BUILDING SITUATION TOOL: INDOOR DISASTER SCENE OVERVIEW

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ABSTRACT

During emergency situations, rescue services dispatch a first response team to the emergency location. Once at the location, the first responders assess the situation, and call for support as needed. Emergency services rely on information received from witnesses on site when committing the initial resources for the emergency. Furthermore, the location and situation of the fire outbreak is unknown to the first responders, as is the extent of the threat, and number of persons inside the building. *The progress of information technology and smart systems allows sensors to be installed into buildings, which automate building operations, monitor people flow, and identify potential risks.* While the new technologies have entered buildings to streamline maintenance, first responders still rely on paper printed building plans located on site.

Keywords: first response, sensors, data visualization, interactive overview, first response planning

1. INTRODUCTION

Each emergency is different, and the information first responders have of the incident is limited. The emergency site, status of victims, or the threat are not clear, making planning and organizing the response challenging [1]. For each case, and type of event, the first responders have drilled procedures and actions to be performed in place [2]. This work [3] focuses on indoor emergencies, examining the case of newer buildings equipped with sensors and building automation: utilizing building sensors to monitor and maintain temperature, access control, security, lightning, and other related systems. However, integration to existing building sensors is challenging due to reasons such as data privacy and use of proprietary systems. To avoid functional and operational issues while prototyping, a set of same types of sensors is purchased and will be tested in the project. In addition, first responders highlighted that information on approximate number of persons within the building is of value in emergency operation. For that reason, person counting is tested as an addition.

The sensor installation guidelines [4] dictate that smoke sensors need to be installed every 60m^2 and temperature sensors every 30m^2, ensuring high coverage for fire outbreaks and early discovery. Building automation standards define values, such as room temperature, that the building sensors monitor for, and adjust to accordingly. The minimum required indoor temperature is 20°C during winter months, with a target value of 21,5°C [5].

2. MATERIALS AND METHODS

In collaboration with first responders, a list of critical information to be shown was developed, which is visualized in a 3D building model, along with sensor values and alerts. The sensors systems and visualization software are referred to as the *Building Situation Tool (BUST).*

2.1. Visualization software

The building visualization software operates on a Windows PC and is developed using Unreal Engine 4. An important requirement for first responders is that the software, while offering interactive 3D elements and touch functionality, can run on laptop devices with lower hardware specifications. An Internet connection is required to receive and send data. Sensor data and alerts are received from KAMK's data server. Visualization software can send user added points of interest and planned path data to the FASTER project Kafka broker, used for sharing and visualizing information at different levels of the command chain in emergency situations.

In addition to existing sensor types, first responders highlighted the need to know the number of persons within the building, as well as their movement within different section, such as main restaurant, ground floor, second floor and sport hall. The first responders can assess the number of persons in the vicinity of the fire outbreak, and how many persons are in the building at any given time.

The purpose of the software is to record data from building sensors and display it over a 3D model of the building. First responders use a mouse and keyboard, or touch input to navigate the building, inspect individual rooms' sensors, review the timeline of events, or current events in real time (Figure 1). The sensor data includes temperature, movement, person count, CO_2, smoke, and door state. In addition, first responders can plan different routes inside the building and place different point of interest markers for better situational awareness.

Figure 1 BUST displaying notifications and alerts in a side window.

2.2. Sensor system

Sensor demonstration system was developed from scratch in the FASTER project [3]. It can be used independently from existing building sensor infrastructure, and thus, easily adopted in any building for demonstration purposes. The system consists of the following hardware: sensors, measurement nodes, mobile network routers and a server.

Sensor models and their measurement variables are: AHT-10 for temperature, CCS811 for CO_2, gas sensor MQ-2 for smoke level, a simple switch for door state, passive infrared (PIR) sensor HC-SR501 for movement detection and ultrasound sensor HC-SR04 for person count. Ultrasound sensors are used as a pair for detecting direction of movement. Environmental sensor values are typically measured and sent once every minute but can be adjusted according to needs. Other sensors measure and send data only when there is a change in sensor state. Sensors are connected to measurement node ESP32 through General Purpose Input/Output pins (GPIO). ESP32 nodes are development kits with Wi-Fi and Bluetooth interfaces. For demonstration purposes up to 15 nodes have been deployed and each equipped with specific set of sensors. Nodes can be powered by power banks for short demonstration use, or by phone chargers for continuous use. Once a node is powered up it connects to predefined Wi-Fi network and starts sending data. Nodes send sensor data through Wi-Fi connection to routers, which pass it to server using 4G mobile network. Number of required routers depends on distribution of nodes. Data is encrypted using Transport Layer Security (TLS). Nodes provide web interface for status checks, latest sensor readings and person counter reset. The status and settings of individual nodes is checked with a mobile device or a computer. The interface is limited to the local Wi-Fi network.

The server is located at Kajaani University of Applied Sciences (KAMK) and is maintained by KAMK personnel. It is a virtual Linux machine running Influx database for time series applications. Sensor data gets timestamps automatically and is stored for authenticated data requests. A Python program runs on the server that will, first, calculate person count in predefined areas of the building based on person counter values collected near exits and in hallways, and second, use sensor data to create alerts using specific thresholds and rules. There is also an integration to Faster Kafka broker for data fusion and review.

2.3. Laboratory testing

The sensors were tested in office surrounding in multiple occasions and up to several days or even weeks at a time and later in a planned demonstration with Kainuu rescue services at Kajaani Lehtikangas school in March 2021.

The cheap environmental sensor was not expected to be highly accurate, and they were not controlled by known precise sensors. Temperature and PIR sensors were found to be working without any problems and were reacting to small temperature changes and movement as expected. Door switches were taped to door frames so that they would have contact to closed door. They needed some adjustment from time to time. Challenge was not to use anything that would leave a permanent mark on any surfaces. The CCS811 for CO_2 was found to be precise enough for demonstration purposes but seems to have tendency to show higher values than expected occasionally. HC-SR04 ultrasound sensor had issues with range and some materials that did not reflect ultrasonic sound waves well enough.

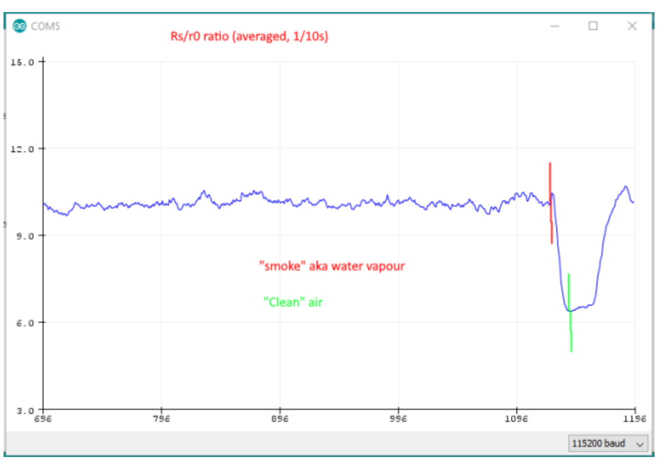

Figure 2 Defining threshold level for alert for smoke sensor.

Each particle sensor MQ-2 were calibrated in clean air (office air) as per instructions by the sensor manufacturer. Precise absolute concentrations of smoke or other gases were not expected, but instead clear and repeatable reaction to smoke or similar substance. The sensors were tested using air humidifier, similar but in smaller scale that fire and rescue units use for practicing, and threshold value was defined for node when to send an alert. Rs/R0 ratio was measured every 10 seconds and after a while "smoke" was induced to the sensor for a short time. R0 means resistance of sensor in clean air and Rs value that is actively measured. Rs/R0 ratio should be 10 for clean air. In Figure 2 is an example of such test. The window size is 500 samples which indicates the reaction speed is a bit sluggish, on the other hand, measurement values have some averaging (old value*0.85+new value*0.15) to prevent unnecessary peak values.

3. RESULTS AND DISCUSSION

Most sensors were usable in demonstration setting. Person count using ultrasound sensor HC-SR04 was found to be unreliable. Operation range was limited, and it had trouble detecting less reflective clothing material. Next iteration will be implemented with ESP32-Cam module which has a compact camera module. Edge computing is used for image processing, and it is not necessary to send any GDPR material over the network. First responders reported that the visualization tool felt a bit hard to use, all fundamental parts worked but user interface and controls needed some clarification. For the next iteration user interface and controls will be updated.

4. CONCLUSION

Through the FASTER project, a set of sensors was tested matching the types of sensors installed in buildings. *The aim is to trial the components together with a visualization software and allow first responders to examine emergency situations already before arriving at the scene.* Initial laboratory and field testing showed that sensors are usable, except for the person counter. For person counting, the camera module will be tested. A second-round usability trial of the visualization software, as well as a field trial exercise with first responders are planned to test the BUST system. The BUST concept trailed through FASTER can be adopted for other buildings for future demonstration purposes.

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