THE UNIVERSITY OF UTAH

The UTAH TEAPOT

Newsletter for Alumni and Friends of the
SCHOOL OF COMPUTING

IN THIS ISSUE

The teapot was one of the first free-form models used in computer graphics. Since it was created at the University of Utah (by Martin Newell) in 1975, the teapot has become a favorite computer graphics benchmark. The teapot symbolizes Utah's distinguished leadership in computer graphics.

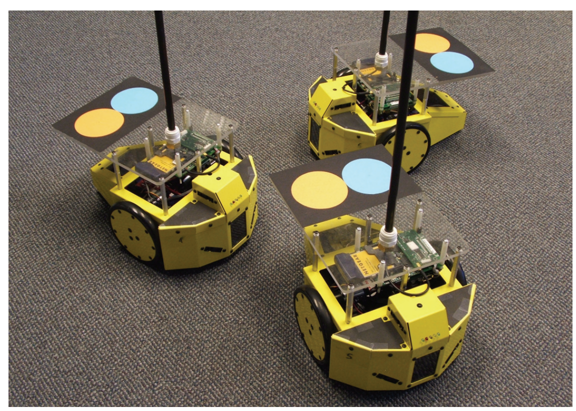
Pete Shirley Wins University Teaching Award

Dean Brown and Pete Shirley

Pete Shirley was awarded the University of Utah Distinguished Teaching Award during College of Engineering Convocation on May 6th. "Pete is deeply committed to teaching as evidenced by the many extra courses he has taught in addition to his normally assigned duties. He has received 6 Dean's Teaching Commendations, the College of Engineering Dean's Teacher Award and the University of Utah Student's Choice Award. He designed the School of Computing's BS/MS program and BS honors program. This year, the second edition of his popular undergraduate computer graphics textbook appears. With this award, we acknowledge Pete Shirley as one of the best teachers at the University of Utah," said Dean Richard Brown during the presentation.

Real Mobility, Real Wireless: A New Kind of Testbed

by David Johnson and Jay Lepreau



Three of the robots in the mobile testbed. Each robot has a PDA-like computer, WiFi card, sensor node, waist-high antenna riser, and a distinctive marker for the vision system.

In the last ten years we have witnessed an explosion of wireless devices. In daily life people use two billion mobile cell phones. Wireless PDAs are used as interfaces to e-mail, the Internet, and to nearby devices. In research, we use tiny new devices called "motes" that consist of an 8-bit computer, environmental sensors, and a radio. Hundreds or thousands of these will be densely deployed to perform tasks like remote habitat monitoring or sniper detection.

But—building reliable, speedy network protocols and applications for these devices is hard! Noisy radio environments, device mobility, and tiny computers greatly worsen the normal problems. How can you show that your latest, greatest routing protocol can deal effectively with radio interference and mobility? You

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might try to validate your design with simulation; however, simulation simply cannot capture the complexity of radio propagation, especially indoors. Research has shown that such wireless simulation often yields wildly inaccurate results.

You could build a small testbed with fixed nodes, but that does nothing to address mobility or automate the tedious process of device configuration and running experiments. The Army can spend large sums having "free" soldiers drive wireless-equipped Humvees around the desert—but normal researchers and students don't have that luxury.

Sponsored by NSF and Cisco, our Flux Research Group had already shown that Emulab, our highly-automated public network testbed, sped up wired experimentation by two orders of magnitude. Experiments are entirely controlled by researchers thousands of miles away, through their Web browsers. Naturally we asked: could we similarly lower the barriers to research in wireless networking, for tiny motes, …*and even for motes mounted on mobile robots?* Could we make it reliable? How accurately could we control and measure position? Could we manage without on-site human operators? Could we do it at modest hardware cost, using standard robots and parts?

After nearly a year of hard work most of the answers are in: "yes." We created the world's first remotely accessible testbed for mobile wireless and sensor net research. Our team included ten people from the School of Computing and ME department, although of course not full time: 3 grad students, 1 undergrad, 4 research staff, and 2 faculty. We developed two entirely new software and hardware subsystems: a localization system ("Exactly where is each robot, right now?") and a robot control system ("Move to x,y without colliding with anything.").

In the mobile Emulab, small computers and wireless devices are mounted on robots that researchers directly control. Users specify positions to which robots move automatically, in real time, avoiding any obstacles along the way. Our localization system tracks robots and provides the "ground truth" location of each robot, accurate to within 1 cm. Such precise information on antenna position enables a fine-grained analysis of the radio environment. Location information is also required to close the robot movement control loop, since robots never go exactly where you tell them.

Armed with these tools, a researcher can use robot motion to study the effect of mobility and real-world RF effects on wireless applications and network protocols. Our extended testbed offers unique evaluation opportunities.

In our current small but production deployment, each of six small robots carries a naked PDA-like computer with an 802.11 WiFi card. The WiFi PDA runs Linux and provides the "control channel" for the robots and motes. Users literally login to their robots. Each of the PDAs hosts the device under test: a "Mica2" sensor network mote with a microcontroller, sensor board, and 900MHz radio. Finally, 25 motes with similar temperature, light, and motion sensors are anchored on the walls and ceilings of the robotic area.

Remote researchers can "drag and drop" robots via a web interface as well as programmatically control their motion and network activity. Researchers monitor robot motion via live video streams, maps, and telemetry, all integrated into the Web pages. Custom software can be easily loaded onto the robots and motes for evaluation.

Two key components underlie these features. First, a network of overhead video cameras provides real-time position and orientation information for each robot. Computer vision algorithms "see" and track the robots. We enhanced an open source computer vision system to handle multiple cameras and to improve the precision from 15 cm to 1 cm. The second component is our robot movement system. Using feedback from the vision system, on each "move" it iteratively guides the robot to that destination. Our path planning and obstacle avoidance algorithms free the experimenter from low-level movement concerns.

This testbed is not only innovative, it is real, in public production use. Both wired and wireless testbeds are freely available to students, researchers, and developers from universities and industry. Visit **www.emulab.net** for more information, or to sign up for a test drive or "real" research use.

Emulab: a portable, device-independent "operating system" to control testbeds of networked devices

- security and containment facilities
- 400,000 lines of code
- 11 other Emulab installations
- The Utah testbed:
  - 1100 users
  - 360 PC nodes
  - 9 miles of cable, in 2600 segments
  - WiFi nodes
  - PDAs & motes: fixed and mounted on robots
  - remote nodes around the world
  - soon: software defined radio!

David Johnson is an MS student and Jay Lepreau is a Research Professor, both in the School of Computing.