

**Project Report (Final): Participatory Urban Sensing with Handheld Devices**  
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**PROJECT OVERVIEW**

The next generation of networked sensing applications will monitor the urban world inhabited by people. The sensor data will come from the people themselves, rather than require a dedicated infrastructure. In this paradigm, referred to as “Participatory Urban Sensing” by many prominent researchers including Deborah Estrin and Henri Tirri, ordinary citizens can contribute sensed data gathered via handheld devices and cell phones, and publish it directly on the web using geo-centric web interfaces such as Google Maps or Microsoft Virtual Earth. Potential applications of Participatory Urban Sensing include people collecting detailed air pollution readings of a neighborhood, or live traffic data and publishing such data on the Internet.

Although urban sensing systems have the potential to transform many application domains, there is a dearth of educational materials and teaching strategies that are suitable for use in the activity-based teaching of students. The goal of this project was to fill this void through the development of a practicum course on participatory and urban sensing at Portland State University, leveraging a related course on sensor networks. We have been using two types of devices, the Nokia N800/N810s for publishing image data and the Sun SPOT devices for scalar data (light, temperature, humidity etc.). For the Nokia N800s, we will be using the Cascades programming framework developed at Portland State University by our research group, to publish data on SensorMap developed by Microsoft Research.

**Collaboration:** For this project, the PI has collaborated with Dr. Jens Mache, a professor at Lewis and Clark college. Dr. Mache plans to use the developed materials as part of a course he will be teaching at Lewis and Clark later in the fall. We have also sought advice from Dr. Suman Nath (Microsoft Research) and Dr. Mark Yarvis (Intel Research).

**Leverage:** This project has leveraged matching support from a wide variety of sources, including the National Science Foundation, Sun Microsystems and Intel Corporations. In particular, this project leverages a highly related NSF-sponsored project on developing activity based laboratory materials for teaching sensor network concepts to undergraduates. The project has been aided by generous equipment donation from Sun Microsystems of several Sun SPOT programming kits. Some of the undergraduate work on this project was supported by NSF and Intel grants.

**Positions filled:** Several graduate students help develop the laboratory material for the project, including Phillip Sitbon, Damon Tyman, Akshay Dua and Seungweon Park. The PI also worked with two undergraduate assistants, Jon Charnas (Lewis and Clark college) and Afreen Khan (Portland State University), as a first step in creating tutorial materials on Cascades and SensorMap for teaching undergraduates. The students have been mostly

supported through NSF and Intel grants. *The NWACC grant was used to partly support Afreen Khan and Akshay Dua in Fall 2007.*

## **ACCOMPLISHMENTS**

The students learned the basic concepts of programming sensor networks in an introductory sensor networks course in Winter 2008, that provides a broad foundation, including for building urban sensing applications. In a follow-up course in Spring 2008, we teach the students how to develop more advanced participatory urban sensing applications. We have developed additional laboratories which allow the students how to publish data on the Internet using the SunSpots or the Nokia devices. At the end of the Winter 2008 course, the students were able to build an application that could track a light iso-contour. For the participatory sensing course, the students will develop a course project on participatory and urban sensing with this practicum knowledge. We have accomplished several of the project goals stated in the proposal, as enumerated below.

### **Completion of Project Goals:**

- 1) We have developed
  1. eight target laboratory exercises for the students on sensor network concepts based on the Sun SPOTs including SPOT Familiarization, Application Deployment, Radio Communication, HTTP Access, Node Localization, Power Management, and Security (for introductory course)
  2. three target laboratory exercises for the students on participatory data publication with Sun SPOTs and Nokia N800s and building a high-level participatory traffic monitoring application called StreetWise (for participatory urban sensing course).
- 2) We have stated the learning goals for each exercise in terms that are appropriate for undergraduates.
- 3) We have identified the prerequisite knowledge for the exercise and determine if the students have this knowledge. This includes a rudimentary understanding of relational databases and data streams, understanding of Internet protocols such as HTTP, and familiarity with Python programming. We have identified preliminary on-line and other available reading materials that can provide the necessary background knowledge. We are working on creating abbreviated versions of the reading materials so as to fit them better to our requirements.
- 4) We have prepared a list of pre-laboratory exercises that include reading the necessary back-ground information so that the students had a better chance of successfully completing the laboratory exercises.
- 5) We have developed a set of post-laboratory evaluation tools that assess the learning that has taken place. During Winter 2008, as a part of the course “CS410/510 Sensor Networks”, the PI used and assessed the developed lab exercises based on Sun SPOTs. Damon Tyman assisted in the implementation and assessment of the laboratory exercises. The exercises will be further modified as a result of the assessment.
- 6) We have prepared a formal lab manual that is accessible via the web page and is in a form that can be accessed by students.

**Technology Transfer and Outreach:** The PI is committed to sharing the resources developed as part of this project with other institutions. All the resources developed for the activity-based materials, including lab exercises and installation manuals have been made available through the project web site at:

<http://www.cs.pdx.edu/~nbulusu/PS-grant.htm>

**Innovation, Outcomes Assessment and Impact:** To the best of our knowledge, the developed course and lab materials are the first of their kind in the Pacific Northwest. We have class-tested the programming laboratories with the Sun Spots during Winter 2008. Student feedback and evaluation were collected using survey forms for each laboratory course and personal interviews conducted by Dr. Jeanette Palmiter, an educational consultant from January to March 2008. A summary of responses to some of the quantitative questions is given in Table 1.

Question	Average of 17 Responses
How difficult was the lab or homework? (-2 too easy, 0 just right, 2 too hard)	-0.23
How interesting was the lab or homework? (-2 not interesting, 0 interesting, 2 very interesting)	1
How long did the lab take you to complete? (minutes)	74 min

**Table 1: Summary of Responses to Selected Questions**

This project and the lab materials have had a demonstrable positive impact for the teaching and learning environment. Nearly 50% of students who took the Winter 2008 course also decided to enroll in the Spring 2008 course. In the end of term course evaluation conducted by Portland State University, the response to the course in general, and in particular, the laboratories was overwhelmingly positive, as indicated by several of these comments on the course.

“Keep it up! One of the best classes in this department “

“The home works and labs We did everything taught in class in the lab too, which was great. Assignments were unique and research oriented as well as practical. Learned a lot”

“Lots of great hands-on-work”

“The course is very lab oriented and it helps in understanding concepts. The lab instructions are very clearly defined.”

“We both learned about the concepts pertaining to the subject matter, and also got to practice working with the technology hands-on.”

## CLOSING FINANCIAL STATEMENT

<b>Item</b>	<b>Expenses</b>
Personnel	5393.78
Equipment	3110.76
Travel	1495.46
<b>Total</b>	<b>10000.00</b>

**Table 2: Summary of Financial Expenditures**

The primary expenditures incurred during the project are summarized in Table 1. The equipment expenditures incurred include the purchase of several Nokia N80 and N95 cell phones, N800/N810 tablet devices, and GPS units, as the computational substrate for the Participatory Sensing work.