Naval Special Warfare Concept Assessment

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LONG-TERM GOALS

The goal of this effort was to conduct concept assessments of technologies having the potential to enhance Naval Special Warfare (NSW) mission capabilities.

OBJECTIVES

Numerous advanced imaging devices such as multispectral, passive millimeter wave, and laser imagers are currently under development. Each imaging device will require image processing and a display so the operator can view the processed image. Since the military is projecting that wearable computers outfitted with a head-mounted display (HMD) will become a common item on the battlefield, it was determined that it would be prudent to evaluate the state of the art of wearable computers. The objective was to determine whether they will be able to handle the processing required by the imaging devices mentioned above. HMDs were also evaluated to determine whether the HMD technology is capable of displaying the fine details of a processed image.

In April, 1998, the Coastal Systems Station (CSS), Nichols Research Corporation (NRC), and Sandia National Laboratory (SNL) evaluated a scannerless range imaging system developed by SNL to ascertain the potential use of this type of device for imaging proud and volume targets in the underwater environment. This approach uses an imaging system that forms an image on the basis of a range map rather than an intensity map. In this case the image is constructed on the basis of phase information, and detection is essentially independent of contrast ratio for proud or volume targets. The technique is also capable of revealing other hazards, such as concertina wire, in the water volume that might be obscured in an intensity image. Testing took place over a period of approximately one week and involved scientists and engineers from CSS, SNL, and NRC. The Sandia Scannerless Range Imaging (SRI) system demonstrated effectiveness in resolving land-based military targets in situations of very little visual background contrast. The objective of the CSS test was to determine whether or not that capability could be effectively extended to the underwater environment.

Oak Ridge National Laboratory conducted a study of night vision devices with the objective of identifying factors influencing NSW detectability.

It is difficult to discriminate objects on the horizon in PMMW imagery when viewing them from near ground level. This is because the horizon is at ambient temperature and metal objects are reflecting the warm portion of the sky into the sensor. In addition, it is difficult to detect plastic mines or objects

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against a soil background. It has been shown that through the use of linear polarization plastic mines can be easily detected from the background. It has also been shown in modeling that through the used of polarization, ships can be picked out from the horizon. A study was conducted to investigate the phenomenology of passive millimeter wave polarimetry with the objective of determining the potential enhancement of PMMW imaging system performance.

APPROACH

HMD/Wearable Computer: A market survey of both wearable computers and HMDs was conducted using the Internet, technical magazines, the Thomas Register, etc. Once companies were identified, they were contacted by to obtain additional information about their future developments. The information was compiled and recommendations on fleet applicability were prepared.

SRI Assessment: A temporary waterproof housing was prepared for the source and receiver components of the Sandia range imaging system, so that it could be evaluated through a series of tests in the Seal Delivery Vehicle (SDV) test tank at CSS. The system was otherwise deployed in a breadboard version of its basic land configuration, and the range gating circuitry was not modified to accommodate the short ranges associated with the underwater imaging application. Tests were also conducted in a configuration that enabled evaluation of the performance potential of the system when looking through the air-water interface.

PMMW Polarimeter: In order to assess the feasibility of a PMMW Polarimeter, Nichols Research Corporation is performing a combined modeling, and data collection analysis. The modeling effort will utilize the newly modified Irma 4.1 code. It was recently modified to include both linear and circular polarization effects. Nichols will also develop Mueller matrix inputs to drive the Irma model. These Mueller matrices will be based on the complex dielectric constants of materials that have already been collected. In addition, they will incorporate surface roughness effects and other material structural effects, such as dichroism, or birefringence. The modeling will follow-up with a proof of principal data collection. Nichols will work with IMT to build a prototype PMMW Stokes vector polarimeter. This device will use optical polarization state analyzer elements.

WORK COMPLETED

HMD/Wearable Computer: The assessment of the HMDs is complete. The survey of the wearable computer survey is approximately 90% complete and should be complete in November.

SRI Assessment: Figure 1 shows the SRI basic setup used in the tests. Underwater performance was then evaluated against a set of targets for both clear and turbid water conditions. Water clarity was monitored by an AC-9 absorption and spectral attenuation meter, and turbidity was modified by the addition and removal of Malox™ to the water. The target set consisted of a standard contrast panel, a range resolution panel, a PDM-1 mine simulant, a 21-inch buoy submerged in the water volume and concertina wire submerged in the water volume. Spectral attenuation coefficients ranged from $c \ll 1$ m to $c > 1.5\ m^{-1}$.

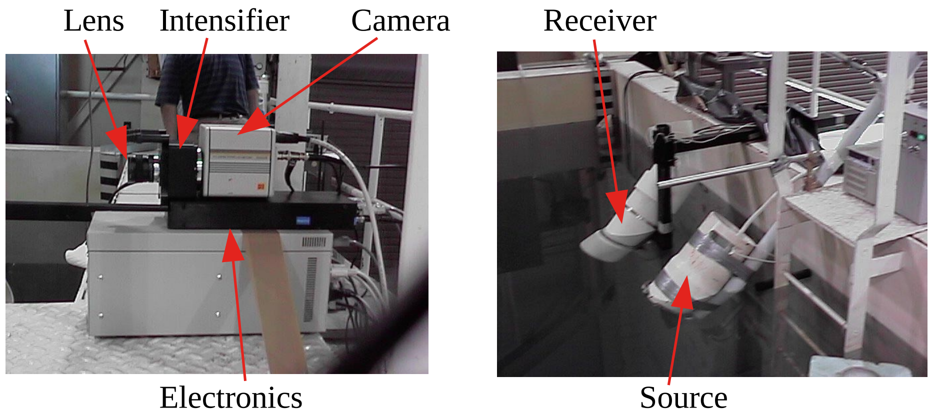

Figure 1. Breadboard System Setup

Night Vision Detectability: Night vision devices were assessed and factors influencing vision with night vision devices were identified. Detectability of NSW personnel and mobility platforms from these devices was assessed and recommendations on minimizing detection probability were developed.

PMMW Polarization: An extensive literature search was performed on the subjects of directional emissivity[1] from rough surfaces and scattering from rough surfaces. Little information was found so efforts to express the directional emissivity in terms of the bi-directional reflectance distribution were initiated. A way to do this was determined from results in a book by Siegel and Howell.

The most thorough discussion of bi-directional reflectance distribution is found in a report by Barrick and Peake. Books, such as one by Ogilvy, only cite specific cases and not the general solution given by Barrick and Peake. The equations by the latter allow the materials to have a complex relative magnetic permeability and a complex relative permittivity. The latter case is for materials that have ohmic losses; the former is for materials that have magnetic losses. Also, except for the work of Barrick and Peake, the relative permeability has been taken to be one. There are many materials of common use for which this is definitely not the case. The material parameters are often given in terms of the complex index-of-refraction and not permittivity and permeability. NRC previously developed algorithm to convert from the complex index-of-refraction to the complex permittivity. The process of developing the codes for computing the directional emissivity from the bidirectional reflectance distribution is underway.

RESULTS

HMD/Wearable Computer: Head-Mounted-Display technologies, both available and under development, were compiled and organized into three general categories: liquid crystal, electroluminescent, and field emission. Their capabilities were assessed as well as the potential to meet NSW requirements.

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[1] We use the term emissivity for both ideal surfaces and non-ideal surfaces instead of emittance for the latter. The practice of using the later term for emissivity conflicts with the established practice of using the ending –*ance* for extensive physical properties.

Wearable computer technologies were also assessed. There are hundreds of wearable computer manufacturers and the list grows daily. After weeding through the companies claiming to have the ultimate wearable, it is apparent that the majority of them have the same basic devices in a different package. Some of the companies that appear to be leading the wearable field include Boeing Data Sentinel with 200MHz Pentium processor, Xybernaut® 133P with 133 MHz processor, and the VIA Inc Via II with 180 MHz processor.

SRI: Results achieved with the SRI were generally impressive, even with a system that was not optimized for the short ranges associated with the underwater environment. Both range images and intensity images were produced during the course of the tests. Results ran along expected lines with three-dimensional objects being readily apparent in the range images, and two-dimensional objects being visible only in the intensity images. There was also a demonstrated ability to recognize 3-D objects at longer distance in the range image than with the intensity image with increasing water turbidity. Imaging through the air-water interface also demonstrated that the range images were enhanced substantially over the intensity images for situations in which capillary waves were present on the surface. The experiments showed that volume targets at a depth of ten feet at a slant range of 39 feet were clearly identifiable in the range image long after the intensity image became irresolvable.

Any system depending on image contrast for target recognition, whether gated or otherwise, will suffer limitations when it comes to resolving low-contrast targets. Identification based on edge detection or intensity maps may be quite difficult when the surface reflectance of the target closely matches that of the background and the edges are hidden or not well defined. This is evident in the intensity image shown in Figure 2 of a simulated tilt-rod mine surrounded by concertina wire that was taken during a recent test of an imaging system in the SDV test tank. The technique is clearly capable of revealing other hazards, such as concertina wire, in the water volume that might be obscured in an intensity image (Figure 3). Although the mine simulant was only barely visible in either of the two images, the range image clearly captures the concertina wire that represents a substantial hazard to the diver.

Preliminary tests against volume targets showed that the range imaging technique offers substantial potential as a diver sensory enhancement tool. Since the technique can basically be used with a continuous source, it also offers potential design simplification and size benefits over existing range-gated imagers.

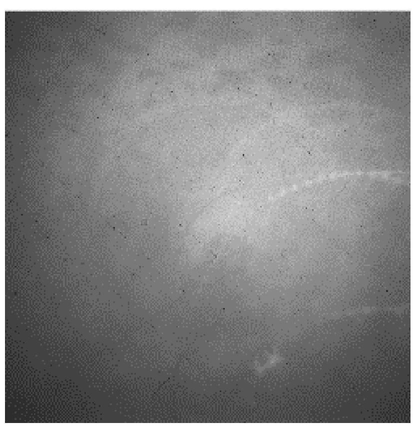

Figure 2. Intensity image of mine simulant surrounded by concertina wire. Range was 17 feet to the mine in turbid water with $c = 0.65\ m^{-1}$.

Figure 3. Range image of mine simulant surrounded by concertina wire. Range was 17 feet to the mine in turbid water with c = 0.65 m^{-1}.

PMMW Polarimeter: A hardware design for the data collection has been developed and the parts necessary have been identified. A design that utilizes a single quarter wave plate placed in front of the radiometer and behind the lens of the radiometer was developed. The system will operate by rotating the quarter-wave plate through a series of angles. This will be done at each pixel. The data will then be reduced to Stokes Vector data at each pixel. The hardware required is simply the quarter wave plate, which is available off-the-shelf from Millitech. The quarter wave plate will be integrated into Intelligent Machine Technologies (IMT) PMMW imaging testbed and tests will be performed at IMT in Dallas, TX.

TRANSITIONS

The SRI technology will most likely transition to the VSWMCM Detachment. The most likely transition for the HMD/wearable computer study and PMMW polarimetry is through either Explosive Ordnance/Low Intensity Conflict (EOD/LIC) or Special Operations Special Technologies (SOST) programs funded through United States Special Operations Command (SOCOM). The results of the night vision threat assessment will be delivered directly to Naval Special Warfare Command.

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