ALANYA
ALAADDİN KEYKUBAT
ÜNİVERSİTESİ

RAFET KAYIŞ ENGINEERING FACULTY

COMPUTER ENGINEERING

Earthquake Emergency Management System

Sepehr LATIFI AZAD

190254082

Abstract

The idea behind this project is to create a system that can send an emergency message to the relevant departments, to report the building situation by using various sensors. This report presents an Arduino-based project aimed at enhancing emergency response in earthquake-prone areas. This project focuses on the afterward of the earthquake, the system activates necessary components to gather vital information such as coordination and temperature of the building, to aid in the rescue and response efforts. This project is important because it addresses the critical need for rapid response and communication during earthquakes. Sending an emergency message to the emergency department automatically would help to initiate rescue operations quickly, and potentially save lives.

The main purpose of implementing this system is to meet the needs of small towns, villages, and isolated houses away from densely populated areas. In these areas, post-earthquake emergency departments tend to focus mainly on big cities, often ignoring search and rescue work in villages. Additionally, buildings in these remote areas are often constructed with inferior materials compared to buildings in urban areas, making them more prone to collapse during an earthquake event. By deploying the system in small towns and villages, we aim to address these specific challenges and provide vital assistance to these often-neglected areas. The system has proven particularly valuable in remote areas where there is a higher risk of building collapse due to poor construction practices.

To improve this project in the future, the following cases would be considered:

- Improved sensor integration: In addition to detecting building collapsing, coordination, and temperature in case of fire, integrating other sensors to detect gas leaks, smoke or other hazardous conditions could provide emergency services with more comprehensive information.
- In addition to sending emergency messages, the system can be further enhanced with integrated microphones to facilitate two-way communication. By integrating a microphone into the system, it can hear sounds in the environment. When the system detects sound above a certain decibel threshold, indicating the presence of a person or a distress signal, it can automatically dial the appropriate emergency department. This feature allows people who are stranded or in need of assistance to communicate directly with emergency services and provide important information about their condition, location, and specific needs. Two-way communication via microphones greatly increases the effectiveness of the system, as it encourages real-time interaction, allowing for better coordination of rescue efforts and increasing the chances of success in critical situations.

- Furthermore, an additional improvement to the system involves implementing a module or sensors, such as a Wi-Fi module or a PIR (Passive Infrared) sensor, to accurately count the number of people present inside the building. By deploying these modules strategically, the system can effectively track and monitor the occupancy within the structure. This valuable information can then be included in the emergency message sent to the relevant department, providing crucial details about the estimated number of individuals requiring assistance. By incorporating people-counting capabilities, the system enhances the efficiency of rescue operations by offering a clearer understanding of the potential scale of the incident and enabling emergency departments to allocate appropriate resources. This feature further strengthens the system's ability to aid in the rapid response and evacuation efforts, thereby increasing the overall effectiveness of the emergency response process.

Introduction

Turkey, being situated in a seismically active region, faces the constant threat of earthquakes. These natural disasters can result in devastating consequences, particularly when buildings collapse, endangering the lives of numerous individuals. The recent earthquake that happened in Turkey, caused more than 50-thousand death and more than 100 thousand injured just in Turkey.

In the face of natural disasters, such as earthquakes, swift response, and effective communication are crucial for ensuring the safety and well-being of affected individuals [1]. This report introduces an innovative Arduino project aimed at enhancing emergency response in the event of a building collapse during an earthquake. By leveraging advanced technologies, including a GSM module, GPS module, and various sensors, this project enables the automatic generation and transmission of critical information to emergency departments, such as 911, ensuring prompt and targeted assistance.

When an earthquake strikes and buildings collapse, an emergency message is sent to the relevant emergency services, such as 911, the emergency number used in the United States and Canada, or 112, the emergency number used in Turkey. The message serves as a detailed report on the condition of the building and contains important information needed for an appropriate response strategy.

Literature Review

Microcontrollers play a vital role in improving emergency management systems during natural disasters. These compact, programmable devices provide the ability to monitor, control and quickly respond to emergencies. Microcontrollers equipped with various sensors can detect seismic activity, measure ground vibrations, etc. They support real-time data collection, processing, and analysis, facilitating early warning systems that can trigger alerts and evacuation protocols. Additionally, microcontrollers can coordinate rescue operations by integrating with communication networks, GPS systems, and drones to locate survivors, gather intelligence, and deliver supplies. Their versatility allows tailoring response strategies to the specific requirements of each disaster scenario. The following literature review aims to provide a comprehensive overview of existing research and scholarly works related to the utilization of microcontrollers in emergency system response:

- An automated tsunami alert system [2]: The detection part of the proposed system consists of a microcontroller and capacitive sensor to detect the occurrence of tsunamis. The theory states that when a tsunami or other such natural disaster arrives, there will be an unprecedented increase in seafloor pressure. It uses capacitive proximity sensors based on power fluctuations and uses a microcontroller to notify victims of an impending tsunami event through mobile computing.
- Simulation of earthquakes and tsunamis through the GSM network [3]: The GSM-based earthquake early warning system can issue earthquake warnings when earthquakes are not predicted. If people in earthquake-prone areas are prepared to withstand these impacts, potential damage can be reduced, and lives saved. It contains warnings before an earthquake with strong ground motion arrives. This early warning system is possible because it travels slower than light due to waves of energy emanating from the earthquake epicenter. Earthquake epicenter warning signals may be transmitted to various locations via a satellite communications network, fiber optic network, pager service, cellular network, or a combination thereof.
- Arduino-based automatic human seeker robot [4]: general concepts of robotics are applied to human search as part of a disaster management system. Several sensors such as PIR, ultrasonic and gas sensors have been used to control toxic gases during operation.
- Firefighter robot using AT89S52 microcontroller [5]: the microcontroller was involved in disaster management, monitoring, and even firefighting. The AT89S52 microcontroller was used as a controller for the robot for firefighting utilizing ultrasonic and ultraviolet sensors.

Method

To implement this system, the following material and sensors are required:

- Arduino UNO Microcontroller
- Medium breadboard
- 9V Adapter 1A
- 3000 mAh chargeable battery
- Relay sensor
- Ultrasonic Sensor (HC-SR04)
- GSM module sensor
- GPS sensor module
- Temperature sensor (TMP36)
- 2x16 LCD
- Piezo buzzer

The Arduino UNO is a widely used microcontroller board that forms the core and main board of this system. It provides the necessary processing power and interfaces for integrating the sensors and modules that are needed to be implemented in this system. A medium breadboard provides a convenient platform for prototyping and connecting various components. It allows for the easy arrangement of electronic components and simplifies the wiring process. The 9V adapter is used as the primary power source for the system. It supplies power to the Arduino board and the connected sensors and modules. The 3000 mAh battery has been used as a backup power source for the system. It ensures that the system remains operational for more than 6 hours during a power failure, in case the primary power source is connected again, the battery can be recharged and reused. The relay sensor can switch between the primary power source and the internal battery. It automatically switches to the battery power when the electricity is cut off. To measure and compare the height of the building and detect the collapse of the building, an ultrasonic sensor has been used, the model and type of the ultrasonic sensor could be changed based on the height of the building, as the ultrasonic sensors have a maximum range of measurement, in this experiment, the available sensor was HC-SR04 that can measure the range at most 4 meters. The GSM module allows communication with the mobile network, it lets the system send emergency messages to the designated emergency departments (e.g., 911). It provides the necessary functionality for sending SMS messages containing important information about the building's situation. The GPS module allows the system to

obtain accurate latitude and longitude coordinates of the building. It enables the inclusion of the building's location information in the emergency message, providing vital details to the emergency departments. Besides latitude and longitude coordinates, the temperature of the building is also important for detecting potential fire hazards within the premises, that's why a temperature sensor is used inside the system to check the temperature. Visual feedback is always beneficial to check if the system and sensors work properly, for this reason, a 2x16 LCD has been used that shows the height of the building, the current temperature that the temperature sensor has measured, and the status of the battery. Finally, a piezo buzzer has been used to provide an audible alert to the local people in the vicinity of the building. It can be activated when the building collapses, notifying people nearby about the emergency.

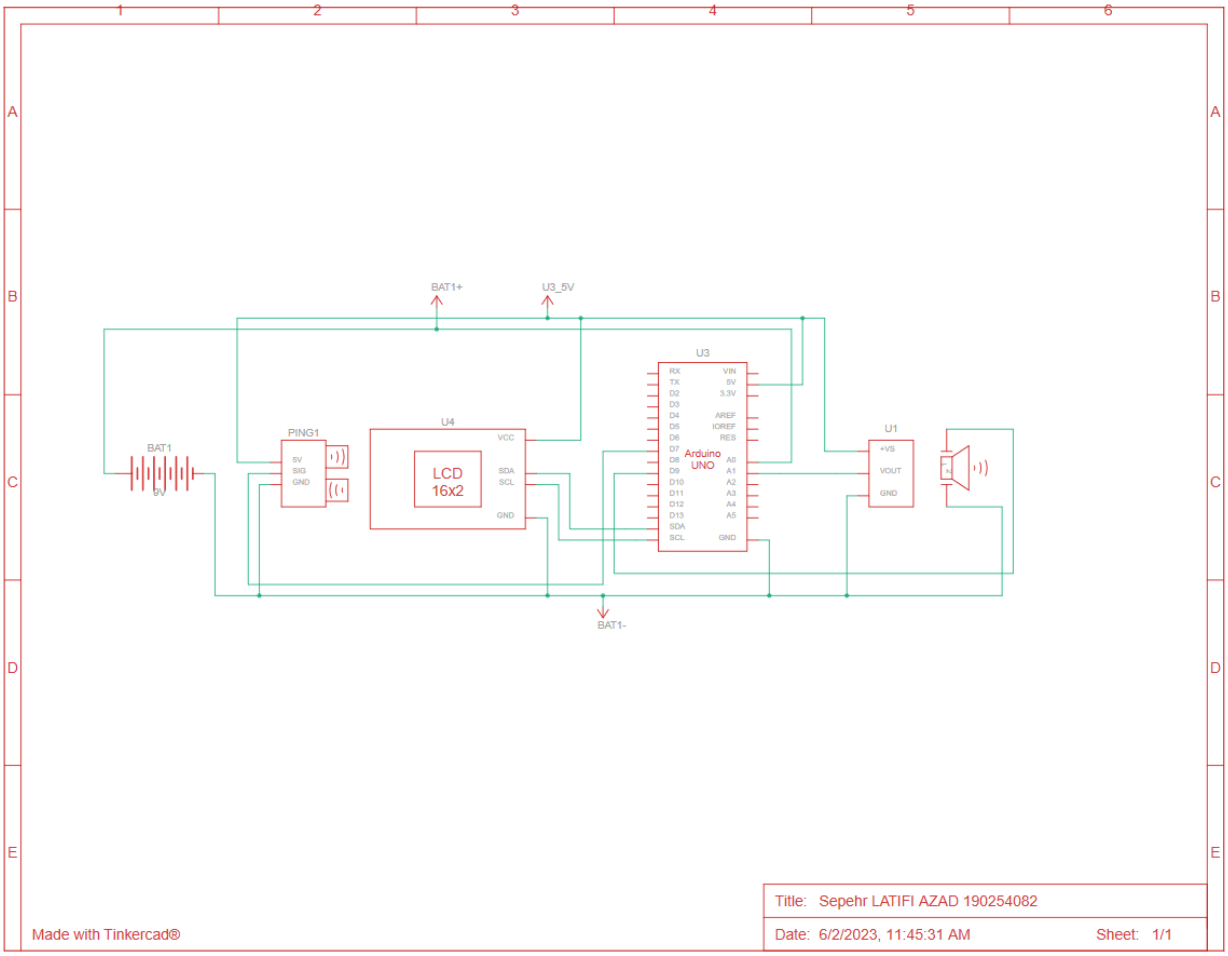

Figure 1: the schematic view of the prototype version of the system

The above figure shows a prototype version of the system using the Tinkercad application. Unfortunately, GSM and GPS modules were not available on the application, for this reason, these two modules have not been implemented in the above schematic view.

Conclusion

This project aims to fulfill the critical need for a reliable and efficient emergency response system during earthquake disasters. By using modules and sensors such as GSM, GPS, temperature sensing, ultrasonic sensor, and a buzzer, the system would detect building collapse, and sending emergency messages to emergency departments (such as 911), and share vital information about the building's coordinates and potential fire hazards, if there is any, and a buzzer has been used to provide an alert to the local people about the building. Moreover, the system can switch to the internal battery in case of a power failure in the primary power source, ensuring it remains operational for more than 6 hours.

Besides the primary application, which is earthquake scenarios, this project can be beneficial for utilization in other areas:

- Industrial Safety: The project's concept can be used in industrial buildings where the risk of accidents, collapses, or fires is high. By implementing additional sensors, (such as a gas detector sensor) and tailoring the triggering conditions to specific hazards, based on the type of industry, this system can notify emergency teams about incidents in real time with important information that has been gathered from the sensors, enabling prompt action to mitigate potential dangers.
- Remote Locations: This project can greatly benefit people living in remote or disadvantaged areas with limited access to emergency services. By incorporating a satellite-based communication module, the system can send distress signals directly to regional or international emergency response centers, ensuring timely assistance in remote locations where infrastructure may be scarce.

For disadvantaged groups or communities with limited resources, this system would be beneficial. As the system uses Arduino-based technology, which is widely available and affordable all around the world, this system could be implemented at a relatively low cost. This will make the system more accessible to communities or regions with low or limited financial resources. In addition, this system makes a rapid response by sending messages to the emergency departments automatically. This ability will lead to improving the chance of rescuing individuals who were trapped inside the collapsed building and need emergency help, specifically in regions where emergency services may have limited resources or longer response times.

There are some steps that would be taken for further development and enhancement of the project:

- Sensor Expansion: by using and integrating additional sensors to detect other specific hazards relevant to the target application. As an example, gas sensors could be incorporated to detect leaks or smoke detectors to identify potential fire incidents, expanding the system's capabilities.
- Mobile application: developing a mobile application would bring many benefits. Using an accelerometer sensor inside the system allows individuals to receive early earthquake alerts on their mobile devices, aware them to quickly identify the situation and find a secure location for their safety.
- Enabling two-way communication: By integrating a microphone into the system, it can hear sounds in the environment. When the system detects sound above a certain decibel threshold, indicating the presence of a person or a distress signal, it can automatically dial the appropriate emergency department. This feature allows people who are stranded or in need of assistance to communicate directly with emergency services and provide important information about their condition, location, and specific needs.

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[5] I. Prasojo, P. T. Nguyen, O. Tanane, and N. Shahu, "Design of ultrasonic sensor and ultraviolet sensor implemented on a firefighter robot using AT89S52," Journal of Robotics and Control, vol. 1, no. 2, pp. 55–58, March 2020.

Materials

Link of the system in the Tinkercad application: (Incomplete version! GSM and GPS module were not available in the application)

https://www.tinkercad.com/things/aX2b5EaYyoC?sharecode=LpEcFdmIDqnrIQrWiprXTntBFlvsyvkP5SrHOzIYvRI

The full version of the code in GitHub: (With GSM and GPS module)

https://github.com/333pehr/Arduino-Earthquake-Emergency-Management-System