2014 NSF Young Professionals Workshop on Exploring New Frontiers in Cyber-Physical System

iRescue: Emergency Response System using Smartphones and Smart Sensors

Hyungchul Yoon
Department of Civil & Environmental Engineering
University of Illinois at Urbana-Champaign
(Advisor: B.F. Spencer Jr.)

13-14 March 2013
American Geophysical Union,
Washington, DC

Background

Recent tragediess such the 2008 Cyclone Nargis (130,000 deaths), the 2010 Haiti earthquake (316,000 deaths) and the 2011 Japan earthquake (15,861 deaths) have show the tremendous devastation that such disasters can wreak on society. When victims are trapped in a building due to these disasters, emergency responses must act quickly to save lives; the more quickly emergency response personnel can locate and identify the status of victims, the more effective life-saving efforts can be. Current emergency response systems are depend heavily on first responders' intuition to search for victims. However, in complex buildings or in situations where the first responders' sight is hindered, finding victims trapped inside the building can be very difficult. Moreover, some parts of the building might be damaged and dangerous to pass through. Therefore, a system that can estimate the location and the status of the victim and provide the safe evacuation route based on this information is needed. At a larger scale, evacuation of a region may be necessary. However, because of the damage buildings, bridges and roads some of the routes might be blocked and consequentially result a traffic congestion. Therefore, the demand for system that can analyze the infrastructure of the disaster site, and optimize the evacuation route is considerable. In this poster, a Cyber-Physical System (CPS) called iRescue (Illini Rescue System) will be proposed that could enhance the emergency response system in both the building scale and the city scale.

Proposed Research

❑ Victim Assessment System (VAS)

Activity of a victim can be estimated by using smartphone sensors (e.g. accelerometer, gyroscope, and magnetic field sensor). In preliminary research, machine learning technique was implemented and it was able to recognize activities of individual victims with 86% accuracy. The sequence of these activity can be then used to estimate the status (e.g. non-ambulatory/ambulatory, injured, and conscious/unconscious) of the victims.

❑ Victim Positioning System (VPS)

Location of a victim can be estimated by using WLAN based indoor localization techniques. From RSSI (received signal strength indicator) of multiple WAP(wireless access point). In preliminary research, it was able to locate victims in room scale for 87%. This can be further improved by combining with the dead reckoning, which tracks the victim with the sensor data from smartphones.

❑ Structure Assessment System (SAS)

Status of the structure can be estimated by measuring the vibration of the structure. Vibration (acceleration) of the structure can be measure by installing wireless smart sensors to the structure. By analyzing the dynamic characteristics of the structure (frequency, mode shape, flexibility, etc.), location of the damage can be estimated.

❑ Bridge and Road Assessment System (BAS, RAS)

Status of the bridges and road can be assessed by taking image from the sky. Quadcopters can be used to carry the digital camera and take the picture. Using computer vision techniques such as SFM(structure from motion). 3D model of the structure can be constructed. By comparing the constructed model with the original model, the status of the bridges and road can be estimated.

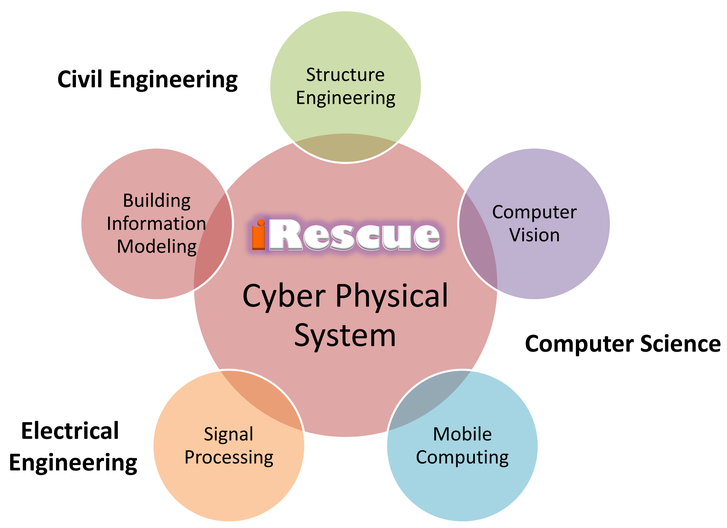
❑ Indoor Evacuation System (IES)

Probabilistic approach can be used to determine the hazard are in the building by using the information from SAS. Considering the status and the location of the victim (VAS and VPS), customized and adaptive evacuation route will be provided to both the victims and first responders.

❑ Outdoor Evacuation System (OES)

Probabilistic approach can be used to determine the hazard are in the area by using the information from SAS. Considering the of bridges and road (BAS and RAS), adaptive evacuation route will be provided.

Potential Impact in CPS



❑ Interdisciplinary Research

The proposed research needs collaboration between civil engineers, computer scientist, and electrical engineers. By adapting the most advanced technologies in the three disciplinary, an accurate and effective emergency response system will be developed. The main task for each disciplinary will be shown below

❑ Civil Engineering

Assessing the status of the infrastructures including building, bridge, and road (SAS, BAS, and RAS) are the most important task for civil engineers. Structure Health Monitoring (SHM) and Non-destructive examination (NDE) are one of the research areas in civil engineering focused on assessing the status of structures. By measuring the dynamic response and analyzing the image of the structure, the status of the structures will be estimated. Also Building Information Modeling (BIM) which is widely being used in construction sites, can be used to manage the information collected in the building and visualize them.

❑ Computer Science

Computer science comes in to most of the components. Machine learning based activity recognition are used to estimate the status of the victim (VAS) and indoor localization are used to locate the trapped victims inside the building (VPS). Also computer vision is used to construct the 3D model of the structure (BAS and RAS). Also, lots of techniques from mobile computing area such as dead reckoning will be used.

❑ Electrical Engineering

Electrical engineering takes role in signal processing. For most of the components, numerous sensor data or image data are being used. Without the signal processing, it is difficult to obtain useful and essential information from the data. Also some knowledge about the sensors will be required to perform the proposed tasks.

References

- Yoon, H., Shiftehfar, R., Cho, S., Spencer, B., Nelson, M., Agha, Gul "Victim Localization and Assessment System for Emergency Responders", In preparation
- Spencer, B. F. "Smart sensor technology: a new paradigm for structural health monitoring." (2006).
- Doebling, S. W., Farrar, C. R., & Prime, M. B. A summary review of vibration-based damage identification methods. *Shock and vibration digest (*1998)
- Ravi, Nishkam, et al. "Activity recognition from accelerometer data." American Association for Artificial Intelligence (2005).
- Paramvir Bahl and Venkata N.Padmanabhan, "RADAR: An In-Building RF-based User Location and Tracking System", IEEE INFOCOM (2000).

Please cut here