AC 2007-296: A MULTIDISCIPLINARY CURRICULAR EFFORT INCORPORATING WIRELESS SENSORS

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A Multidisciplinary Curricular Effort Incorporating Wireless Sensors

Introduction

In order to develop robust and reliable systems, engineers rely on accurate data often obtained using sensors. Recently, advances in sensor, embedded computing, and wireless technologies have enabled engineers to collect data using wireless sensors on phenomenon and in environments that had previously been impossible to monitor. Example applications include measurement of localized strain on civil structures to characterization of microclimates in forest canopies. From these examples, we see the design and utilization of such sensor systems to be truly a multidisciplinary effort. In addition to being a timely topic, the effort discussed herein demonstrates that wireless sensors lend themselves to hands-on educational activities precisely due to the wide variety of applications for which they can be deployed. In this paper, we detail ongoing efforts at the University of Vermont (UVM) to develop new and enhance existing courses by incorporating wireless sensors. The efforts to date have impacted students from our four engineering disciplines (civil, electrical, environmental and mechanical) and computer science.

Curricular Enhancements

Our efforts to utilize wireless sensors for hands-on activities began in 2004 with our first-year, engineering design course. More recently, upper level courses have been developed and revised to incorporate this technology. In addition, new courses are in development that will utilize wireless sensor hardware. Table 1 summarizes these courses which are detailed in the remainder of this paper.

Table 1. UVM courses impacted by wireless sensor use

Year / Discipline	Course	Status	Students per year	Sensor Implementation
First-year / EE & ME	*First-year Design Experience*	Offered since Spring 2004	~80	Utilizes CricketSat wireless sensor as project platform
Senior/Grad / All Engineering & CS	*Wireless Sensor Networks*	New offering for Fall 2006	~15	Utilizes commercial wireless sensors to develop networks for custom applications
Junior / ME	*Mechanical Engineering Lab III*	Revised for Spring 2007	~40	Integration of commercial wireless sensors for beam mechanics and vibration monitoring
Junior / CE & EnvE	*Modeling Environmental/ Transportation Systems*	In development for Spring 2008	~40	Acquisition and analysis of environmental and traffic data obtained using commercial wireless sensors
Sophomore / All Engineering	*Sensors & Circuits*	In development for Fall 2008	~200	Development of a USB-based sensor platform is proposed

First-year Design Experience

This course was introduced in Spring 2004 as a curricular requirement for electrical and mechanical engineering students and utilizes wireless sensor systems to motivate an interdisciplinary introduction to engineering [1]. Throughout the semester, students develop fundamental skills and knowledge of electronic and mechanical systems with the development of a wireless temperature sensor based on the CricketSat platform (Fig. 1).

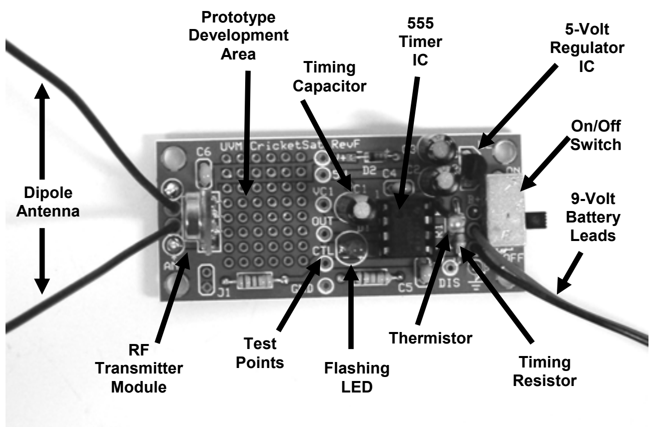


Figure 1. CricketSat wireless sensor platform utilized in a first-year design course

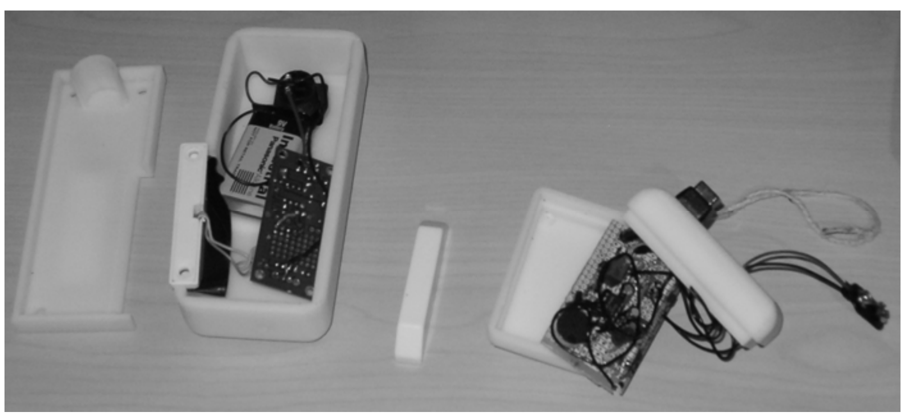


Figure 2. Student project based on CricketSat circuit. Dorm door monitoring system: wireless sensor with magnetic switch (left) and remote receiver (right)

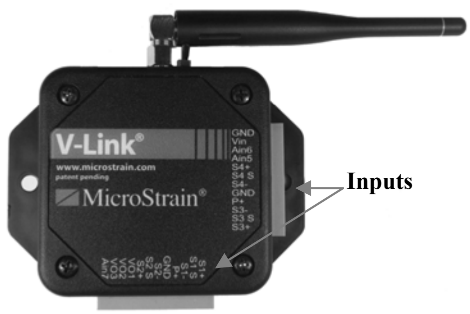
This simple, 555-timer based circuit is subsequently used as a platform for a wireless sensor application for which student teams conceive and develop a system. Example team projects have included wireless systems to monitor noise level, assess the viability of solar energy, ascertain the shock performance on mountain bikes, and monitor entry into dorm rooms (Fig. 2). In the four offerings to date, ~300 students have developed ~75 unique systems using this platform. More details on the CricketSat design, implementation in the first-year design course and assessment results are provided in [2]. In addition, printed circuit board (PCB) layouts, project specific circuit diagrams and design documentation can be found online [3].

Wireless Sensor Networks

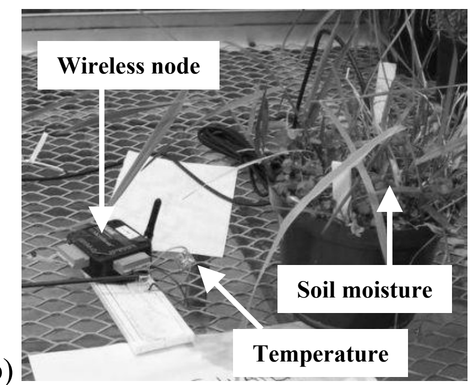
This course, first offered in Fall 2006, introduces senior/graduate students to the fundamentals associated with nascent field of wireless sensor networks. In its first offering, the course attracted 13 students (5 undergraduate and 8 graduate) from electrical engineering and computer science. In addition to theoretical underpinnings of wireless sensor *networks*, this course utilizes wireless sensor hardware donated by MicroStrain, Inc. [4] (Fig. 3a, courtesy of MicroStrain).

Each student was provided a sensor node and basestation for use throughout the semester. During the early part of the semester, students individually conducted experiments to gain experience with the hardware and to quantify its performance (e.g., communication range, sampling capabilities, energy use, etc.). These experiments also gave the students real world numbers to provide context for the concepts developed in class. For example, the communication range experimental results complemented in-class discussion on sensor network connectivity requirements.

In the latter part of the semester, students work in teams to develop a multi-node network for an application of their choice. Example monitoring projects included soil moisture, leaf wetness and temperature in greenhouses (Fig. 3b), traffic patterns in parking lots, and movement of pavement during freeze/thaw conditions.



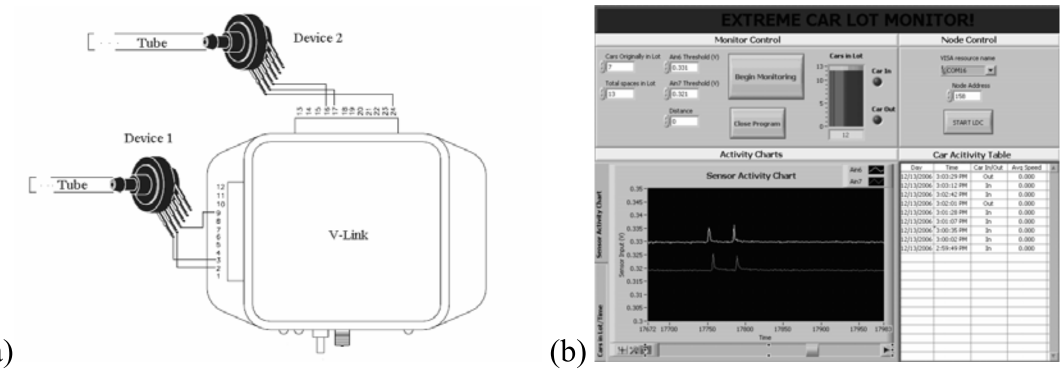
(a)



(b)

Figure 3. (a) MicroStrain V-Link and (b) greenhouse monitoring deployment

Presently there are several wireless sensor platforms available that could be used to develop such systems. Arguably, Crossbow's Motes [5] are the most common platform used for university research. The advantage however of MicroStrain's V-Link is the ease of interfacing the wireless node to a wide range of sensors. For example, student projects have utilized temperature, displacement, moisture, acoustic, magnetic and pressure sensors (Fig. 4a). In addition, sensors that normally require special signal conditioning are also easily implemented (e.g., differential inputs and bridge resistors for strain gages are provided along with programmable gains). The numerous inputs (four differential and three analog) have enabled our students to develop the unique, custom applications. In addition, the MicroStrain node software (Agile-Link) allows one to create data files in formats (e.g., .txt and .csv) that are easily imported into a variety of applications (e.g., Excel, MATLAB and LabView) for further analysis. For example, Fig. 4b illustrates a LabView GUI developed for a traffic monitoring project collecting data from pressure tube sensors (Fig. 4a).



(a) (b)

Figure 4. A wireless automobile counting system. (a) Interfacing pressure sensors to V-Link wireless sensor (b) LabView GUI for configuring system and displaying data.

Mechanical Engineering Laboratory

This laboratory course is a requirement of our mechanical engineering juniors and has an annual enrollment of ~40 students. Wireless sensors are being utilized to study the deformation of beams and their modes of vibration. To illustrate the use, Fig. 5 shows an experiment in which the response of a small structure to vibration is being analyzed. A small electric motor with an eccentric drive induces vibration into the structure. The flexible vertical beams will exhibit different modes of vibration depending on the motors rotational speed. Vibration will alternatively put the beams in tension and compression. To assess this effect, strain gages are glued on these vertical beams and are interfaced with the V-Link wireless node. The wireless node is fixed to the engine's platform, and its receiver is connected to a USB port of a data collection computer located elsewhere in the lab. As noted earlier, the V-Link platform enables the strain gage data to be exported to a variety of applications for further analysis (e.g., determining modes of vibration).

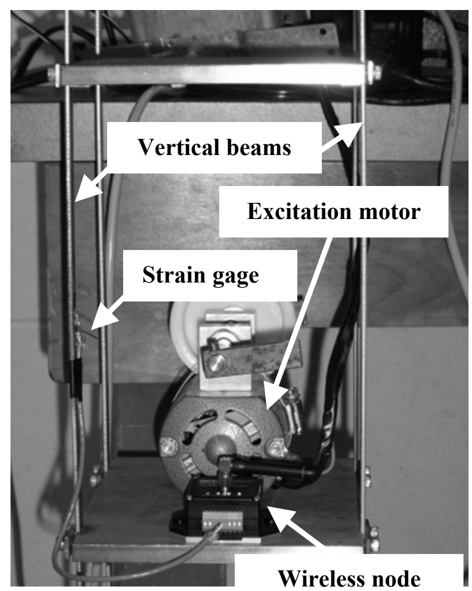


Figure 5. Wireless strain gage experiment

While this implementation is not particularly novel; there are several advantages to utilizing wireless hardware. First, as noted, the data collection computer can be located separately from the test station (e.g., in a neighboring room). Second, the same data collection computer can be used with other test setups by moving the existing or adding another wireless node. Third, this system enables the test setup to be moved easily to classrooms for demonstrations. The system's data acquisition is performed by the wireless node and there are no special computer requirements beyond the USB receiver and downloadable software (i.e., the computer does not require a special data acquisition card). Furthermore, this wireless setup enables instrumentation of other devices (e.g., rotating machinery, civil structures, and vehicles) which may otherwise not be practical or even possible using wired sensors.

In Development: Circuits & Sensors

As part of the ongoing engineering curricular reform that the occurring at UVM, there is a new common core, circuits course being developed. As illustrated in the above discussion, the use of sensors, and wireless sensors in particular, has broad interdisciplinary appeal. Therefore, to ensure that the circuits material is motivating for all the engineering disciplines, the circuit theory will be presented along with applications that utilize sensors. With this strategy, material that is currently viewed as peripheral to our civil, mechanical and environmental engineering students will be put into a context relevant to their chosen profession. At the same time, it is important that electrical engineering students receive a solid foundation for subsequent courses. To ensure this, hands-on exercises that reinforce the fundamentals and utilize sensors are being developed. However, for the large enrollments expected (i.e., all ~200 sophomores engineering major) providing adequate physical laboratory space to conduct these experiments will be a resource constraint. As such, a low-cost, USB powered sensor board and data acquisition software is being developed in collaboration with MicroStrain to support these exercises. Each student will have their own sensor board and thus can conduct their experiments utilizing only a PC and their own low-cost instrumentation (i.e., multimeter) and inexpensive parts. This course is scheduled for implementation beginning in the Fall semester of 2008.

In Development: Modeling Environmental & Transportation Systems

UVM's Civil and Environmental Engineering programs are in the midst of curricular reform in which multiple, stand-alone courses are being integrated to provide greater appreciation of system level performance and constraints. One course being developed along these lines will focus on environmental and transportation systems. To complement lectures, students will utilize wireless sensors to monitor, for example, traffic flow, watershed, surface and ground water parameters that are indicators of stream stability as well as biotic health (i.e., flowrates and variety of water quality parameters). As noted earlier, wireless enables mobility and thus sensors that are presently being utilized in laboratory experiments can now be deployed in the field, which put results in the context of real world systems. Students will utilize their field data to test and validate complex systems models utilized in the subsequent courses.

Additional Educational Efforts and Conclusions

Early classroom experience with wireless sensors has been leveraged by students for a variety of projects outside these particular courses. For example, in summer undergraduate research experiences supported by McNair Scholars Program and the Barrett Foundation, wireless sensors have been deployed for the purpose of environmental monitoring. Example projects have included microclimate monitoring stations and stream bank erosion monitoring systems. The MicroStrain hardware has also been utilized by our students for a variety of Capstone and graduate research projects. Examples include *in situ* strain measurements of mountain bike frames and historic structures. In addition to supporting projects in the freshman course, the CricketSat has been utilized in a variety of K-12 outreach activities associated with the University [6].

While it is no longer uncommon for universities to conduct research in the area of wireless sensor networks, the use of this technology in the classroom is still in development (one notable exception being University of Washington's "Flock of Birds" [7]). Herein, we have presented an ongoing program at the University of Vermont in which wireless sensors networks are not only studied as a course topic but also utilized to enable new laboratory and field experiences in a wide variety of courses which support multiple engineering disciplines. We view our implementation of wireless sensors in the curriculum to be readily repeatable at other institutions; this being especially true for the low-cost CricketSat platform ($15/node). Investigators however should be aware that commercial hardware is presently, in comparison, quite costly (over $100 per node, excluding sensors).

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Bibliography

[1] J. Frolik and T. Keller, "Wireless Sensor Networks: An interdisciplinary topic for freshman design," 2005 ASEE Annual Conference, Portland, OR, June 12-15.
[2] J. Frolik and M. Fortney, "A Low-Cost Wireless Platform for First Year, Interdisciplinary Projects," IEEE Trans. Education, Vol. 49, No. 1, February 2006.
[3] UVM CricketSat Program, CricketSat Web Site, online: www.uvm.edu/~cricksat (accessed: March 2007)
[4] MicroStrain, Inc., online: www.microstrain.com (accessed: March 2007)
[5] Crossbow Technologies, Inc., Wireless Module Portfolio, online: www.xbow.com (accessed: March 2007)
[6] M. Fortney and J. Frolik, "Adaptation of a low-cost wireless sensor for freshman and outreach programs," 2005 ASEE New England Section Conference, Fairfield, CT, April 8-9.
[7] B. Hemingway, W. Brunette, T. Anderl and G. Borriello, "The Flock: mote sensors sing in undergraduate curriculum," Computer, August 2004, pp. 44-50.