DEVELOPMENT OF AN AUTOMATED CRASH NOTIFICATION SYSTEM: AN UNDERGRADUATE RESEARCH EXPERIENCE

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Abstract *– This paper reports on a multidisciplinary undergraduate research project to design, develop, and test a low cost Automated Crash Notification system. The completed in-vehicle system combines wireless communications and Global Positioning Systems with a network of silicon accelerometers to detect a serious automotive collision and automatically summon Emergency Medical Services (EMS) to the crash site. The paper discusses the results of the development effort, the multidisciplinary nature of the project and the undergraduate team, and the challenge of balancing contractual commitments and ensuring a rewarding undergraduate research experience.*

INTRODUCTION

With the advent of trauma centers, the fatality rate of persons reaching a hospital after a car crash has dropped dramatically over the last twenty years. However, nearly 20,000 crash victims die every year before ever reaching the hospital [1]. Undoubtedly, some fraction of these deaths result from catastrophic crashes. However, many of these deaths can be attributed to the failure of EMS personnel to reach the victim during the so-called “Golden Hour” after the accident when emergency medical treatment is most effective. National statistics clearly show that despite a growing wireless communications network and the availability of medivac transport, the time to notify emergency personnel of a crash and respond the crash victims can be quite lengthy. For fatal crashes in the U.S., the average pre-hospital time is approximately 30 minutes in urban areas and 1 hour in rural areas [2].

Currently, emergency personnel must rely on passing motorists, highway patrols, and traffic reporters to report crashes. Often the individual reporting the emergency may not know where he or she is, let alone be able to direct help to his or her location. These delays can be especially lengthy in rural, relatively unpopulated, areas where a crash site may go undetected for hours – and occasionally days.

Crucial to getting help to a crash victim is prompt notification that (a) a crash has occurred, (b) the location of the crash, and (c) some measure of the severity or injury-causing potential of the collision. Automated Crash Notification Systems capable of performing many of these tasks have been installed as expensive options on a limited number of high-end luxury cars. The OnStar System, for example, costs $700 for installation, carries a $200-400 annual fee, and is currently offered only for select General Motors models [3].

FIGURE 1
THE OBJECTIVE OF AUTOMATED CRASH NOTIFICATION IS TO IMPROVE EMERGENCY RESPONSE TIMES

The idea behind Automated Crash Notification is to equip cars with a crash sensor which can detect that an accident has taken place, and automatically notify the emergency medical personnel of the severity and precise location of the accident. Once activated, an Automated Crash Notification system would automatically transmits a signal to a 9-1-1 dispatch center, where an electronic map pinpoints the signal location. Precise location of the traveler in trouble enables rapid emergency response. More advanced sensors can also estimate the injury-producing capability of the crash. The first estimates of the number of potential lives saved by ACN technology are 3000 lives per year [2].

Under the sponsorship of the New Jersey Department of Transportation, Rowan University has undertaken a research effort to design, build, and test a low cost Automated Crash Notification system that combines wireless communications

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and Global Positioning Systems with a network of inexpensive sensors for crash detection. The purpose of the system is not only to shorten the time it takes to notify authorities of the crash event, but to improve the quality of the response.

OBJECTIVE

This paper will present the system requirements for development of a low-cost Automated Crash Notification (ACN) System, the plan to develop this system as an undergraduate research project, and the results of the project – both technical and educational.

SYSTEM REQUIREMENTS

The system is composed of two major subsystems: (1) the Mobile Unit which is installed in the occupant compartment of the vehicle, and (2) the Base Station which is responsible for receiving distress calls from the Mobile Units and reporting their location to emergency response dispatch personnel. This section describes the requirements of each of these subsystems.

Mobile Unit

The mobile unit is responsible for detecting a crash, determining the location of the crash, and communicating crash severity and crash site location to the Base Station. Figure 2 presents the system architecture of the proposed device. The system consists of a single chip embedded microcomputer which is connected to a crash sensor, a Global Positioning System (GPS) sensor, and an embedded wireless modem. In the event of a crash, the crash sensor(s) will detect the vehicle impact, and output a signal proportional to the deceleration of the vehicle. The crash sensor signal output will be continuously monitored by the microprocessor which will decide whether or not a crash has taken place. Upon detecting a collis ion, the microprocessor will poll the GPS sensor to determine the final resting position of the car. The microprocessor will then use its wireless modem to establish a communications link with the Base Station. Once a link has been established, the Mobile Unit will transmit crash site location and the crash pulse to the Base Station. Ideally, the entire process, including linkup, will be completed within 30 seconds after the crash occurred – giving EMS personnel a crucial edge in rapidly reaching the crash victim

The mobile unit will be installed either under the driver's seat or in another occupant compartment location. Locating the mobile unit in the occupant compartment will provide an accurate measure of the deceleration experienced by the occupants in a crash, and will protect the mobile unit with the same structural cage which protects the occupants.

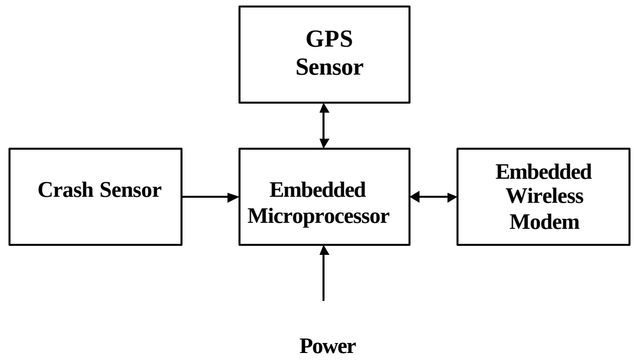

FIGURE 2
SYSTEM ARCHITECTURE

Note that there is some degree of overlap between the Mobile Unit and components in late model cars. Since the early 1990's, all passenger vehicles sold in the U.S. have been required to have airbags. Increasingly, the sensors used in these systems are electronic sensors of the type to be used in this program. However, modification or connection to the airbag or any other safety systems of the car has been strictly avoided in the Mobile Unit for liability reasons. Eventually, automakers may choose to use these sensors to drive both airbags and ACN systems of the type discussed here in production cars. However, the Mobile Unit has been designed to be completely independent of all in-vehicle systems with the exception of the car battery.

Base Station

The prototype Base Station will (1) serve as a test bed for later development into a full-featured Base Station in later phases of the project, and (2) for checkout of the prototype in-vehicle device proposed here. Note that this system is intended only for laboratory use: it is not intended for use as a production system. The Base Station software system will (1) receive the simulated emergency call over the Mobile Unit, (2) receive GPS data and crash pulse from the simulated crash site, and (3) display the location and severity of the simulated crash using computerized maps for Emergency Response Team dispatch.

IMPLEMENTATION AS AN UNDERGRADUATE RESEARCH PROJECT

The hallmark of the engineering program at Rowan University is the multidisciplinary, project-oriented Engineering Clinic sequence [4]. The ACN Project was conducted as part of the Rowan University Junior/Senior Engineering Clinic.

TABLE 1
OVERVIEW OF COURSE CONTENT IN THE 8-SEMESTER ENGINEERING CLINIC SEQUENCE

	Clinic Theme (Fall)	Clinic Theme (Spring)
Frosh	Engineering Measurements	Competitive Assessment Lab
Soph	Multidisciplinary Design Project	Structured Design Project
Junior	Small System Design Project	
Senior	Large System Design Project	

Every engineering student at Rowan University takes Engineering Clinic each semester. In the Engineering Clinic, which is based on the medical school clinic model, students and faculty from all four engineering departments work side-by-side on laboratory experiments, design projects, applied research, and product development. The theme of engineering design is pervasive. The four-year Engineering Clinic sequence offers students the opportunity to *incrementally* learn the science and art of design by continuously applying the technical skills they have obtained in traditional coursework. This *just-in-time* approach to engineering design education enables students to complete ambitious design projects as early as the sophomore year. By their Junior and Senior years, students have tackled a series of increasingly involved design projects, and have acquired invaluable hands-on experience in design, rapid prototyping, and testing methodologies.

Organization of the Project

This project was conducted over two semesters of the Engineering Clinic at the Junior and Senior Level. In the first semester, two three-person student teams conducted the design effort. The first team was responsible for design of the Mobile Unit/Base Station. The second team was tasked with the design, fabrication, and testing of an experimental impactor for testing Mobile Unit crash survivability. During the first semester, the teams finalized the design of the system architecture, procured the initial hardware components, and performed the first bench scale component tests.

In the second semester, the objectives were the detailed design, fabrication, and testing of a prototype system. Three three-person student research teams – each under the supervision of a faculty advisor – conducted this second phase of the project. The teams were responsible for (1) Mobile Unit development, (2) Base Station / Wireless Communications development, and (3) Impact Testing.

The teams were multidisciplinary and consisted of three mechanical engineering students and six electrical and computer engineering students. Three of the students were juniors, and six were seniors. The seniors were the product of seven previous semesters of Engineering Clinic, and had well-developed skills in rapid prototyping, working in multidisciplinary teams, and use of modern fabrication and design tools.

The student teams met with their faculty advisor weekly to discuss project progress. Project management duties, which primarily entailed ensuring that interim deliverables were completed on time, were rotated monthly among the student members. Additional meetings were conducted as necessary to coordinate with the other student research teams.

Assessment

Several instruments were used to assess student progress throughout the project duration. Two weeks after the beginning of the first semester, the student teams were required to submit a Preliminary Design Report (PDR). The PDR contained an initial survey of competing technologies for an ACN system, the objectives of the project, initial design approaches to meet project objectives, and a timeline for completion of the project. Although the PDR was developed very early in the project, the students were assured that the document was intended to be a living report that the student could evolve into a final report as the project progressed.

Midway through each semester, a project design review was conducted to assess design approaches, anticipated problems, and progress to date. The design review was attended by the Principal Investigator, faculty supervisor, and a third faculty member, unassociated with the project, who acted as an external reviewer. Finally, at the end of the semester, the results of the project were presented in a final oral presentation to the faculty and documented in a final written report.

RESULTS – A TECHNICAL PERSPECTIVE

Six weeks into the second semester, the undergraduate teams completed the first working prototype of an in-vehicle ACN system. This section summarizes the design of the Mobile Unit, Base Station, and the results of performance tests of the integrated system.

Mobile Unit. The Mobile unit, shown in Figure 3, contained a two-axis silicon accelerometer, embedded 8-channel GPS system, embedded Z-World Z180 microcomputer, and embedded wireless modem. All components were mounted on a custom printed circuit board which was designed by the student teams, and constructed by an outside fabrication facility.

Power for this system was provided by the car 12-volt electrical system. Note that per our design guidelines this was the only interconnection between the Mobile Unit and the car. Power from the car battery was conditioned as necessary before input to the Mobile Unit electronics. Storage of backup power in a small onboard battery is currently being implemented to permit successful operation of the Mobile Unit even if car battery power were lost because of the crash.

FIGURE 3
MOBILE UNIT: RESEARCH PROTOTYPE

A crash algorithm, a software module in the microprocessor, was developed to detect a crash while avoiding false alarms. The Mobile Unit must be able to distinguish between actual crashes and low-severity crashes or non-crashes such as panic braking or backing into a shopping cart. To detect a crash, the microprocessor samples the accelerometer output at 1000 Hz (1 sample per millisecond). Based upon examination of National Highway Traffic Safety Administration crash tests coupled with crash test modeling, the crash detection algorithm was designed to signal that a crash has occurred if a 10-miles/hour change in velocity occurs in under 50 milliseconds. To put these time intervals in perspective, the typical frontal-barrier crash has a duration of approximately 150 milliseconds while panic braking requires over 1000 milliseconds.

To ensure that the first prototype would not have shielding problems, the electronics were mounted in a casing machined out of single block of aluminum. The casing was machined on a CNC vertical milling center from drawings developed in Pro/Engineer. Later casing designs will be developed using lighter weight materials that provide comparable shielding.

Base Station. In the event of a crash, the Mobile Unit and Base Station will communicate using wireless Cellular Digital Packet Data (CDPD) technology over analog cellular networks. CDPD is a new wireless Web access technology with widespread coverage in New Jersey. CDPD allows a direct TCP/IP link to be established between the mobile unit and base station. Using CDPD, the base station is designed as a Web Server, and the Mobile Unit reports a crash to the Server via a wireless Internet connection. This approach allows the base station to monitor multiple vehicles involved in crashes without the requirement for banks of dedicated phone lines. When the Base Station receives a message from a Mobile Unit, the Base Station displays the crash location and severity on a commercially available mapping product.

Performance Testing. To check the communication between the Mobile Unit and the Base Station, the completed prototype was tested in tracking mode. In this test, the Mobile Unit and associated antennas were mounted in a car, and the Mobile Unit was switched to its special diagnostic-tracking mode. When in tracking mode, the Mobile Unit automatically reads the GPS and transmits its location every second. Note that tracking mode is a research diagnostic only: this mode will not be included in the production prototype. During the test, the car with installed Mobile Unit was driven on a 10-mile circuit around Rowan University. From the continuously updated map on the Base Station, we were able to track the student team as they drove from street to street, and even identify which lot they parked in upon their return.

Future tests will subject the in-vehicle system to a low-severity impact test. Using an eighteen-foot drop tower constructed for this task, the student teams will subject the system to a 0 to 15-mph impact. This test will evaluate the survivability of the electronics to impact as well as testing the ability of the system to detect and report collisions of this magnitude. If successful, we plan to test the Mobile Unit at higher severities by piggy-backing on a crash test conducted by other crash safety researchers.

RESULTS -- AN EDUCATIONAL PERSPECTIVE

In many ways, the ACN project was an ideal candidate for the Engineering Clinic, and a perfect project for the development of research/design skills in undergraduate engineers. The project was design-oriented and required hands-on fabrication of hardware – the primary deliverable. The project is sufficiently complex to require multiple teams, and required frequent interaction and careful collaboration between these teams. The system required the design of multiple subsystems including a GPS subsystem, wireless communication, embedded microprocessor software development, crash modeling, rapid prototyping, and crash hardening. Thus, the project provided an unusual number of opportunities for all participants to contribute to some aspect of the design phase of the project. The ACN system, an electronic device capable of responding to severe mechanical loads, was cross-disciplinary by its nature, and required the talents of multiple disciplines. The students and faculty members were drawn from the Mechanical, Electrical, and Computer Engineering departments.

However, we did not launch this research effort as a Clinic project without a degree of trepidation. There are a number of unavoidable risks associated with conducting a funded research effort as an undergraduate research and design effort. For funded projects, the project must adhere to contractual deadlines, operate within budget constraints, and produce high-quality deliverables. We shared our concerns of contractual accountability with the student researchers.

From an educational perspective, this requirement of adhering to a research contract injected a very definite sense of urgency and realism into the student design experience. When asked by our sponsor early in the second semester to schedule a date for demonstration of the first prototype – a major contractual deliverable, we obtained that date from consultation with the student research teams. Starting from a schematic and a few subsystem tests, the teams estimated they would require four weeks to construct, test, and demonstrate a first prototype of the Mobile Unit/Base Station. We believed this was an aggressive, but not unreasonable deadline, and scheduled the demonstration with the sponsor. Clearly motivated by what they also now saw as an aggressive deadline, the students began a four-week surge of engineering and astounding productivity in which they completed the design, fabrication, and testing of the first prototype. The device shown in Figure 3 was successfully demonstrated on time and within budget.

Reflecting on this project, there appear to be several key factors which led to the success of this undergraduate research and design effort. First, the project was technologically feasible. A market survey had showed that the technology existed for higher cost systems such as GM OnStar. The objective of the project was to develop new approaches for performing the same functions by drawing on emerging technologies for GPS location, crash detection, and wireless communications. Second, the project was backed by sufficient funding to meet the research objectives, and allow the simultaneous pursuit of parallel design approaches. Third, the project schedule for completion of 12-18 months closely matched the Engineering Clinic timetable. Finally, the project was supported by strong cross-disciplinary faculty involvement.

In contrast, it is our belief that some research efforts are difficult to manage successfully in the Engineering Clinic program. These include the investigation of open-ended problems of uncertain feasibility, projects with limited or shoestring funding, projects which lack a faculty champion, and projects conducted by student teams with limited design / fabrication skills. While these projects may succeed with graduate students operating on a longer time scale, our experience is that they are less than ideal for undergraduate researchers.

CONCLUSIONS

This paper has presented the results of a multidisciplinary undergraduate research project to design, develop, and test a low cost Automated Crash Notification system that combines wireless communications and Global Positioning Systems with a network of inexpensive sensors for crash detection. Under the framework of the Rowan University Engineering Clinic, a group of undergraduate engineering students, working in multidisciplinary teams, have successfully designed and constructed a working prototype system. Successful operation of the prototype has been demonstrated in establishing a wireless communication link between the Mobile Unit and the Base Station. This paper has discussed the results of the development effort, the multidisciplinary nature of the project and the undergraduate team, and the challenge of balancing contractual commitments and ensuring a rewarding undergraduate research experience.

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