordnance showed that the sonar reliably detected ordnance up to a burial depth of 0.8 meters, the deepest depth that ordnance was buried by divers. The 1x1 meter sonar vehicle was towed about 1.5 to 2 meters above the seabed. The transmission rate was 20 pings per second. The 32 data records generated during each transmission are processed by a matched filter and time delay nearfield beamformer. Tests showed that the best SNR is obtained when the transmission beam is steered 10 to 15 degrees ahead of normal incidence. That transmission angle reduces the sediment water interface scattering which is a problem near normal incidence, but is not so high as to significantly reduce target echo strength due to two way boundary losses. The slices of the seabed are stored in a buffer which is accessed when a target is detected and needs to be viewed in 3D. Figure 4 shows a slice of the seabed with an ordnance shell buried at 0.8 meters. Figure 5 shows the surface rendering of a set of 10 slices containing a hedgehog shell.



4. Typical output of nearfield focusing processor showing an across track slice of the seabed that is generated after each transmission. The echo at a range of 2.9 meters is from the sand-water interface. The echo at a range of 3.7 meters is from the top of an ordnance shell buried 0.8 meters under the seabed.



5. Surface rendering of hedgehog ordnance (36 in long x 7 in diameter ordnance) buried under 50 cm of sand. Surface rendering was performed with the marching cubes algorithm. The image is constructed from echos off the near surface of the buried target.

IMPACT/APPLICATIONS

The imaging sonars developed under this program can be used for finding mines and ordnance which are buried or lying on the seabed. A buried object imaging sonar, developed by cost sharing between this grant and a CEROS/DARPA contract, can be incorporated into UUVs. Scattering and target strength measurements can be used to predict sonar performance and to aid in the development of other buried object sonars by the Navy. Real time target detection has been implemented in real time in an AUV mounted 1.2 MHz chirp sidescan which can detect and report mines lying on the seabed.

TRANSITIONS

The general purpose sonar technology has been transitioned to industry, academia and the Navy. The general purpose sonar was licensed to Edgetech. The technology is contained in sonars used by Naval Facilities Engineering Service Center and Woods Hole Oceanographic Institute who will be using the sonars to measure the impulse response of the seabed over the range of 1 to 14 kHz for the purposes of classifying ocean sediments.

The buried object imaging technology developed under this grant was modified for a DARPA sponsored program, administered by CEROS, for the development of a system for detecting and classifying buried ordnance. The system has the additional capability of fore/aft beamsteering in addition to across track beamsteering and is much more compact so it is suitable for UUV applications. The sonar transmits over the range of 4 to 30 kHz.

RELATED PROJECTS

CEROS/DARPA contract "Development of a 3-D, Forward/Aft Sweeping, High Resolution Buried Object Imaging System"

PUBLICATIONS

Tellier, Arnaud, “Visualization of Buried Objects in 3D Acoustic Data Acquired By a Buried Object Scanning Sonar” Masters of Science Thesis, Florida Atlantic University, August 1999.

Ericksen, M. and S. Schock, “ Development of a 3D Forward/Aft Sweeping High Resolution Buried Object Imaging System,” CEROS Phase 1 Final Report, April 1999.