Electrical and Computer Engineering Department
100 Institute Road, Worcester, MA 01609-2280
Phone 508-831-5231 Fax 508-831-5491
http://www.ece.wpi.edu

White Paper

Development of a system for tracking and location of firefighters and other emergency personnel inside buildings

December 23, 1999

Submitted on behalf of the relevant WPI faculty,

John A. Orr
Professor and Head
Electrical and Computer Engineering Dept.

WPI

Electrical and Computer Engineering Department

Worcester Polytechnic Institute
100 Institute Rd, Worcester, MA 01609
Phone 508-831-5231 Fax 508-831-5491

White Paper

December 23, 1999

Development of a system for tracking and location of firefighters and other emergency personnel inside buildings

Problem Statement

The first and most important job of a firefighter is the rescue of persons. To accomplish this task, a firefighter must enter a burning building, equipped only with an air tank of limited duration, a two-way radio, and possibly a lifeline to provide assistance in finding the way out. This equipment may be completely insufficient for the personal safety of the firefighter in the extremely hostile environment of a burning building. The combination of limited air supply, increasing fire and smoke intensity, and destruction of escape paths, make the development of a superior firefighter safety system vital. Recent advances in information technology and integrated electronics make such a system feasible. Several technologies and areas of expertise can be brought to bear on this problem, ultimately resulting in a wearable device which will:

- identify the current location of each rescue team member (in three dimensions) to the incident command post outside the building,
- provide status (health and motion) information on each team member, and on conditions in the exit path
- provide emergency exit guidance (back-tracking) to each team member synthesized via voice commands, and to the incident command post,
- provide "homing" signals to guide searchers in locating firefighters in trouble.

Technologies

The needed technologies include:

- High-accuracy geolocation, parallel in concept to the Global Positioning System (GPS) but specialized for indoor applications and enhanced in accuracy,
- Rugged and miniature low-power communications and computation equipment,

- Portable, rugged, easy-to-use computerized system control unit,
- Self-configuring, fault-tolerant, distributed software systems.

Background

On the state of the art in firefighter safety

Following is a brief review of currently-available safety systems for firefighters. The equipment currently available to firefighters appears to be quite limited, compared to what could be developed, given current technology.

The **SmartCoat** system (http://www.smartcoat.com) is a microprocessor-based heat sensor for firefighters. It integrates heat sensors into the thermally insulated coats that firefighters wear inside buildings. If the temperature on the surface of the coat is too high, an audio alarm is sounded to warn the firefighter.

The **Bernard Easy Exit** system addresses the problem of finding your way out of a building if you have a hose. The product (http://www.bernardeasyexit.com/what.htm) is essentially a set of raised arrows that can be attached to a hose. This allows the firefighter to "feel" the direction of the arrows and therefore follow the hose in the correct direction to the exit.

The **Cairns IRIS** system (http://www.cairnsiris.com) is one of several systems that use helmet mounted infrared sensors to allow firefighters to "see" in a smoke filled building.

A variety of **umbilical cords** and **lifelines** are commonly used directly or indirectly. The primary lifeline is a rope which is attached to a winch or pulley. Other forms of alternate lifelines are hardwired communications systems, air hoses for breathing and pneumatic equipment, and delivery hoses. A significant problem seems to be knotting, kinking, and tangling, particularly in restricted environments.

The **PASS** Man Down alarm equipment is manufactured by Grace Industries [1]. This is a wearable device which includes a motion sensor and audible alarm. The alarm sounds when the wearer is motionless for 30 seconds. Grace Industries also produces a product that flashes a light to assist in identifying and locating firefighters.

On geolocation

"Geolocation" is the term used for the general problem of locating anything on or near the surface of the earth. The largest recent effort has been that conducted by the FAA to provide a means to identify the location of aircraft to centimeter accuracy for navigation and landing using the Global Positioning System (GPS). More directly related to locating individuals, there is a considerable body of prior work from which to draw. Major areas of prior investigation include: location of soldiers in the urban battle environment (DARPA), location of forest firefighters (U. S. Forest Service), location of persons dialing 911 from a cell phone (FCC), and numerous materiel and inventory control problems and approaches.

Overview of the Technical Approach

This is a challenging technical problem, but with a broad range of approaches to its solution. WPI's Electrical and Computer Engineering faculty have specific experience and expertise in all of the areas of technology which are likely to be needed. Indoor geolocation is more difficult than outdoor; challenges in the indoor environment include multiple radio transmission paths, signal attenuation through walls, and the need to find a clear path to the person once he/she is located in space. Possible approaches to solutions may be partitioned in several ways. One such partition is "active" (where the wearer emits signals) vs. "passive" (where the wearer receives signals only). Standard GPS is an example of a passive system. Another partition is between time-based systems and homing-based systems. GPS is an example of a time-based system wherein the speed of light is used to determine the distance between transmitter and receiver. Homing-based systems locate the direction from which the signal is emanating, to provide a direction to the source. In either case, to determine a location in three-dimensional space, several such measurements are needed. We plan to pursue both approaches; a robust solution may well require redundancy in the means of location determination. Further, we plan that the ultimate system will provide location and exit information both to the wearer, and to the incident command post.

A key aspect of the proposed work will be the active involvement and assistance of the firefighting community, as well as the Fire Protection Engineering program at WPI.

WPI Expertise

WPI faculty have substantial demonstrated experience and expertise in all of the relevant areas of the proposed work:

- Firesafety, research expertise and collaboration with the firefighting community,
- Global positioning systems,
- Indoor geolocation,
- Networking and embedded systems,
- Distributed computing and fault tolerance.

In particular, two major centers at WPI are recognized for their contributions to the state of the art in topics critical to this work. These are:

- The Center for Firesafety Studies, one of the world's leading laboratories for R&D in topics including combustion/explosion phenomena, fire and smoke performance of structures, and firesafety design.
- The Center for Wireless Information Network Studies (CWINS), widely recognized for its pioneering work in wireless data communications, and in particular for research in radio propagation in the indoor environment.

Tentative Schedule and Budget

This schedule and budget is quite tentative at this point. The listed amounts are the minimum expected to be necessary to accomplish basic goals. It should be noted that some of the listed tasks may overlap, shortening the overall project duration to approximately 3 years.

Feasibility study and system design: 1 year, $250,000

Initial prototype (design, construction, initial tests): 1 year, $250,000

Field testing: 1 year, $200,000

Second prototype, final design, final report: 1 year, $250,000

Personnel

Personnel who have participated in the preparation of this White Paper, and from whom the primary project personnel will be drawn, include the following, with their areas of expertise:

David Cyganski, Prof. of Electrical and Computer Engineering, distributed and fault tolerant networking,

David Lucht, Professor and Director, Center for Firesafety Studies, firesafety engineering,

William Michalson, Assoc. Prof. of Electrical and Computer Engineering, positioning systems (GPS), embedded computer systems,

John A. Orr, Prof. and Head, Electrical and Computer Engineering Dept., communications systems design,

Kaveh Pahlavan, Prof. of Electrical and Computer Engineering, wireless communications systems, indoor RF propagation.

References and Bibliography

1. NFPA 1982, Standard on Personal Alert Safety Systems (PASS), 1998 edition, National Fire Protection Association, Quincy, MA.
2. J. Werb, C. Lanzl, "Designing a Positioning System for finding things and people indoors," *IEEE Spectrum*, Vol. 35, No. 9, September, 1998.
3. P. Krishnamurthy, K. Pahlavan, J. Beneat, "Radio Propagation Modeling for Indoor Geolocation Applications," Proc. IEEE PIMRC '98, Boston, MA, Sept. 8-11, 1998.
4. W. R. Michalson, J. Single, M. Spadazzi, and M. Wehr, "A Real-Time GPS System for Monitoring Forestry Operations," Sixth Biennial Forest Service Remote Sensing Applications Conference, Denver, CO, May 1-3, 1996.
5. W. R. Michalson, D. B. Cox, and H. Hua, "GPS Carrier-Phase RAIM," ION GPS-95, 8th International Meeting of the Satellite Division of the Institute of Navigation, Sep 12-15, 1995.