KEEP on RUNNING

5D Robotics Tests Endurance Through Human-Robot Interaction Military Tests

By David Bruemmer

5D Robotics Inc. has been working with funding and direction from the U.S. Army on robotic technology designed to lighten the load for war fighters who must walk for many miles on dismounted patrols. The robots carry the soldier's packs and equipment and go in front of them to detect and neutralize improvised explosive devices.

To test the efficacy of the capability, 5D worked with soldiers during real-world robotic assessments with both small and large robots. The goal: learn how to make human and robotic interactions safer, more reliable and, ultimately, more intuitive.

5D's Behavior Engine software uses a combination of lead and follow behaviors to autonomously drive the robot in front of and behind humans at a minimal safe distance. The company performed multiple tests at Fort Leonard Wood, Mo., and Fort Benning, Ga., to complete soldier assessments of real-world issues confronting soldiers.

The focus of the military assessments was on supporting soldiers on long-range dismounted missions on single- and double-track paths, in order to better understand the concept of operations for inserting autonomous vehicles into a squad as a trusted peer. Another goal was to measure the ability of the system to lower cognitive and physical workload by providing a user interface that is easy to use and simple.

Behavior Engine Software

The Behavior Engine is a suite of robot software behaviors that provides interoperable, plug-and-play mission capabilities on robots ranging in size from 10 to 4,500 pounds. The Behavior Engine provides guarded motion, obstacle avoidance, autonomous driving, mapping, follow and lead behaviors, wagon training, waypoint navigation, and manipulation behaviors.

Two ACERs used in Fort Leonard Wood assessment. One with the flail and one with a roller from Humanistic Robotics. All photos courtesy 5D Robotics.

The Behavior Engine enables a number of modular robot payload kits for lighten-the-load missions and for responding to a wide variety of chemical, radiological and explosive hazards. The payload kits are designed to ensure that each robot can be tasked from the same handheld display regardless of the manufacturer.

One version of the kit called the Adaptive Mission Payload (AMP) was made in partnership with DRS Technologies. The AMP kit ensures that soldiers can plug and play the same payload onto multiple robots that each have their own benefits and limitations depending on size, weight, power and mobility. In a test at Fort Benning, the same AMP was moved between three different robots in less than five minutes, allowing the same controller to drive each one with the same behaviors while using a variety of sensors that soldiers already have in the inventory.

Although radio communications are possible, the robot behaviors are primarily reactive in nature and don't depend on world models, human input or external signals, such as GPS, to work. At the heart of the 5D technology is an approach which emphasizes peer-to-peer positioning, which allows the systems to work indoors and in caves, bunkers and tunnels where communications and GPS may not be available. In real time, the robot senses the relative position of people and other robots using laser tracking and, when appropriate, ultra-wideband tags that provide highly accurate positioning. An advantage of the tag-based approach is that the tags can be seen through vegetation, fog, rain and even around corners.

Hazard Detection and Neutralization

In Fort Leonard Wood, two Mesa Robotics Armored Combat Engineer Robots were used together in a variety of route clearance exercises where the soldiers were permitted to try various configurations and formations of the soldiers, vehicles and sensors in order to accomplish the mission. The assessment involved 32 combat engineers who had been trained to accomplish mine detection and IED defeat operations.

At their disposal, soldiers had two ACER robots, a removable flail made by Mesa and a mine roller developed by Humanistic Robotics. Soldiers successfully used an Xbox

Wagon training at Fort Benning, where the first ACER was driven by remote control while a Segway 440X and another ACER followed autonomously behind.

controller to cue both autonomous lead and follow capabilities while traversing unimproved paths. They could attach the roller and flail as needed to address various mission scenarios and threats. Soldiers preferred teleoperation for control when the roller or flail was attached with the robot in front. Soldiers stated that they would normally keep one robot in front to detect and neutralize hazards and one robot in follow mode behind the squad to carry critical equipment such as ammunition, food and water.

Soldiers liked the reduction in workload due to using the lead and follow behaviors as opposed to the direct teleoperation they had used in the past. One soldier said, "There were a lot of sore thumbs out there. This technology gives us our hands back."

Results of the assessment indicate that soldiers preferred to have two robots but, with only one robot, would alternate between using the lead and follow capability. Some soldiers said they would use lead 60 percent of the time and follow 40 percent whereas others inverted that ratio. Ultimately, the soldiers liked the ability to reconfigure the patrol formation based on the task.

Wagon training multiple vehicles, both manned and unmanned, has been another goal of 5D. Originally, requirements dictated that the squad-support robot needed to carry up to 1,200 pounds of equipment but also be able to fit through narrow doorways, tunnels and passages, so 5D decided to use multiple smaller robots virtually linked through the follow capability. Multiple Segways make it possible to carry the 1,200 pounds of equipment, but with greater flexibility, redundancy and a lower cost. One test at Fort Benning used two ACERs and a Segway together to demonstrate that heterogeneous systems could be driven as one unit.

In this configuration, the first ACER was driven through teleoperation while another ACER and a Segway followed autonomously behind. Each robot could autonomously go around obstacles in its path or stop for pedestrians while maintaining a lock on the target robot ahead. In practice, this allows soldiers to reconfigure their capabilities based on mission needs. Smaller vehicles can be used to look inside of tunnels, bunkers and buildings while the larger robots can carry heavy equipment, neutralize hazards and provide long-term power.

Lighten the Load

Through a collaboration between the Rapid Equipping Force and the Maneuver Support Center of Excellence, 5D Robotics performed a lighten-the-load assessment with the Segway 440X at Fort Leonard Wood. This test involved six participants using a single robot to carry 200 pounds of critical equipment (including packs, water and food) in what is called a lighten-the-load follow formation where the squad members ignore the robot and rely on it to keep up, following behind them over various terrain.

The robot could also be driven in a teleoperated fashion to perform a variety of reconnaissance tasks to scout ahead of the squad. The enabling technology is the follow capability, which uses laser tracking to follow the soldiers through a variety of terrain. The laser provides smooth, accurate tracking and allows the vehicle to get around obstacles and untagged entities safely.

The Segway 440X system was loaded with about 200 pounds (sandbags, water and assorted personal items) and included a generator that can be used to power soldiers’ equipment. The system was powered on at 7:45 a.m. and placed in follow-me mode using the hybrid drive scheme that includes battery and generator power.

Test participants took turns leading the robot over varied terrain at the Fort Leonard Wood TA-190 test area. After three hours and 32 minutes of near-continual movement, the fuel tank was approximately half full and the batteries retained a full charge. The team switched off the generator and the system operated on battery power, which provided a quieter operational mode. The system ran on battery power for three hours and 23 minutes before it was necessary to pause the test due to lightning. After a safety break, the system operated in light-to-moderate rain with the generator on for an additional 37 minutes until darkness and weather conditions ended the test.

Over the course of nine hours and 22 minutes, the system was in motion for approximately seven and a half hours, during which time it covered more than 16 miles without additional fuel or battery power. The system was able to follow autonomously throughout a very wide variety of terrains with only nine interventions required over the course of the day. Five interventions were caused by high vegetation, two because of downed tree limbs and two due to purposeful obstruction by humans.

After 16 miles, the test ended with about 50 percent of battery life and 33 percent of the fuel remaining in the generator. Although the average operational speed was 2 to 3 mph, the robot did do one half-mile segment at an average speed of 4.4 mph. The Army program management representatives who ran the test said the test results indicated the robot could keep up with a patrol throughout the course of a mission, which generally lasts 10 to 12 miles. Participants indicated that the system was easy to understand, natural to use and believed robots would be beneficial in carrying soldiers’ gear.

The real-world user assessments showed the benefit to using robots that can lead and follow soldiers on dismounted patrols. 5D met the Army’s requirements including lowering the workload to below 5 percent, maintaining an operational tempo of 5 mph and ensuring that one or more robots can autonomously follow the squad for up to 15 miles on a narrow trail.

Most importantly, the assessments indicate that there is a potential benefit to moving away from the traditional map-based, GPS-driven approach toward a new scheme more akin to working with a trained dog. The U.S. Army has bought into this new approach and has initiated a Phase 3 Small Business Innovation Research contract to purchase multiple systems for immediate testing and fielding.

Future research involves adding dexterous arms to enable autonomous scanning, grasping and cutting as well as providing soldiers with a smartphone display that shows relative position of each of the squad members and the robots in real time.

David Bruemmer is vice president and chief technology officer of 5D Robotics Inc., located in Carlsbad, Calif. He has written more than 65 publications in robotics and has been awarded 10 patents with 12 more pending.