EE392S: Sensor Networks:

A Series of Ten Lectures *
to be given Winter quarter of the '03-'04 academic year

John S. Wenstrand

1 Abstract

Silicon sensor technology has been under active development for more than thirty years, with well-established technologies for sensing force, temperature, strain, pressure, flow, presence of chemical and biological agents, voltage, current, charge, photons, images, relative motion, acceleration, distance, and position to name a few. At the same time, digital silicon technology has advanced to the point where significant computational power can be integrated with analog structures, permitting local interpretation of data in the very low cost, low power integrated systems sometimes referred to as smart sensors.

A third technological vector, that of low power, ad hoc radio networks, is currently a topic of active research. This emerging technology offers the promise of low cost, low power, wireless interconnection of smart sensors.

This seminar series will explore the interplay of these technologies as enablers of sensing systems formed from networks of cooperating, smart sensors. A survey of sensing technology, ad hoc radio networks, and integration issues will suggest the range of capabilities and design trade-offs for smart sensing network nodes. Information theoretical and networking considerations will provide a sense of the system trade-offs of power, volume of data, data rate, and sensor count. Human factors and practical considerations for widespread, consumer adoption of smart sensing networks will be presented. Finally, future applications and barriers to adoption of sensing systems in consumer, industrial, medical, military, and medical fields will be presented.

*Professors Dasher, Dutton and El Gamal and others have offered many helpful ideas on structure, content, and organization of this series.

Speakers from industry, government, Stanford, and other academic institutions will provide diverse views of the state of the art and build bridges to the Stanford community in this emerging field.

It is intended that a participant in this series will be left with a broad understanding the confluence of technologies which are enabling the creation of networks of smart sensors, the range of capabilities and design trade-offs which govern such systems, and the requirements for making these systems truly pervasive.

A seminar, EE402S offered Spring quarter by Professor Dasher, will focus on advanced sensing applications, presenting a global view of emerging applications of such systems. Close coordination with Professor Dasher, already in progress, will result in this seminar and 402S being quite complementary. It is expected that the proposed seminar will initiate an enduring, multidisciplinary conversation on the topic of sensor networks.

2 Outline

A conceptual outline for the series follows. This initial outline is expected to change significantly over the next quarter with input from prospective speakers, so as to better achieve the intent described above.

1. *Overview of Sensing Systems.* January 6, 2004. Summarize the rich history of silicon sensors. Analyze trends in silicon manufacturing technology, processor technology, and mixed signal design, enabling low power, inexpensive *smart sensors.* Highlight the emergence of ad hoc radio network technology. Discuss the size and growth of the silicon sensors in the global electronics market. Present the purpose of series, the conceptual framework for the course, and requirements for credit.

2. *Silicon Sensor Technology.* January 13, 2004. Survey existing and emerging silicon sensor technologies. Highlight the large number of mature technologies. Discuss the cost, silicon area, special fabrication, and environmental requirements relevant to widespread deployment. Exclude discussion of image sensors.

3. *Sensing and Computation: Image Sensors.* January 20, 2004. The historical vision for “measurement, computing, and communications (MC^2)” and “pervasive computing” still rings true today. Motivate the integration of smart sensors. Analyze trade-offs in generation of silicon technology, power, silicon area, and yield. Present examples

of smart sensors with significant integrated computation using image sensors as an example.

4. *Low Power Ad Hoc Radio Networks.* January 27, 2004. Present current research and emerging standards for low power radio networks, considering energy vs. hop length, energy per hop, energy for forwarding, bandwidth limitations, and robustness. What can be learned of topology from the network? Estimate the time-line for commercial availability of different types of networks.

5. *Information theoretical issues for collaborative networks of sensors.* February 3, 2004. This lecture will examine constraints on system architecture for high-bandwidth sensing applications such as imaging. Link and network bandwidth limitations dictate the degree of local data reduction required, and may bound non-local collaboration.

6. *Energy Scavenging.* February 10, 2004. Enumerate energy sources in the environment. Quantify usable energy to be extracted from various environments. Compare long-lived battery operated systems to energy scavenging systems. Discuss opportunities for creating energy-rich environments. Present examples of existing systems. Summarize implications for design of future energy scavenging systems.

7. *Human Factors and Product Design.* February 17, 2004. Wireless, low power, low cost sensing systems are requirements for rapid, ultra-high-volume deployment of sensing systems. Widespread acceptance of such systems requires ease of use and accommodation of human preferences. This lecture will look at principles of design for adoption of new technologies in general and for sensing systems in particular. Examples of good and bad design will be presented.

8. *Integration bounds and examples.* February 24, 2004. Design trade-offs, cost constraints, and market acceptance for a smart sensing system will be presented. Alternatively, a more specialized domain may be presented, such as *Toward an Integrated System for Interpretation of Neurological Activity. Military Applications of Distributed Sensing Systems.* What can be done with today's sensing system technology if cost constraints are removed?

9. *Research Directions for Sensor Networks* March 2, 2004. A government sponsor of sensor network research will survey current topics of

research in sensor networks and interesting problems in need of attention. What are the key technical problems in need of solution in support of military, homeland security, industrial, and commercial deployment of sensor networks? What are the speakers priorities for future sensor network research, and why?

10. *Panel Discussion: Architecture and Applications of Sensing Systems.* March 9, 2004. A panel composed of industrial, academic, and financial leaders will discuss the future of distributed sensing systems. What are the barriers and where are the opportunities for widespread deployment of sensor networks? Significant time will be alloted for Q&A.

3 Logistics

Electrical Engineering 392S is open to the public. Students may enroll for one unit of academic credit.

Time	Tuesdays, 4:15–5:30, January 6–March 9, 2004
Format	Introduction, 5-10 minutes Speaker presentation, 55 minutes Q&A
Location	Main Quad, Bldg. 420 Jordan Hall, room 041 Stanford University
Sponsorship	Agilent Technologies, Inc. Stanford Center for Integrated Systems (CIS) Stanford Photonics Research Center (SPRC)

February 3, 2004