Sense and Respond Systems

An Emerging Application of Wireless and Digital Networks

by K. Mani Chandy

Living things thrive when they sense what is going on in their environments and respond effectively. Threats and opportunities arise in many personal and business environments. Sense and respond information systems amplify the ability of individuals and organizations to respond in a timely, appropriate manner to situations that occur. Examples of such situations include: financial market turbulance; natural events such as severe weather, earthquakes, and tsunamis; and acts of terrorism. The Lee Center supported research on the theory and application of sense and respond systems. Most importantly, the Lee Center provided seed funds to do early exploration of problems when government funding for such exploration was unavailable. The results of this research have had immediate benefit to government and business; and are described in a recent book, *Event Processing: Designing IT Systems for Agile Companies*, co-authored by Mani Chandy and Roy Schulte, and published by McGraw Hill.

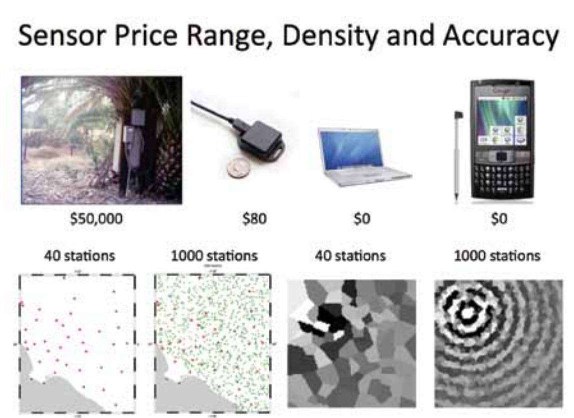

Figure 1: Earthquake Warning Systems: These systems detect early tremors in the ground due to earthquakes and warn of imminent severe shaking. The systems respond by stopping elevators, slowing down trains, and securing the electric and communication networks. A team of students and Prof. Rob Clayton in Geology, Prof. Tom Heaton in Civil Engineering, Prof. Andreas Krause in Computer Science, and Mani Chandy are carrying out this research.

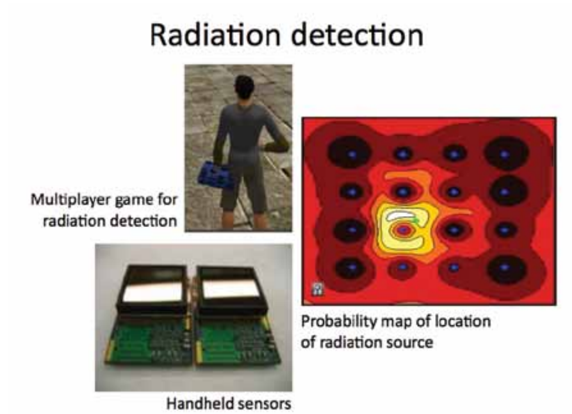

Figure 2: Radiation Detection and Interdiction Systems: These systems detect radiation from nuclear material or moved inappropriately by laboratory personnel or, as might occur in a terrorist attack. The systems respond by identifying the location of the sources of radiation and the isotopes, and then guiding security personnel. A team of Caltech students with scientists from Lawrence Livermore National Laboratory and Smiths Detection Corp is now carrying out this work.

Theory and Framework for Sense and Respond Systems

This portion of the research effort developed a common architecture for sense and respond systems. The architecture identified the key common functions—such as acquiring data, enriching data, detecting events, and responding—and then mapped the functions to enterprise applications. Businesses that want to develop support for sense and respond applications require a systematic methodology to evaluate costs, benefits and return on investment (ROI) for these applications. The Lee Center also supported research on developing such a framework.

The work first studied ways of specifying events: How does one specify what conditions to respond to? How to respond? What is normal and what is anomalous? Our work showed the promise of a compositional approach in which components dealing with different concerns are composed or "plugged together."

Lee Center research also developed theories on when and how to respond. Consider the example of a system that warns about imminent shaking from earthquakes. The data on which the warning is based is uncertain and diffuse. The system cannot wait to gather

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enough data to be certain because the value of a warning depends on its timeliness. How to trade-off designs that warn early but give too many false warnings with designs that give few false warnings but warn late has been studied.

Applications of Sense and Respond Systems

Besides supporting study of an architecture for sense and respond systems, the Lee center also supported research that directed these ideas towards specific applications as described below. Considerations such as use of low-cost, existing networks that can be adapted for sense and respond (see Figure 1) were considered. Much of this work was well ahead of its time when started. Although each project is now supported through government or industrial contracts, the Lee center provided the seed funding in each case.

One application concerned sensing and tracking of nuclear material, such as might occur in the case of a terrorist threat (see Figure 2). Our research dealt with integration of data from different types of sensors and data sources. For example, low-cost sensors can detect photons from radiation sources, but the sensors do not generally know the direction from which the photons came or the distance of the source. Moreover, photons are generated in an intermittent manner, and so radiation sources cannot be "seen" continuously. Lee Center funds helped to answer basic questions such as: how much time is required to detect a source in an open area with N sensors of different types? Now, the results of this research are being leveraged in contracts with the Department of Homeland Security.

A second application deals with electric grid control using modern digital technology (i.e., a smart grid). The power grid has not been an area of extensive research for the past 30 years. The area was considered staid and stable, and researchers moved on to more dynamic topics. Lee Center funds helped us to study the power grid, an area in which our group had absolutely no experience. The challenge with the smart grid is to use communication and computing technology to help manage a grid with green sources of energy, such as solar and wind, that are very dynamic. We now have a sizable contract with Southern California Edison, a major utility, to study this problem.

We expect that research on community based sense and response systems, energy, national security and medical applications will continue for several years.

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Read more at: http://www.infospheres.caltech.edu

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