Real-Time Fleet Protection

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Introduction: Recent advances in infrared sensor technology, detection algorithms, and high performance commercial computing hardware have enabled powerful new approaches to autonomous day/night video imaging-based protection systems for Navy surface ships. Under the ONR Fleet and Force Protection Future Naval Capabilities program, NRL has developed the Distributed Aperture System Infrared Search and Track (DAS IRST) system[1] for that purpose. The DAS IRST system provides situational awareness against terrorist-class threats such as surfaced divers, rafts, small boats, and light aircraft, and covert surveillance capability, including autonomous detection, tracking, and threat designation for antiship missiles. The performance characteristics of the system are superior to prior implementations as the result of the development very-large-format high-sensitivity infrared focal planes and improved real-time detection, tracking, and threat declaration algorithms.[2]

Antiterrorist Force Protection: The importance of shipboard situational awareness against asymmetric threats is dramatically illustrated by the October 2000 attack on the USS *Cole* during a routine fuel stop in Yemen. In that event, a small surface craft approached the port side of the destroyer and delivered explosives that put a 40-by-40-foot gash in the ship and killed 17 sailors. There is a clear need for around-the-clock, high-resolution, 360-degree continuous video imagery with computer-based detection and warning to counter such actions. Several field tests in 2005 and 2006 quantified the capability of the DAS IRST system to perform this task under a wide range of conditions, demonstrating the ability to monitor the activity of small boats, rubber rafts, and swimmers within several kilometers of the ship. Figure 10 is a view of the DAS IRST GUI (graphical user interface) with a view from the Naval Surface Warfare Center Dahlgren, VA, test range in which there are small boats. The algorithms in the system automatically find the moving objects that require additional attention, highlight them in the display, and provide track information to the ship combat system for further action.

Covert "Radar Off" Ship Operation: In today's Naval fleets, ship radars provide constant surveillance for antiship cruise missiles (ASCM), up to and even beyond the visible horizon. In tomorrow's fleets, this surveillance capability potentially will be supplemented by a "passive" surveillance system such as the DAS IRST system. Radars are "active" in that they send out a signal that informs anyone listening to the presence of the ship. An Infrared Search and Track system is "passive" in that it provides a similar ASCM surveillance capability without sending any signal. These future ships will then be able to operate covertly by turning off their radars and using their DAS IRST system for constant surveillance of the horizon.

The stringent performance requirements associated with detecting and tracking subsonic sea-skimming cruise missiles led to an extensive effort at NRL to find the best algorithms for ASCM detection, tracking, and automatic threat declaration. In realistic field tests at the Navy Surface Combatant Center at Wallops Island, VA, the decoy target shown in Fig. 11 was towed by a LearJet so that ASCM-like data could be collected by the sensor. These data were used to create Receiver Operator Characteristic (ROC) plots, such as the one shown in Fig. 11, that compare the performance of the standard 2D spatial signal-to-clutter ratio method to three new methods (absolute deviation ratio (ADR), temporal signal-clutter ratio (SCR), and combined) created here at NRL. The goal was to find all the true detections with as few false detections as possible. As illustrated in Fig. 11, the performance of all three new algorithms is significantly superior to the standard method. Furthermore, an automatic threat declaration system was created that uses all available physical property information such as persistence, velocities, scintillation of the target intensity, and track history.

System Description: The DAS IRST sensor is shown in Fig. 12. It is a 30-Hz frame-rate infrared camera that employs a unique 512 × 2560 molecular-beam epitaxy (MBE)-grown midwave HgCdTe focal plane array (FPA) and an anamorphic optical system (appears green in the figure) that permits two fields of view: 3.6 × 48 degrees for distant horizon surveillance and 10 × 48 degrees for closer-in situation awareness. A combination of filters provides midwave spectral band capabilities in the 3.4 to 4.8, 3.8 to 4.1, or 4.6 to 4.8 μm ranges. A temporal noise-limited noise equivalent differential temperature (NEDT) of ~20 mK has been achieved. The minimum ensquared energy for the sensor is 65%, resulting in a noise equivalent irradiance (NEI) of approximately 10^{-15} W/cm^2, a value commensurate with long-range missile detection.

In addition to the sensor, two subsystems are required for detection, tracking, and declaration of threats. A PC-hosted FPGA-based subsystem on the PCI bus performs real-time signal processing of this voluminous image data and finds "detections." These detections go to a PC-based subsystem, which discerns false alarms from real tracks and correctly declares possible threats.

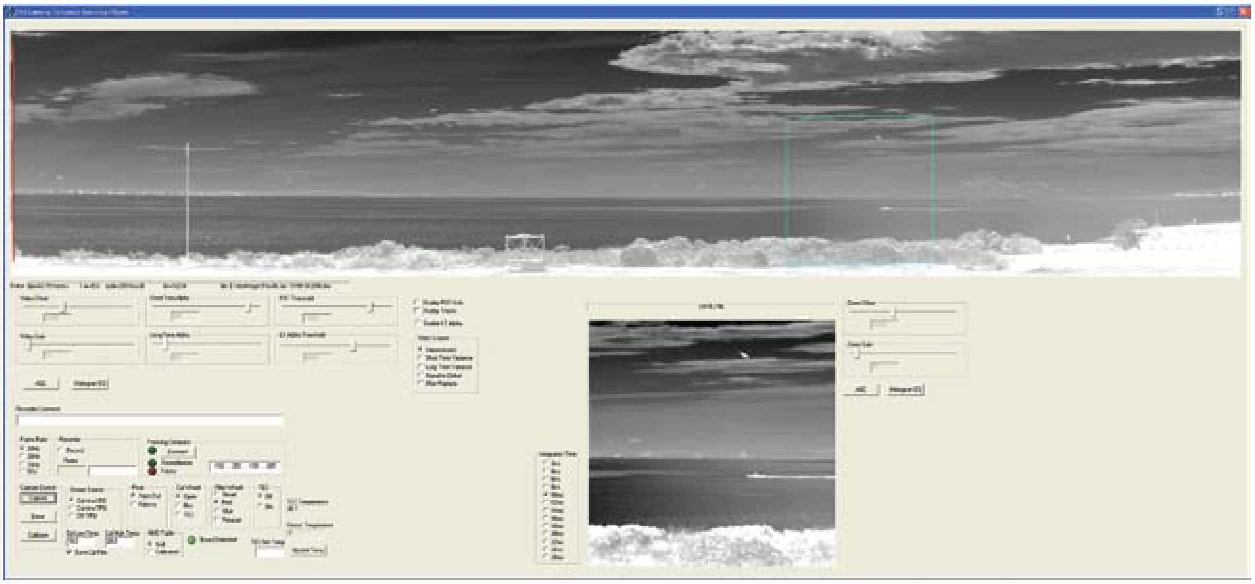

FIGURE 10
An image from the sensor taken at Dahlgren, VA, displayed on the DAS system GUI. The upper image is the full 10 x 48 degree field of view of the sensor. The lower image highlights a detected surface threat at higher magnification. The remainder of the screen is employed for user control of image display, detection, and tracking.

The DAS IRST system is the result of a coordinated effort by several groups led by NRL. The optics were fabricated by Axsys Infrared Systems, the FPA by Raytheon Vision Systems, FPGA hardware implementations were done by Smart Logic, and software was developed by V_Systems. NRL staff was responsible for the overall specification and design of the system, sensor hardware integration and testing, algorithm development, and field testing.

[Sponsored by ONR]

References

[1] J.R. Waterman, L.N. Smith, J. Griffith, S. Black, and A. Childs, "Performance Characterization of the Navy's Staring DAS IRST System," Proceedings 2005 MSS Specialty Group Meeting on Passive Sensors, Feb. 2005.

[2] L.N. Smith, J.R. Waterman, and R. Smith, "Demonstration of Novel Detection Algorithms for the Navy DAS IRST System with 2005 Shore-Based Test Data," Proceedings of MSS Conference on Passive Sensors, Feb. 2006.

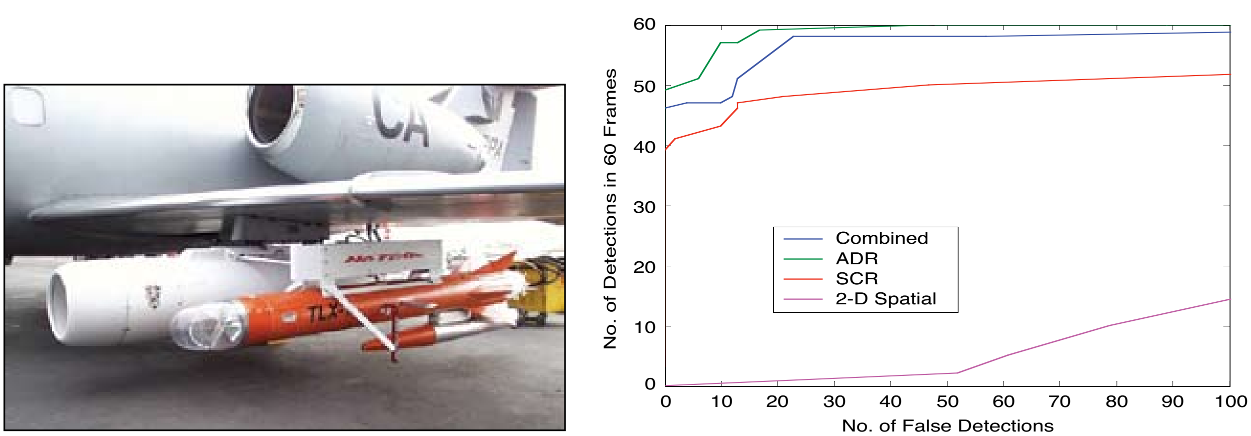

FIGURE 11
This towed target (left) provided a realistic test of the algorithms for detecting ASCMs at ranges out to 25 km. The ROC curve (right) generated from this data compares the original 2D spatial detection algorithm to three novel algorithms developed in this project.

FIGURE 12
DAS IRST sensor (bronze-colored assembly) mounted on pan-tilt positioning system.