Bigger Not Always Better: The Power of Small Systems

Jaclyn Pitts

Today's insurgent warfare requires Soldiers to exhibit agility, speed, and stealth to adapt to rapidly changing threats and environments. In response to these complex challenges, the Army is pursuing technology on a smaller scale, through mobile microsystems. While there is still much to be discovered, the capabilities such systems may provide are too great to ignore.

The Micro Autonomous Systems and Technology-Collaborative Technology Alliance of the U.S. Army Research Laboratory is working to deliver technology to enable the development of micro-autonomous systems. (Graphic courtesy of BAE Systems.)

The Micro Autonomous Systems and Technology-Collaborative Technology Alliance (MAST-CTA) of the U.S. Army Research Laboratory (ARL) is working to deliver technology to enable the development of such systems to team with Soldiers.

"We are trying to enhance tactical situational awareness in urban and complex terrain. That is our mission, and that is the environment we're working in," said Joseph Mait, Ph.D., Senior Technical Researcher for Electromagnetics at ARL. "Platforms need to be capable of stable, robust mobility and air-to-ground collaboration, and they need to be able to identify points of ingress."

Mait, who chaired a panel on MAST Dec. 2 at the 27th Army Science Conference, emphasized how such small platforms could provide substantial capabilities for situational awareness, including path planning, threat identification and labeling, and map generation.

Development Challenges

Ronald Fearing, Ph.D., Professor in the Department of Electrical Engineering and Computer Sciences at the University of California, Berkeley, and a member of the MAST-CTA, discussed several challenges facing micro-autonomous systems. Energy management was one challenge, echoed by panel members. "It's not just the amount of energy we have available in a rechargeable battery or how much we can generate from a motor, but how we can use that energy," Fearing said.

Flight, for example, takes a significant amount of power. According to Fearing, battery capacity is the limiting factor, providing a hover time of about 10 minutes or less on average. He explained that trade-offs must be made between climbing and flying capabilities, and between covering long distances or operating for long periods. "What if we make a robot that can either fly when it needs to fly, or run or walk when it needs to run or walk?" Fearing said.

Additionally, power for computation and communication on such a small scale creates an energy struggle. Computation costs can be reduced, but communication energy costs generally reflect a fixed need for power, Fearing said. "As a robot gets smaller, the amount of power we have available for computation needs to scale," he said.

Another challenge the experts addressed was lack of a Global Positioning System signal in operational areas. To address this problem, "[Robotic] ensembles must be adaptive … responsive to human commands and responsive to adversarial settings," said Vijay Kumar, Ph.D., UPS Foundation Professor and Deputy Dean for Education at the University of Pennsylvania's School of Engineering and Applied Science, and Director of the MAST-CTA Center for Processing and Autonomous Operation. The MAST robots must navigate using cameras or laser range finders and collaborate as a cohesive unit to map locations. "Can one operator control a robot to go through a whole complex? We think big, but in this case, we want to deliver small and many," Kumar said.

Actuation was another challenge the experts discussed. "As motors get smaller, performance goes down," Fearing said. "There are always trade-offs between power density and efficiency and how fast these things operate."

Biological Inspiration

Robert J. Wood, Ph.D., Assistant Professor at the Harvard University School of Engineering and Applied Sciences, discussed robotic insects and flight. "We want to use biological trends to guide us," he said. As an example, he cited the Harvard Microbiotic Fly, which has demonstrated flapping wings capable of tethered takeoff, but noted that this development also highlights several areas for future improvement in flight: fabrication, power, control, and aerodynamics.

Robert Full, Ph.D., Chancellor Professor and Director of the Poly-PEDAL (Performance, Energetics, Dynamics, Animal Locomotion) Laboratory at the University of California, Berkeley, reiterated the importance of biological inspiration. "We need to look at the organism and the robot environment as if they were one," he said. "Nature has a huge number of sensors. Ultimately, we need multiple sensors. Robustness is critical. … Nature can learn, and in the future, I think we will be able to move to something far more adaptable."

"Lots of insects have hairs on them for a variety of reasons—sensing, navigation, protection," said Kamal Sarabandi, Ph.D., Rufus S. Teesdale Professor of Engineering and Director of the Radiation Laboratory in the Department of Electrical Engineering and Computer Science at the University of Michigan, and Director of the MAST-CTA Center for Microelectronics. "We are developing hair sensors that can do the same things."

Advantages of Going Smaller

"We're going smaller and gaining some advantages by having more robots that are cheaper, disposable, and more mobile than one large robot," Fearing said. He posed a disaster situation involving collapsed rubble, in which a microrobot would be useful. The tiny robot could easily navigate through small spaces to find trapped Soldiers or civilians, as opposed to a large robot that would be unable to fit through.

Reduced cost is another great advantage of microsystems. "They can be made very inexpensively, without much raw material in them," Fearing said. "You're not going to worry as much if you've got 100 or even 1,000 small robots at

Air and ground MAST systems work with a relatively larger Small Unmanned Ground Vehicle. (Illustration courtesy of ARL.)

$10 each, and you lose 90 percent of them trying to crawl through rubble—as long as you've got enough robots that can get through into the space, leaving behind radio relay tags to relay information back out to a user."

Networking capability is another advantage of microrobotics. Although each robot alone may not possess great processing capability, together they can form a strong computing network, Fearing noted.

Fearing also discussed communication relay capability. By breaking up large communication maps into several shorter paths, a microrobotic system will use less power than that needed for a single large map.

Probably one of the biggest advantages of microrobots is robustness. If a very small robot is dropped from a great height, "it will hit the ground just like an insect, in a way that will not affect its operation," Fearing said. "Making things really small is good for survivability."

Research Directions

Robots in the field today weigh several kilograms, but research is bringing that down to approximately 100 grams or less, Fearing said. Current research and development for small robots is aimed at an even smaller scale, with the capability of running at speeds greater than 1 meter per second.

In battery technology, research is underway to develop greater capacity in smaller packages, Fearing said. However, "we are facing really significant challenges to make significant improvements over what the cell phone industry is driving in batteries," he said.

Looking ahead, Full said, "I think in five years, we'll have specialized in hybrid platforms with added behaviors, such as burrowing, jumping, climbing, and other manipulation. In 10 years, I think we'll have multimodal platforms with specializations for certain tasks."

Sarabandi said much work has been done on mission endurance and lightweight solar cells that can be used as part of a wing structure and provide power for charging a battery or enhancing the mission. Other future developments are likely to include hair sensors, advanced multifunctional wings, and improved flight dynamics.

Slide presentations from the Army Science Conference are available at **http://www.armyscienceconference.com/agenda4.htm**.

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