Mobile robots: big benefits for US military

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Abstract
Describes two types of mobile robots designed for the US military. One is the mobile detection assessment response system (MDARS), which is an automated robotic security and inventory system capable of patrolling interior and exterior warehouses and storage sites for the Department of Defense. The other is the spiral track autonomous robot (STAR), a multi-terrain military vehicle used to reduce risk to military personnel and equipment. Both autonomous robots allow the US military to decrease unsecured threats and to increase savings which arise from the prevention of expensive hardware loss.

Mobile detection assessment response system: security robots could save millions for US Army and Navy

Over the past several years, the reduction of security personnel and the need for a cost-effective inventory assessment programme have forced the US military to look at new safeguard options. As a result, the mobile detection assessment response system (MDARS) was established in 1989 as a joint US Army-Navy effort to develop interior and exterior semi-autonomous robotic systems for security and inventory management missions. The MDARS interior programme (MDARS-I) targets Department of Defense (DoD) warehouse interiors, while the MDARS exterior programme (MDARS-E) specifically applies to outdoor storage areas. The programme is managed by the US Army Physical Security Equipment Management Office (PSEMO) at Fort Belvoir, Virginia.

The overall technical direction and systems integration functions are provided by the Naval Command Control and Ocean Surveillance Center (NCCOSC) in San Diego, California.

The goal of MDARS is to provide multiple mobile platforms which detect intruders and verify the status of valuable inventory as the platforms patrol a warehouse or storage site. MDARS is also able to function in an environment with other human security guards and can accommodate a large number of mobile robots (up to 32).

MDARS-I utilizes the Cybermotion K2A Navmaster mobility base developed by Cybermotion, Inc., Salem, Virginia, while MDARS-E employs a diesel-powered, four-wheel, hydrostatic-drive vehicle about the size of a golf cart, built by Robotic Systems Technology (RST), Westminster, Maryland. Both MDARS-I and MDARS-E can operate in a supervised-autonomous mode and are equipped with autonomous navigation and collision avoidance, intruder detection capabilities and a product assessment system.

Most of the real-world evaluation for MDARS-I has taken place at a warehouse test-site at Camp Elliott, San Diego, California. The exterior vehicle recently demonstrated autonomous path execution under differential GPS control at the RST development facility in Maryland.
Navigation
MDARS-I uses the Cybermotion K2A’s built-in navigational capabilities for the mapping of the semi-structured warehouse environment. Pre-planned virtual paths are rendered for various guidance modes. Dead reckoning is used in the absence of navigational landmarks, such as walls and shelving, with supplemental optical re-referencing. This horizontal scanning system requires at least two fixed-location, retro-reflective targets, such as reflective stripe markers attached to structural support posts within the warehouse. When the K2A robot detects a potential obstruction via its ultrasonic sensors, the robot stops and uploads a history buffer of sensor data to the planner/dispatcher computer, which generates an alternate unrestricted path allowing the robot to avoid the obstacle.

The navigational tasks for MDARS-E are different from those for the interior programme. The vehicle must follow a network of roads which require both traversability assessment and obstacle avoidance. The collision avoidance strategy utilizes a two-tier, layered approach, incorporating longer-range (0-100ft) low-resolution sensors and shorter-range (0-30ft) higher-resolution sensors, which are employed for more precise manoeuvring. During autonomous execution of unrestricted paths, microwave radar, laser ranging and video image processing are employed, in addition to ultrasonic sensors for obstacle and hazard detection.

Intruder detection
The MDARS-I intruder detection system utilizes the Cybermotion security patrol instrumentation (SPI) module developed under a co-operative research and development agreement with NCCOSC. The SPI scanner rotates at one revolution per second and contains a vertical array of passive-infrared (PIR) motion detectors, a K-Band microwave transceiver and an optical flame detector. In an effort to improve mechanical robustness, Cybermotion is currently producing for MDARS a system which combines the scanner with an integrated pan-and-tilt for the surveillance camera, all packaged in a water-resistant, cast aluminium housing with shock mounting. The scanner is also being reconfigured to include:

1. an additional PIR, sensor-oriented 180 degrees with respect to the existing sensor;
2. a higher-gain microwave antenna (developed by VSE, Inc.);
3. an upgraded CPU which provides the computing power required to run more sophisticated radial tracking algorithms; and
4. an improved slip ring.

The intrusion detection system for MDARS-E consists of a pan-and-tilt turret with several motion detection sensors. Candidate
technologies include: microwave, vision, and radar systems which can be used to detect motion of intruders within a 6.6 to 328ft range and 360° around the stationary robotic platform, thermal signatures, pattern characteristics and behaviour over time. Similar to the collision avoidance solution, a two-layer sensing strategy is being evaluated. The first layer provides a broad area alert and is characterized by fast angular coverage. The second layer has a detailed assessment capability with high angular and range resolution.

Product assessment system

The MDARS product assessment system (see Figure 1) provides an automated method for the location of inventory during routine patrol in a warehouse or exterior storage facility. Specific items are checked against a database of perceived inventory and assigned storage locations. The product assessment system is comprised of interactive RF transponder tags (the Savi Technologies TyTag for the interior platform and Savi SealTags for the exterior programme), tag probing components (Savi interrogators and tag reader computers located on the robotic platforms), a host inventory assessment database and user interface components. The RF tags are placed on high-value items, and are equipped with on-board piezoelectric locator beepers which can be activated individually by the interrogator.

A tag-read operation begins when the tag reader computer instructs the interrogator to upload data from all tags within its transmission range (about 100ft). Several thousands of tagged assets are able to be identified at a single read location in a matter of minutes. After uploading, the buffered tag data are compressed into the tag reader computer's on-board memory until requested by the host console. The data are then compared to previous inventory data to determine if items are missing, have been moved, or were never accounted for.

Big cost savings

A recent cost-benefit analysis indicated that as much as four hundred million dollars over the next ten years could be saved by utilization of the MDARS platforms. Specifically, MDARS can save an estimated:

- $8 million over a ten-year period for each rack warehouse application;
- $2 million over a ten-year period for each bulk warehouse application;
- $6 million in security operations at an average arms, ammunition and explosives storage depot.

Utilizing MDARS to perform security plus inventory functions can save an additional $6 million per site.

The spiral track autonomous robot for hostile environments

The spiral track autonomous robot (STAR) is an innovative and versatile multi-terrain military vehicle used to help reduce risk to
military personnel and equipment during surveillance, reconnaissance and infiltration missions. At highest risk are those soldiers who stand a chance of coming under enemy attack, or being exposed to unexploded or alternative warfare weapons. The highly manoeuvrable STAR, which utilizes state-of-the-art computer technology and two Archimedes screws in contact with its local environment, intelligently negotiates a hostile environment, resulting in reduced casualties and hardware loss.

Unique to military vehicles

The STAR has several exciting features which make it unique compared to other military vehicles such as jeeps, tanks and trucks. The STAR:

- **Is compact.** It measures 38 inches square and 30 inches high, and weighs 175 pounds. It has a low centre of gravity, allowing for the climbing of steep terrain.
- **Can be built for under $15,000.** The entire robotic system (as shown in Plate 3), which consists of the on-board computer, motion controller, all the mechanical components including the frame and screws, motors, servo amplifiers, the necessary power sources, as well as the wireless video camera, is available for under $15,000. Sensor package options are available to enhance military operations and vary in price. Options include: mounting a micropower impulse radar (MIR), a land-mine detection technology which was developed at the Lawrence Livermore National Laboratory in Livermore, California to create a low-cost, sensor deployment vehicle; equipping the STAR with charge-coupled device video cameras and infrared sensors for multi-sensor operation in land-mine detection and unmanned reconnaissance; placing radiation and gas sensors for unmanned radiation detection; and providing heat sensing technology and audio microphones for the utilization of the STAR as a search and rescue vehicle in hostile environments.

- **Is adaptable and flexible in directional travel.** The vehicle uses two Archimedes screws (one left-hand screw and one right-hand screw) in contact with the local environment, to propel itself along the ground. Rotating the screws in different directions causes the system to move instantly in four possible directions and to rotate clockwise or counterclockwise from a standstill. Additionally, the Archimedes screws are constructed of hollow cylinders, allowing for enough buoyancy to negotiate saturated terrain as well as rivers and streams.

Autonomous or remote operation

The STAR is capable of being operated autonomously or remotely. Autonomous operation works well for cleaning up unexploded ordinances, reconnoitering and patrolling secured areas. During autonomous operation, the operator can preprogramme a start point and an end-point, thus allowing the robot to accomplish the task without any human assistance.

Remote operation mode is advantageous when personnel must enter an unsecured environment which may house nerve gases, radiation, or possible ambush attacks. During remote operation, the operator controls the robot from a remote station using a wireless data link and control system software resident in a laptop computer. The operator is able to view the surrounding environment using the wireless video link and camera system.

For both remote and autonomous operations, ultrasonic sensors are mounted around the external perimeter of the robot to provide collision avoidance capabilities. All power is placed on board the system to allow for missions involving distant travel. Inside the electronics enclosure is a central processing unit, motion controller and sensor card. The STAR is also equipped with a complete on-board electronic control system and wireless data/video links for high-level decision making, motion control, autonomous path planning and execution. The control system
and software provide the STAR with enough intelligence to execute decisions which are typically required of their human counterparts.

STAR has progressed in multiple phases. Phase one of the project was completed in August 1995 and produced a “proof-of-concept” prototype used to verify directional operation in hard and soft soils, sand, water, mud and trenches. Phase two, currently in progress, has produced a working prototype with remote video presence and operation capabilities. In Phase three, which began on 1 January 1997 for three months, the STAR was equipped with a differential GPS system for autonomous operation and the MIR landmine detection technology. Plans are also under way for the integration of other sensor packages. For further information on this low-cost vehicle, contact Mark Perez, Lawrence Livermore National Laboratory, University of California, 7000 East Avenue, L-443, Livermore, California 94551, USA. Tel: (001) 510 424 5594.

Further reading