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Smart Surveillance Systems for Enhancing Urban Security in Smart Cities

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Abstract
Smart cities are environments where digital devices are connected over the Internet and operate in sync. Security is of great importance in such environments. This work addresses aspects of a distressed user triggering the surveillance camera through an app on his Android mobile phone. The camera turns to the user and captures the scene, and turns ON an alarm. SMS is sent to his emergency contacts, and a call is placed to security agents. The application also shows the location of the user. The hardware for the device consists of an Arduino board, a Wi-Fi module, an IP camera, a buzzer and a servo motor to build the Smart Surveillance System. Also, an Android mobile phone is used. The software is written in Java and C++. The Wi-Fi Module, Buzzer and IP camera module are connected to the Arduino Microcontroller Board. The app alerts the device during an emergency by using the Google Firebase service to trigger the microcontroller. The application is built in Android Studio and connected to Firebase. Using the Arduino IDE, the Arduino Device is also connected to Firebase. The device and app communicate through the Google Firebase using the Real-Time Database and APIs. The need to safeguard lives and property is paramount. This work presents a solution using the notion of Internet of Things (IoT) to monitor and gather evidence against perpetrators. Also, to get quick access to emergency services. Thus, the system is highly important in Nigeria today.

Keywords: Android, Google Firebase, Arduino, IoT (Internet of things), Surveillance

Introduction

The Internet of Things (IoT) can be described as connecting everyday objects like smartphones, Internet TVs, sensors and actuators to the Internet, where the devices are intelligently linked together, enabling new forms of communication between things and people, and between things themselves. Building IoT has advanced significantly in the last couple of years since it has added a new dimension to the world of information and communication technologies (Godha et al., 2014). In recent times, "Smart City" is a development goal for many cities around the world. A smart city can be developed by the implementation of digital technologies in different aspects of urban management and is considered one of the pillars of Industry 4.0. The main reason for developing a smart city is to create a new urban management perspective that focuses on all aspects of urban real life. Over the years, a lot of research has been carried out, and results have shown that surveillance systems are very important for smart cities (Ghoniem et al., 2022). Surveillance systems can be considered the "eyes" of a smart city. Hence, the design of the surveillance systems for a smart city must be smart. In traditional surveillance systems, human operators are mainly responsible for manipulating the processing of captured video. Soon, most homes, institutions and organisations will have surveillance cameras installed. Consequently, this will reduce burglary incidents and enhance social stability. This study talks about the connection of an Android application to an Arduino microcontroller device with the intent of surveillance triggered from the app. It details the necessary components required in building the system. Both software and hardware requirements and their functions are explicitly explained. Smart surveillance is the key to safeguarding lives and properties in our developed world. This study helps take us a step further in our technological advancement in developing a Smart city in our country. The designed system detects suspicious criminal activities by clicking an SOS button on an Android application. (Kunda & Pidakala, 2018). The system has two main hardware components: a monitoring component (camera) and a processor that is activated when the victim presses a button on their phone.

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(Kumar et al., 2021) The camera rotates to the position of the victim. The suspicious activity is monitored by a base camera. (Amol et al., 2015) The input data from the camera is processed by the processor, the output from the system triggers an alarm and an SMS is sent to the victim's emergency contacts, which includes the victim's location, and the footage is saved to the cloud. (Gunnemeda et al., 2018)

Materials and Methods

Hardware materials

Below is the list of the entire electronic components and the other materials that were used for this work.

- Arduino Uno board
- Wi-Fi Module ESP8266
- ESP 32 IP Camera
- Servo motor MG996
- Android Phone
- Buzzer
- Resistor (1kΩ)
- Jumper wires (Male-to-male and Female-to-male wires)
- Breadboard

Software Materials

The software used for the Emergency app is the Android Studio platform. Android Studio is a fully integrated development environment which was launched by Google for the Android operating system. It has been designed to provide new tools for app development. Android Studio allows users to see any visual changes made to the app in real-time, and also see how it will look on several different Android devices, each with different configurations and resolutions, simultaneously. Coding on Android Studio can be done in Java or Kotlin programming languages. Java was used in this work. The Arduino IDE was also used in programming the Arduino Uno board, ESP 32 IP camera, the ESP 8266 Wi-Fi Module, the servo motor and the buzzer. Google Firebase was used to connect the application to the Smart Camera device.

System Architecture

The IP camera, Wi-Fi Module and the buzzer are connected to the Arduino board. When the victim activates the Android application, it establishes a connection with the Smart system. (Akram et al., 2019) An SMS stating the victim's location is sent to ICE (In Case of Emergency) contacts, and a call is placed to security authorities. A signal is sent to the microcontroller. (Nasima et al., 2014) The microcontroller sends a signal to the IP camera to rotate to the location of the Android Phone. This is as illustrated in Figure 1.

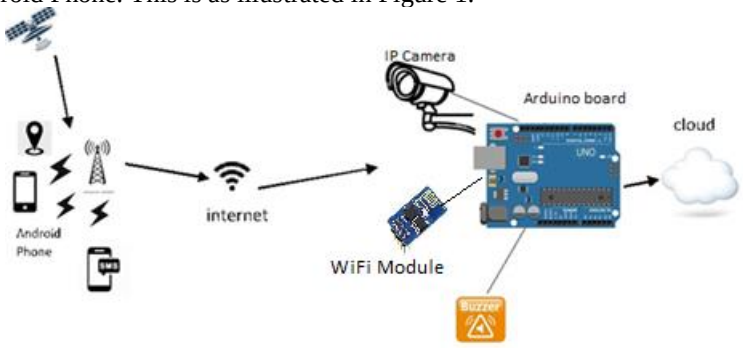

Figure 1: The system architecture

Design and Connection of the Hardware Components

The microcontroller used is the Arduino Uno. (Siddappa et al., 2022) It is powered by a 7v to 12V AC- DC adapter and also works well when connected to a steady 5v source (laptop). But for testing, a USB cable was used to power and program the Arduino Uno board. The Arduino Integrated Development Environment - or Arduino Software (IDE) - connects to the Arduino boards to upload programs and communicate with them. (Pawar et al., 2022) Programs

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were written using Arduino Software (IDE) called sketches. These sketches were written in the text editor and saved with the file extension. After installing the required libraries, the codes for the buzzer, ESP32 IP camera, ESP 8266 Wi-Fi Module and the MG996 Servo motor were written and then uploaded to the Arduino Uno board.

Design of the Emergency App

The main function of the app is to alert or send information to the saved emergency contacts of the victim and to the authorities. The app also alerts the Smart Camera system to capture the scene of the assault. Using the Android Studio, five activity layouts and their XML files were built. Each layout was coded in Java and designed in their respective XML files. Two database classes were also created to store the data from the registered users and their emergency contacts.

Key Features of the Android Application

For the user's convenience, the Android app has the following features;

1) Login Activity layout: This is designed for the user to sign in to his/her account after registration. It gives the user access to the app.
2) Registration Activity layout: This layout displays the most important data for the user's registration for the first time. It requires that the user inputs a username, email address and an Alphanumeric password with special characters.
3) Emergency Contacts Registration: This activity layout is designed for the user to input two emergency contacts' names and phone numbers. Registration at this stage is complete. The user is then redirected to login to have access to the app's Home.
4) Home Activity Layout: This activity layout is the most important part of the app. It is designed to show the button for the user to click to get help. Messages are sent to the emergency contacts, a call is placed to security authorities and a signal is sent to the Arduino microcontroller.
5) Map Activity Layout: This activity layout designed to show the user, his location on the Google Map and send SMS notification to his contacts.
6) Registration Database: This database stores the user's name and password.
7) Emergency Contacts Database: This database stores the names and phone numbers of the user's emergency contacts.

Connecting the App to the Smart Surveillance Device

Google Firebase can be easily used as an intermediate communication medium for IoT devices using Real-time Database and its APIs. When a field in the database is updated, the applications which are connected to the database can be notified of those changes using the APIs provided by the database. After signing into Firebase using a Google account and then Android Application was added. The Second phase is to configure the hardware and connect the database. The Arduino is connected to the code uploaded. The hardware is configured successfully. For connecting the Arduino with the Android application database, the Firebase Arduino Library is used to set it up.

Results

The Designed Surveillance System Integration, Deployment and Testing

After the components are connected, the designed system is as shown in Figure 2. The developed surveillance system was then deployed for security surveillance, and its operation as well as its performance met the specific design objectives, which is activated by the application user during an emergency. The Arduino UNO controls the Wi-Fi Module ESP8266, the Servo motor, the ESP-32 IP Camera and the buzzer, which communicates with the app through Google Firebase. The camera, which sits on the MG996 Servo motor, captures the environment under surveillance in real-time as motor rotates 360 degrees. The process, action and status of the system during testing is summarized in the Table 1 below. Once the system is activated, the Arduino embedded system development board, the camera module, the Wi-Fi module and the buzzer are initialized. This is immediately followed by the scanning of the IP camera. The IP camera starts delivering real-time streaming, an SMS is sent to the specified emergency phone number (Ayesha et al, 2014) while the electronic alarm system is automatically activated as an indication of the presence of danger.

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Table 1. The processes, actions and the status of the system during testing

Processes	Actions	Status
MA	App is activated by a click	App communicates via Firebase to the system
SSA	The system is initialized and camera is ready	Alarm sounds, camera pans the environment
MAAA	App communicates with system	SMS is sent to specified ICE number
MAAC	App communicates with system	Call is place to security agency

Key: Mobile Application=MA, Surveillance system activated=SSA, Mobile application after alarm=MAAA, Mobile application after activation= MAAC

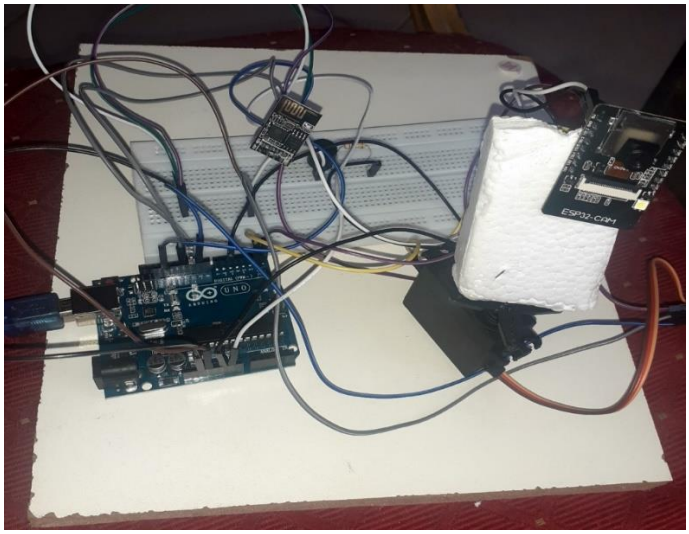

Figure 2: The hardware system of the Smart surveillance device

The following layouts are the results of the android application built for emergency.

1. Login Activity Layout 2. Registration Layout 3.EmergencyContacts Layout

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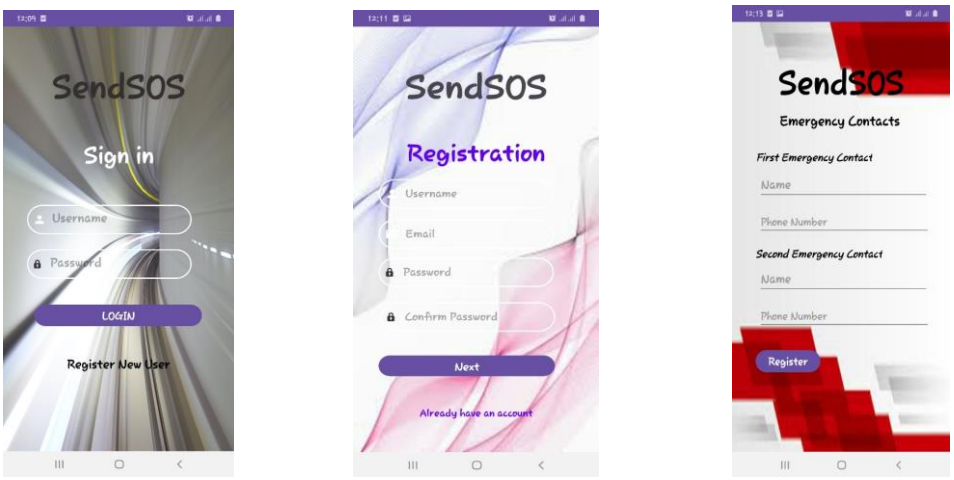

Figure 3: The Login Layout, The Registration Layout, Emergency Contacts Layout

1. Home Activity Layout 5. The Permission notification and Call to emergency Number

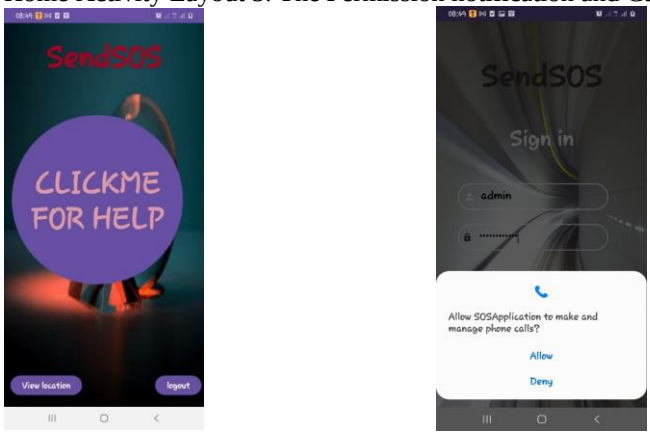

Figure 4: The Home Layout, Permission notification to have access to make calls

7. Call to Emergency Number 8. SMS to Emergency Number

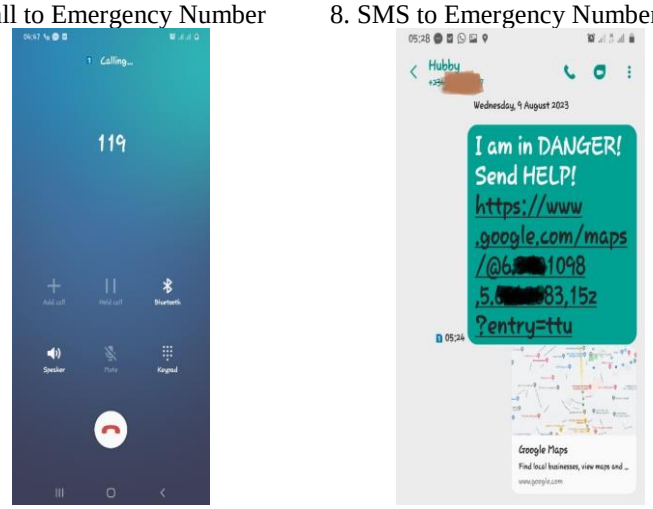

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Figure 5: Call to Emergency number, SMS notification showing location to the victim's contact

Discussion

The integrated emergency response system combines tangible hardware and intuitive software to create a cohesive lifeline during crises. (Aya, 2017) When a person in distress activates the alert through the Android emergency app on their smartphone, the system springs into action. This trigger is wirelessly transmitted to an Arduino microcontroller, which orchestrates two immediate responses: activating a video feed to document the situation and sounding a physical alarm to deter escalation. At the heart of this coordination lies Google Firebase, which acts as the digital "middleman"—securely relaying data between the app and hardware in real time. To ensure rapid human intervention, the system simultaneously initiates two lifesaving protocols:

(1) an automated SMS is dispatched to the user's pre-designated emergency contact (ICE), pinpointing the incident's GPS coordinates, and
(2) a voice call is routed to the nearest emergency response team, bridging the gap between urgency and action. Firebase's reliability in synchronizing these steps underscores its role as the silent backbone of the system, enabling split-second decisions when they matter most.

Conclusion

IoT surveillance systems are very important in our lives. (David, 2023) Using smart surveillance cameras can solve many security-related issues in our country today. (Ajay et al., 2015) An IoT based Surveillance system was developed and the User Emergency App was also built. A surveillance system was developed using android application to control the movement of the camera and sound an alarm. The following results were achieved;

1. a Smart video surveillance system using Arduino board, which works using open-source development tools, was developed.
2. a Smart system that is capable of alerting relevant authorities as soon as an incident occurs was also developed.
3. An SMS notification to emergency family contact and a call to the authorities was achieved.

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Conflict of interest

There is no conflict of interest associated with this work.

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