Comments to Accompany Slide Set, “Multi-scale sensor networks for border security”
U.S. House of Representatives, Committee on Science
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Greetings. I’m Greg Pottie, deputy director of the Center for Embedded Networked Sensing. I’ve been active in research in sensor networks in a variety of capacities since the mid-90s, and have published a textbook detailing what I’ve learned. I’ll briefly describe what a sensor network is, some relevant experience in developing and deploying systems, and what I see as the main challenges for border security networks.

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The simplest sensor node consists of one or more sensors, an energy source such as a battery, a computational engine such as a microprocessor, and communications capability such as a radio. Over the past dozen years, nodes have gone both in the directions of smaller size and increased capabilities. Some of these are now to the point that they are supported by commercial vendors. Our early idea was that large numbers of nodes could be deployed, and while individually not that useful, the network of nodes would be powerful. Practical experience, as we’ll see, has modified this vision.

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CENS is an NSF-supported STC, with the goal of developing sensor networks for basic science applications in seismology, contaminant transport in ground water, terrestrial ecology, and aquatic ecology. Our thesis in forming the center was that only with the close interaction of engineers and the end-users, the scientists, would useful instruments result. Four years into the life of the center, our technical research agenda has been radically changed by this interaction, with increased emphasis on robotic elements, humans in the sensing loop, and design for reliability.

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In essence, the original vision of thousands of simple autonomous devices was both unrealistic and incomplete. Small nodes continue to have a role, but only as one tier in a layered system with an emphasis on interactions with the expert human user. This leads to faster progress in meeting user objectives, and more flexibility in applying lessons learned from field deployments.

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As an example, to study high altitude plant ecology, engineers and scientists collaborated to develop a robotic system with a suite of sensors specifically tuned to answer the science questions. This provided data at unprecedented spatial scales, in a form that would have been extremely costly to collect with static nodes. Variations of the rapidly deployable system have been used in other application areas.

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Another direction of sensor network research has been sponsored by DARPA. These pictures are from a deployment of static nodes, with the objective of tracking and identifying military vehicles. At the time, deploying even the 37 nodes was a major logistical task. Things have since improved, but long-term deployments in harsh conditions remain challenging.

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Illustrated here is a successful test in tracking an AAV. The message is that relatively simple sensor networks can be effective in tracking vehicles, sometimes at significant range.

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But for personnel, the story is different. Instead of generating lots of noise, heat and vibrations, people produce only small signals and so a dense network would be needed. This density will strongly depend on terrain and obstructions, and even with sophisticated signal processing will produce false alarms. Thus, simple sensors must be part of a tiered network that includes imaging devices such as pan/zoom/tilt cameras and infrared arrays. Humans monitoring the network at a distance then make the final detection decisions and determine what actions to take.

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For example, along a border installation there may be ground sensor fields supplemented by short-range imagers. The fence may have sensors registering contact or strain, with power and other infrastructure supplied along its length. Terrain features may be such that vehicles are limited to particular regions or choke points, where additional sensors are placed. Longer-range imagers may also be placed at higher elevation to provide supplemental views, along with communication relays. Border Patrol agents in vehicles and on foot will provide important supplemental information, and the entire system must be designed so that it works for them, rather than they having to work to support a system (for example, wasting a lot of time on maintenance tasks and false alarms).

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To conclude, it’s very difficult to reliably detect personnel with simple sensors. Wind, soil conditions, obstructions and a variety of other factors present many challenges. A better approach is to have simple sensors focus the attention of imaging devices. Signal processing will then reduce the image set, with humans making the final decisions. Due to the many ways systems can fail, and to deal with active countermeasures, redundant deployments are needed both with respect to sensor type and location. But in any case, it’s almost certain that systems designed without the expert end-users, the Border Patrol, will not work in the intended manner. Our experience with multiple generations of deployments is that the end users must be involved through multiple stages of prototypes and deployments. This is because what people think they need at the beginning is seldom what they realize they really need after seeing the capabilities and limitations of new tools. Thus, a phased development program is the most likely path to success.

Biography

Gregory J. Pottie was born in Wilmington DE and raised in Ottawa, Canada. He received his B.Sc. in Engineering Physics from Queen's University, Kingston, Ontario in 1984, and his M.Eng. and Ph.D. in Electrical Engineering from McMaster University, Hamilton, Ontario, in 1985 and 1988 respectively. From 1989 to 1991 he worked in the transmission research department of Motorola/Codex in Canton MA, with projects related to voice band modems and digital subscriber lines. Since 1991 he has been a faculty member of the UCLA Electrical Engineering Department, serving in vice-chair roles from 1999-2003. Since 2003 he has also served as Associate Dean for Research and Physical Resources of the Henry Samueli School of Engineering and Applied Science. His research interests include reliable communications, wireless communication systems, and wireless sensor networks. His current focus is on the information theory of sensor networks. From 1997 to 1999 he was secretary to the board of governors for the IEEE Information Theory Society. In 1998 he received the Allied Signal Award for outstanding faculty research for UCLA engineering. In 2005 he became a Fellow of the IEEE for contributions to the modeling and applications of sensor networks. Dr. Pottie is the deputy director of the NSF-sponsored science and technology Center for Embedded Networked Sensing, a member of the Bruin Master's Swim Club (butterfly), the St. Alban's Choir (2^{nd} bass), and is a co-founder of Sensoria Corporation.