Description of projects for ECE 5564
February 10, 2005

E-textile projects:

1. Shape-sensing garment

A shape-sensing garment such as [1] could be used for sports training (improving the user's golf swing or tennis serve), physical therapy (providing feedback to the patient and therapist about the user's range of motion and how well the patient is performing exercises), and human motion studies (balance and falling, computer animation).

One particular issue to be addressed is that many of the sensors that have been used so far involve a time rate of change, e.g., accelerometers. For applications that require absolute distances integrating the values from these sensors necessarily introduces error into the distance estimate due to the integration constants, as well as the accumulation of errors due to noise. Calculating the distance requires having some boundary condition that allows a correction factor to be found; for some applications calculating this correction factor may require additional sensors or complex computation. One possible way to remedy this is with sensors that measure the distance directly, e.g. via time-of-flight of ultrasonic pulses from one point on the body to another. At least four ultrasonic detectors in relatively fixed, known locations will be necessary, most likely the shoulders and hips, with an electrical synchronization signal between the emitter and the detector through the conductive fibers in the fabric. Sensors that enable the direct measurement of distance between body points will solve the problem of finding the correction factor required of rate-of-change sensors, but they will introduce other issues, such as blocking of signals by the human body. A likely outcome is that a combination of rate-of-change and absolute distance sensors will be a better solution than either alone, by having the absolute distance sensors periodically provide boundary conditions to rate-of-change sensors.

Questions to be answered include:

- How does being near the body affect the propagation of the ultrasonic sensors?
- Where should the emitters and detectors be placed on the body? How does this vary with the required accuracy?
- How does accuracy vary with the number of sensors?
- What combination of time-of-flight and rate-of-change sensors is necessary or desirable for shape sensing?
- Are there more attractive alternatives to ultrasound, e.g. UWB? What are the trade-offs involved in these alternatives?

[1] Farringdon, J., Moore, A.J., Tilbury, N., Church, J., and Biemond, P.D., "Wearable sensor badge and sensor jacket for context awareness," Proceedings of the Third International Symposium on Wearable Computers, October 1999, pp.107 -113.

2. Context-awareness for physiological monitoring

Many health monitoring applications, such as Holter monitors for ECGs [2], require that the patient keep a diary of activities. The physiological data is analyzed off-line and correlated to the activity diary. Unfortunately, patients are notoriously bad at self-reporting their activities. Furthermore, they are unable to reliably log environmental conditions that could influence their condition, e.g., room temperature and humidity. The proposed garment will automatically annotate physiological data such as heart rate, blood pressure, and energy expenditure with the user’s activities and other context, including environmental conditions, thus giving medical personnel insight into whether a physiological event should be a concern or was simply due to what the user was doing at the time.

There are a number of issues that must be addressed in designing this garment:

- What is the set of activities that should be identified?
- What is the set of sensors necessary for determining those activities?
- Can adequate estimates of energy expenditure be made using accelerometers? If not, what additional sensors are needed?
- What are the power-accuracy trade-offs involved in the garment? (Ideally the garment should be able to log several days of activities.)
- What are the privacy issues involved in collecting the activity data? Where should the data be stored and who controls access to the data?

[2] Raskovic, D., Martin, T., and Jovanov, E. "Medical Monitoring Applications for Wearable Computing," *Computer Journal*, July 2004, vol, 47, issue 4, pp. 495-504.

3. Autonomous indoor location awareness

Many indoor location awareness systems require modifications to the infrastructure such as the addition of beacons. A previous project in this course developed a device for autonomous indoor location awareness using ultrasonic emitters/detectors and an architectural drawing of the building [3]. This device could be augmented in several ways: First, it would be preferable to have the device be able to function without having a map of the building. This would allow the device to automatically create a map of a space for which drawings did not exist, as well as to operate in areas with large objects that are not in the drawings (e.g. tables, desks, cabinets). Second, it is desirable for the device to make the user aware of impending obstacles, both fixed and moving, similar to [4]. Finally, the device should account for changes in elevation (e.g., ramps, stairs, and elevators).

Issues to be addressed in this project include:

- What are the algorithms for automatic mapping and feature detection (e.g., walls, corners, and openings such as doorways)?
- What sensors are needed to detect obstacles and accounting for changes in elevation?
- What additional features of the device would make it useful for people with various disabilities?

[3] Madhup Chandra, Mark Jones, Thomas Martin, "E-Textiles for Autonomous Location Awareness," Proceedings of the Eighth International Symposium on Wearable Computers, Oct. 31-Nov. 3, 2004, pp. 48-55.
[4] Ram, S.; Sharf, J. "The people sensor: a mobility aid for the visually impaired," Proceedings of the Second International Symposium on Wearable Computers, Oct. 1998, pp. 166 – 167.

Assistive Technologies projects:

(The Assistive Technologies Lab has graciously provided me with a list of their ideas for wearable/pervasive computing applications for people with disabilities. The following set of projects are those that I have culled from their list as being appropriate for the technologies and time frames of the course. The full list is available on the course web site. Please feel free to look at it and let me know if any of the other projects interest you.)

4. Secure automatic door entrance system

Wireless keycard door entry systems exist, but they require that the user carry a special identification card. With the proliferation of cell phones, PDAs and other wireless personal devices, it is desirable to create a secure, keyless entry system based upon them. Examples of similar devices include [1][2][3]. The goal of this project is to create a secure automatic door entrance system based upon readily available personal computing devices.

Issues to be addressed include:

- Ease of use, particularly for people with disabilities
- Physical aspects of the security of the device (e.g., the device should not unlock every door that the user has access to as the user walks down the hallway, only the door that user intends to enter; the device should be secure against eavesdropping and replay attacks)
- Scalability, i.e. the system should work well for many users and many doors
- Security versus the constraints on performance and energy of personal devices
- Choice of wireless medium (e.g., Bluetooth, RFID, 802.11, Zigbee)

[5] Smart, N, and Muller, H. "A Wearable Public Key Infrastructure (WPKI)," Proceedings of the International Symposium on Wearable Computers, Oct. 2000, pp. 127-134.

[6] Matsushita, N., Tajima, S., Ayatsuka, Y., and Rekimoto, J. "Wearable Key: Device for Personalizing Nearby Environment," Proceedings of the International Symposium on Wearable Computers, Oct. 2000, pp. 119-126.

[7] Beaufour, A. and Bonnet, P. "Personal Servers as Digital Keys," Proceedings of the Second IEEE International Conference on Pervasive Computing and Communications, March 2004, pp. 319-328.

5. Notifications on Arrival/Departure

Goal: Determine what would be required to model, design, and build a notification system and/or pervasive control mechanisms to assist users on a range of everyday tasks when arriving or departing work or living spaces.

Issue: People when arriving or departing work or living spaces often spend a great amount of time collecting information from computers, email, phones, etc. and changing or checking state of appliances, lighting, temperature, security systems, and other electronic devices.

Objective:

Modeling a notification system might require polling information from a wide range of computers, email, phones, appliances, lighting, temperature, security systems, etc., so as to provide appropriate notifications to specific users when arriving or departing work or a living space. The model might permit users to handle critical items and postpone items that can wait until later or be dismissed altogether. The system may also permit the user on arrival or departure to set or change states of controlled devices based on predetermined or scheduled activities or to set controlled devices to a one-time setting, a new default setting, or establish a recurring setting. Advanced modeling may also make inferences from user patterns over time so as to suggest or make settings based on time of day, schedule, or other information. Lastly, polling information for a notification system implies that a pervasive networking system and a way to probe and alter a variety of disparate devices can be envisioned.

Issue: For persons with certain disabilities or simple memory issues suitable clothing may not be worn outside for forecast weather conditions and appropriate materials (e.g., portable computer, notebooks, lunch, wallet or purse, keys) may not be carried with them when traveling to/from work or classes. A notification system that prompts users only when needed regarding items they have forgotten or not considered when departing their living space.

Objective:
Modeling a notification system might range from simple verbal reminders of clothing and materials based on forecast weather conditions and a user's daily schedule. A more advanced system might pervasively identify the clothing being worn and the materials being carried by a user so to ensure that nothing is easily forgotten. For a more advanced system, one possible method might be a radio frequency identification (RFID) system with transponders embedded into articles of clothing and materials commonly used for work, classes, and items to transport a meal.

Issues to be addressed include:

- Ease of use of the system
- Inference of necessary notifications from user patterns

6. Daily Medication Storage/Metering

Goal: Many individuals with memory/cognitive issues and physical disabilities are required to take a complex daily schedule of medications. Three goals exist. First, ordering medications from a pharmacy when needed. Second, it is important to safely store, prepare, and meter the proper dosages of daily medications usually in a portable pillbox. Third, to ensure the proper dosages are taken at the correct times, so as to not endanger a person's health

Objective:
The objective for storing, preparing and metering medication into a daily pillbox can be achieved by the designing an intelligent pill dispenser. Such a device will enable a user to transfer the proper dosage of medications from a long-term storage device to a portable carry-along medium. The intelligent pill dispenser should both remind the user when refills of a prescription are due, but also insure that the user leaves home their medications in a pillbox with an RFID transponder. Additionally, the pillbox should be capable of reminding the user to take medications at a certain time, and verifying that the medications have actually been taken (a simple alarm when medications are due is not

sufficient). Model and design both devices to help assist of a wide range of possible physical abilities, so that individuals with physical disabilities as well as memory/cognitive issues will be able to utilize the devices.

Infrastructure:

7. Indoor location awareness system
Location awareness is an important facet of pervasive computing. GPS suffices for some outdoor applications, but does not work indoors or near buildings. This project would involve choosing an indoor location awareness system, e.g. Cricket [8] or PlaceLab [9], deploying the system, and demonstrating its functionality with an application. Potential applications include a campus tour guide (the whole campus is infeasible, but two-three buildings would be interesting) or a location-aware game (e.g., a scavenger hunt). Also of interest is a multi-building deployment, demonstrating hand-off between the indoor location system in one building to GPS and to the indoor location system in another building. Issues to be addressed include ease of deployment, cost, and limits on potential applications due to the accuracy of the system.

[8]Cricket, http://nms.lcs.mit.edu/projects/cricket/
[9] PlaceLab, http://www.placelab.org

8. Roll your own infrastructure project:
I am open to other suggestions for projects that involve "building blocks" for future work. For example, in the wireless area, several technologies have recently become available such as Zigbee and the Near Field Communications initiative [10]. It would be useful to obtain design kits for one of these technologies, create the necessary software to interface it with PDAs and/or laptops, and a proof-of-concept application. Another area for building blocks includes user input/output devices for handheld and wearable systems. Your proposal must include a list of issues to be addressed, an demonstration to be deployed, an estimated budget, and a list of potential future projects. The project should result in a tangible artifact (software and/or hardware) that can be built upon for projects in future offerings of the course.

[10] Near Field Communications Forum, http://www.nfc-forum.org/

General notes:
1) The group is jointly and severally responsible for its completion and quality. Learning how to work with people that have different work styles is an important part of this project.

2) Grading will be as follows:

Weekly written progress reports:	15%
Final oral presentation	15%
Final project report:	35%
Final project demonstration	35%

3) Important dates:

Teams formed:	Feb. 17

Final oral presentation/demonstrations:	April 28, May 3
Final written report due:	May 3

Weekly written progress reports are due every Wednesday by noon. I will meet briefly with each team during class on Thursdays.

Weekly progress reports should usually be less than one page, and should include the progress of each member of the team and each member's goals for the upcoming week.