Robots Hunt for New Role as Man's Best Friend on Battlefield

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The Mobile Detection Assessment and Response System is the recipient of laser radar technology developed under a previous Army Research Laboratory Collaborative Technology Alliance.

Autonomous machines that interact intelligently within their environment are part of Army's plan to help the warfighter.

Based on technology being developed through the U.S. Army's Robotics Collaborative Technology Alliance, unmanned systems of the future could become trusted companions on the battlefield—much like canines have been for thousands of years.

Operations Enduring Freedom and Iraqi Freedom have demonstrated the value of robotic platforms on the ground and in the air. Armed, remotely piloted unmanned aerial vehicles have become essential battlefield tools, and explosive ordnance disposal robots are indispensable for countering improvised explosive devices (IEDs). But current systems rely largely on remote control, involving high-bandwidth communications links and intense interaction with human operators that limit functionality and utilization, according to Collaborative Technology Alliance (CTA) representatives.

The robotics CTA is a collaborative effort among the Army Research Laboratory, industry and academia with the purpose of advancing basic research into robotic technologies and transferring those technologies to Army programs.

Robots are limited by what their wiring and programming allow. Dogs, however, relate to people, often understanding gestures, voice tones and moods. They learn from humans, learn about humans and anticipate what humans will do next. If this technology is successful, "Robots will be like a K-9 police officer—a trusted member of a team," explains Jonathon Bornstein, the Army Research Laboratory's robotics CTA manager, clarifying that this is not an effort to develop robotic soldiers.

CTA researchers hope their work will lead to robotic systems that are better able to carry out dull, dirty and dangerous missions entirely autonomously. Potential missions include packing supplies, sniffing out enemies in an urban combat scenario and detecting mines and other explosive devices, as well as providing force protection, reconnaissance, route clearing, unit resupply and countering chemical, nuclear and biological weapons.

The warfighter would benefit from unmanned systems that can sense and comprehend fully both their surroundings and the action taking place in a cluttered, complex, even chaotic scenario. Scientists are developing technology necessary to enable robots to interact intelligently with their surroundings, to act individually or as part of a team, to adapt readily to changing situations and learn from prior experience, to integrate safely and successfully into human activity, and to manipulate objects successfully and dexterously, in a human-like fashion through the worst scenarios.

When the technology reaches the field, soldiers and robots will collaborate as partners and team members. They will require a shared situational awareness and understanding and common ground. This will entail the mutual ability to understand soldiers' intent and then execute their intent, according to CTA representatives.

To collaborate with soldiers as fully autonomous team members, robots will need to understand, maneuver through and manipulate complex environments, and to understand their even more complex human counterparts. CTA members are researching several key areas—perception, intelligence, human-robot interaction and dexterous manipulation, and unique mobility—to make this possible.

Bornstein openly discusses the daunting challenges associated with making machines to do things that come naturally to humans and animals, such as shifting their gait when going from flat to hilly terrain, maneuvering up a flight of stairs or intuitively understanding what other team members are doing and why they are doing it.

"One of the greatest barriers is the area of perception—something people do on a daily basis. People understand the local environment. They see a computer, and they recognize it. They intuitively know what a maître d' is going to say when he approaches the table at a restaurant. These are simple tasks for humans, but it's very difficult to give that level of understanding to an unmanned system," Bornstein says.

Adding to that difficulty is the infinite variety of scenarios an unmanned system might encounter, including buildings, equipment and vehicles. Other factors include different types of terrain, urban or rural environments, a variety of people, including soldiers, civilians and foreign nationals and an array of threats—all things that soldiers sense, understand and learn to cope with fairly easily.

"It's impossible to write a program to cover every scenario," Bornstein says. "Having unmanned systems teamed seamlessly with soldiers means they will need to understand how people react. Developing perception technologies will allow robotic vehicles to understand their environment—even in the chaos of combat."

And to develop a trusting bond, understanding must go both ways. "Robots have to understand the task and the mission, and humans have to understand why robots make the decisions they make," explains Bill Borgia, the program manager for the Robotics CTA at General Dynamics Robotic Systems, the CTA's industry lead. "We're looking at a future where humans don't just control robots but actually work in full collaboration with robots."

Martial Hebert, a professor at Carnegie Mellon University, agrees that developments in intelligence and perception are critical to building the type of trust soldiers need from their team members and says the goal is to get the robots' intelligence as close as possible to that of their human counterparts. "If soldiers do not trust it, they will not use it," Hebert warns.

BigDog hikes a snow-covered trail.

Intelligent control will enable robotic systems to plan, execute and monitor operational tasks undertaken in those same complex environments autonomously. Improved human-machine interface will allow soldiers effectively to send a robotic system on a task and expect it to accomplish the mission with minimal soldier involvement.

For the systems to become fully autonomous, though, robotics will need to make technological leaps and bounds in the area of unique mobility and dexterous manipulation, which is the ability to move objects or use tools. Mobility and dexterity are closely linked and combined into one research area because, for example, robots may need to move debris out of the way so that they and their human teammates can move forward. Future systems need to go beyond obstacle avoidance to obstacle clearance and be capable of traversing terrain that contemporary vehicles, whether manned or unmanned, simply cannot. Both technology subsets currently rely on remotely controlled, fixed configurations with limited joint movement, low applied power to energy consumption and lack of high-fidelity sensor feedback. Manipulator automation usually is addressed through the use of scripts in a controlled environment, but military systems often operate amidst unstructured, chaotic environments—the so-called fog of war—that make scripted behaviors difficult to implement.

In addition, robots must work in environments designed by and for humans. All tools, devices, doors, furniture and appliances are designed around humans and are based on human dexterity, range of motion and ability to manipulate objects.

Effective, generic robotic manipulators for military applications need to replicate, and preferably exceed, the range of motion, grasping capabilities and strength of a human. In addition to picking up heavy objects, the robotic manipulators should be able to pick up tiny objects, turn doorknobs and even treat wounded soldiers.

Regarding mobility, Bornstein explains that the CTA is looking for technology leaps beyond the tracked and wheeled systems available today. "We're looking for mobility in a highly complex, three-dimensional environment—not the normal tracks or wheels—but something that can maneuver through tunnels and caves, over logs or up the side of a building," Bornstein asserts. "We're not conducting research on things that are conventional. We're looking for mobility technologies that are unique."

CTA member Boston Dynamics, for example, has developed BigDog (*SIGNAL* Magazine, August 2006), a heavy-duty, tough terrain traversing, heavy pack carrying, four-legged beast of a robot that mimics canine movements, runs at four miles per hour, climbs slopes up to 35 degrees, walks across rubble, climbs muddy hiking trails, walks in snow and water, and carries a 340-pound load. BigDog set a world's record for legged vehicles by traveling 12.8 miles without stopping or refueling.

BigDog includes an onboard computer that controls locomotion and handles a variety of sensors. The robot's control system keeps it balanced, navigates and regulates its "energetics" as conditions vary. Sensors for locomotion include joint position, joint force, ground contact, ground load, a gyroscope, a laser radar system and a stereo vision system. Other sensors focus on BigDog's internal state, monitoring the hydraulic pressure, oil temperature, engine functions and battery charge, among other things.

Boston Dynamics announced in February that the Defense Advanced Research Projects Agency is providing $32 million in funding to leverage BigDog technology into the development of the Legged Squad Support System, which is expected to carry up to 400 pounds of gear and enough fuel for missions covering 20 miles and lasting 24 hours. It will not need a driver because it will follow a leader using computer vision or will travel to designated locations using sensors and Global Positioning System technology. Development is scheduled for 30 months with the system taking its first walk next year.

The idea is to use the Legged Squad Support System as a pack animal, just as early man used dogs. The system literally will take a load off—50 pounds, to be exact—the back of each soldier in a squad, reducing fatigue and injuries and increasing each squad's combat effectiveness.

Bornstein indicates that soldiers already are developing a great deal of trust for their robotic teammates, in part because the systems already perform valuable missions. He cites anecdotal evidence of military explosive ordinance disposal teams tasked with the tough and dangerous job of dealing with IEDs. These teams sometimes depend on robotic vehicles to detect, remove or safely detonate such devices. "When they see robotic vehicles performing valuable missions on a regular basis, they build a bond of trust through experience, basically," Bornstein says.

The latest CTA was signed in May. It includes a $63.2 million investment over five years and includes a $66.5 million, five-year option. It will involve both basic research for development of fundamental technologies and applied research focused on transferring technology directly to the military. It follows a similar agreement signed in 2001, which resulted in advanced laser radar technology being transitioned to the Army for the Mobile Detection Assessment and Response System. The system is billed as the first semi-autonomous physical security robotic system to enter production and is essentially a robotic guard dog patrolling secure areas, relieving soldiers of a task that most often is mundane but sometimes dangerous. The laser radar guidance system enables obstacle avoidance and road navigation.

Other CTA team members include Carnegie Mellon University, California Institute of Technology, Jet Propulsion Laboratory, Florida A&M University, QinetiQ North America, the University of Central Florida and the University of Pennsylvania. General Dynamics received a $9.4 million Army contract in June to advance the state-of-the-art in perception and control technologies, permitting unmanned systems to autonomously conduct missions in populated urban environments while adapting to changing conditions. The Jet Propulsion Laboratory has developed a wide range of unmanned systems for space exploration and has a specialized Mobility and Robotic Systems Section. QinetiQ, meanwhile, has 30 years of experience developing fielded robotic systems in support of counterterrorism and battlefield robotic requirements, and the universities on the team conduct a broad range of research.

WEB RESOURCES

U.S. Army Research Laboratory Robotics Collaborative Technology Alliance:
www.arl.army.mil/www/default.cfm?Action=93&Page=392
General Dynamics Robotic Systems: www.gdrs.com/
Boston Dynamics BigDog: www.bostondynamics.com/robot_bigdog.html
Youtube BigDog Video: www.youtube.com/watch?v=W1czBcnX1Ww

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