IoT Based Security System: Pre-College Research Project

Salma Abdelgawad[1], Kumar Yelamarthi[2]
[1]Mt. Pleasant High School, Mount Pleasant, MI
[2] College of Science and Engineering, Central Michigan University, Mount Pleasant, MI
Email: yelam1k@cmich.edu

Abstract **-** The Internet of Things (IoT) is a growing network that exchanges data in a quick and feasible manner. This network creates opportunities for more efficient and direct connections between the real world and computer systems. The banking industry would highly benefit from the IoT as it devises a system in which information from security devices can be quickly sent to the bank manager and security officials. The IoT application increases the speed of communication between the bank and authorized officials. This paper explains how equipping a bank with security devices and technology that detects intruders can help the banking industry. When this system senses motion in secured areas of the bank, it sends a text message to alert the bank manager and security officials. Then, the camera will proceed to take pictures of the area every second until the motion stops. The camera can also take a video beginning when motion is sensed and ending when the motion stops. As the system is capable of taking both pictures and videos, the discretion will be left to the bank manager to determine if they would like their security system to take pictures or videos. The pictures or video will be sent to the manager and officers via email.

Keywords - IoT, Raspberry Pi, PIR sensor, USB camera, Twilio, SMTP.

I. Introduction

The Pre-College Summer Scholars Engineering Research Program is an excellent opportunity for middle and high school students to gain in-depth knowledge of the engineering field and get real, hands-on experiences working in an engineering research lab alongside engineering student mentors. This program focused on a relatively new technology, the Internet of Things (IoT). This program included a project that was based on the IoT and how it can be used to make a security device for banks. The student chose a project for a certain scenario to create during the program. The goal of the project was to produce a IoT device for a smart bank. The student had little prior knowledge about the IoT, so this program was an excellent way for them to expand their knowledge of it. IoT is a system of communication and data exchanges between objects, machines, and humans that does not require direct interaction. Technology is growing faster and faster at an exponential rate. In 2016, there were 6.38 billion IoT devices and that number is predicted to reach 20.42 billion in 2020[1]. Many industries are showing a large increase in interest towards the IoT technologies. Industries such as food processing, agriculture, security surveillance, and many others are switching to IoT systems[2]. Banks have begun to implement the IoT in their industry to provide more services in a cheaper and more feasible manner[3]. According to the U.S. Department of Justice, there were 4,185 bank robberies in 2016[4]. In the event of a bank robbery, the average response time of police is between six and ten minutes. Police reaction time takes as long as an hour in about a third of robbery situations[5]. The police are usually notified of a robbery through the means of a phone call from a night guard or passerby. This could take a couple minutes, therefore delaying the reaction time of the police

even further. This paper proposes a system that was created and tested in the six-week research program to eliminate the reaction time and send an alert in real-time. In addition, the system will send footage of the robbery following the alert. Currently, many banks have security systems that will only set off an alarm in the building, but will not send an alert directly to the bank managers and security officials. IoT can be used to produce an automatic notification. Using the IoT, a notification is sent right away to the users programmed into the system via text message. The message will notify them of a suspected intruder. The system will then enable the camera to take multiple pictures or a video of the area and send them via email. This will increase the speed and efficiency of alerting officials about intruders in the bank. To make this system, the student learned about Raspberry Pi, a microcontroller, which is a small computer on a single integrated system. The participant in this program also learned about the many parts of the Raspberry Pi and how each part functions. The pins on the Raspberry Pi are used to connect wires to a project to control their functions. The input pin sends data and information that is collected from the sensors and parts of the project to the Raspberry Pi, where the data is then processed. The output pin sends information and signals from the Raspberry Pi to the project created to give it instructions on how to operate. The student learned that the Raspberry Pi functions as a computer. When the Raspberry Pi is connected to a monitor it functions as a microcontroller which can be programmed by writing and running codes. The code used in this security system is Python. Python is a coding language that is easy to learn, so the student was able to learn and get used to it in a short amount of time. Understanding Raspberry Pi and Python were crucial in creating the security system for banks. The student practiced for many days before starting the project. The Raspberry Pi was used as the controller for the system and Python was used to write the code to run the system.

II. Related Works

This program taught the participant how to conduct a literature review to find previous studies conducted about their topics. They searched for papers about their given topic for their projects and found many useful papers. They were able to extract new information that was beneficial in conducting their own projects. The purpose of the literature review was to find papers about the Internet of Things used for security. A literature review gives multiple results on the benefits of using the IoT and previously conducted security projects using motion detectors. A study showed that using the IoT in an industry increases productivity while simultaneously decreasing expenditures[6]. Another study revealed how the IoT can be used in the banking industry specifically. The IoT is a way for banks to provide more efficient banking services at a lower cost. One of the difficulties in providing banking services is theft and lack of communication. The IoT can eliminate these problems by improving data analysis and communicating between the network and the bank in a short amount of time while saving resources, energy, and money[3]. One project created a motion security system to monitor their home using a PIR sensor, and a temperature and smoke sensors. This system was used to check for unwanted presence and fires in their homes[7]. A project relating to smart homes discussed how using a Raspberry Pi, PIR sensor, and Pi camera can secure your home. This system used the PIR sensor to detect motion in the home which then signals for the camera to take a picture of the room and send it to the owner of the house[8]. An intrusion detection system in an additional project, used a PIR sensor to detect motion and then send data to a remote server[9]. An automated security system in another project showed how a system featuring a PIR sensor connected to a Raspberry Pi can sense motion in a room and then send a text message notification to the user using the Twilio messaging service[10].

III. Proposed System

After an in-depth literature review, the student devised a specialized project to create a smart bank security system. This system provides an automatic response to a suspected intruder in a bank. A microprocessor and sensors are used to detect motion and send the information to the Cloud about a suspected intruder. This notification is then sent as a text message to the bank managers and security officials, such as the police. Once the initial alert is sent from the Cloud, the security system will then proceed to take a picture of the area every second or take a video for the entire duration of detected motion. The images or video will be sent to the bank manager and security officials immediately after it is taken. For the sake of this research program, the banking situation was chosen as the hypothetical scenario. To implement the proposed system, additional security measures would have to be taken. For example, passwords and anti-hacking software would have to be installed into the system to prevent unauthorized access to the Cloud based system. The system proposed in the research program focused on how to use the Internet of Things, how to code using the Python language, and how to create a project using the Raspberry Pi and other sensors. Fig. 1 shows the diagram of the proposed system.

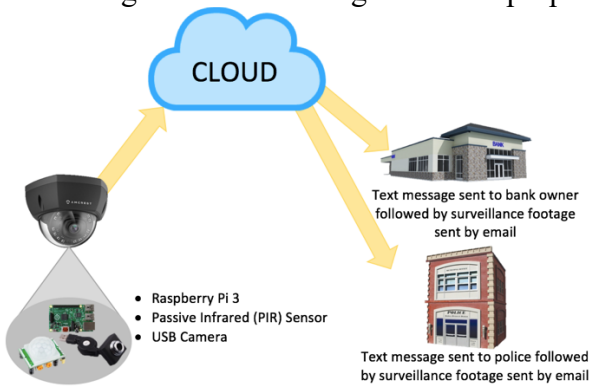

Fig. 1. Proposed system overview

The motion detection security system is placed in private areas of the bank that are restricted to the public. This system is enclosed in a case which is mounted to the ceiling at a location where the room is clearly visible to the camera. Inside the surveillance case, a passive infrared sensor (PIR sensor) and a USB camera are connected to a Raspberry Pi. The PIR sensor is constantly detecting if there is motion or not. When this sensor detects motion, a text message reading "Motion detected! Suspected intruder in the bank!" will be sent to the Cloud. From there, the message will be sent to the bank manager and the police station in real-time. Following the text message, the system will take a picture of the room using the USB camera every second until the sensor detects that the motion has stopped. The USB camera can also take a video of the motion. Each picture will be sent to the Cloud as soon as it is taken and will then be emailed to the manager and police using simple mail transfer protocol (SMTP). The same procedure will be used to send the videos taken by the USB camera. The diagram in Fig. 2 shows the steps for the proposed system.

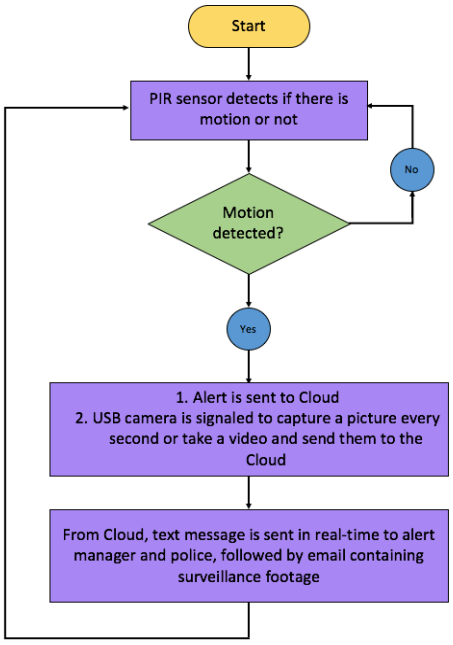

Fig. 2. Diagram of steps in proposed system

A. *Raspberry Pi 3B+*:
The Raspberry Pi 3 Model B+ [Fig. 3] is a low-cost 64-bit microprocessor with four USB ports, fast Ethernet, and a strong network connection. The Raspberry Pi's network provides fast communication in the system and strong connection between the code and the system. A microprocessor is an integrated circuit with all of the functions as a central processing unit of a computer. This product is able to sustain high power for extended periods of time. This Raspberry Pi has the strength and speed to fulfill its purpose in this security system.

Fig. 3. Raspberry Pi 3 Model B+

B. *Passive Infrared Sensor*:
A passive infrared sensor [Fig. 4], or PIR sensor, is commonly used as a motion detector. This sensor measures infrared light emitted from objects in its surrounding. The sensor is split into two halves. Both halves of the sensor have a small slot with radiation sensors that detect the amount infrared radiation in the surroundings. When there is an imbalance of infrared radiation

in the two sections, that signifies that there is motion surrounding the sensor. When the two halves are at a neutral, even state, there is no motion. A Passive Infrared sensor was chosen over other types of motion sensors because it is more accurate than many other models. One example of another type of motion sensor is the Active Infrared sensor. This type of sensor emits an infrared beam with a certain frequency. A disruption in frequency signifies motion. This sensor was not the optimal product for the security project as the frequency can be manipulated and the sensor is difficult to conceal. A PIR sensor was selected over an AIR sensor because it produced accurate results and its small size is easy to conceal. PIR sensors are highly accurate which make them beneficial for this motion detection security system.

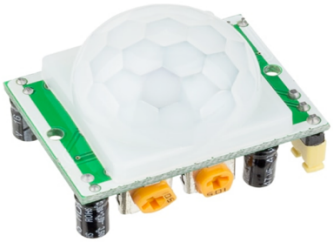

Fig. 4. Adafruit PIR Motion Sensor

C. *USB Camera*:
A USB camera is very simple to use and does not require any meticulous set-up. The resolution can be adjusted to customize the dimensions of the pictures and videos. Another camera that could be used in this system is the Pi camera. It is very similar to the USB camera, but it is more delicate. The USB camera was chosen over the Pi camera because it is more resistant and it has additional features, such as adjustable resolution and customizable dimensions. The USB camera, as shown in Fig. 5, was chosen because of its quality, features, and feasibility.

Fig. 5. Raspberry Pi 3 Model B/b+/a+/b USB Camera

D. *Twilio*:
Twilio is an online messaging service. An account can be created in just a few minutes and the program is straightforward and easy to understand. Twilio enables users to program Raspberry Pis to send text messages to their desired phone number. Twilio is a well-known messaging service with many users. This service was chosen because of its high ratings, easy to use system, and straightforward instructions. The Python code and the phone numbers used to send and receive text messages through Twilio were installed into the Raspberry Pi terminal. Then a line of code was written into the system code to signal a text message to be sent to the predetermined number at the time of motion detection.

E. *SMTP*:
Simple mail transfer protocol (SMTP) is an Internet standard for sending emails. The installation is quick and easy and it allows the users to send emails including text, images, videos, and files.

IV. Implementation & Results

For the experimentation, materials from a research lab were used to make the system. The USB camera has a cord that can be extended or shortened. It was connected to the Raspberry Pi and the rest of the system. The cord was extended and mounted to a wall.

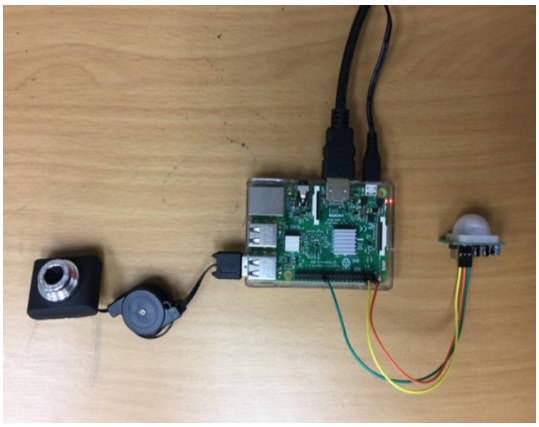

Fig. 6. Final built prototype

The system was tested in a lab where a person was moving. When the PIR sensor detected the motion of the person moving in the room, a text message was sent to the phone right away. The emails were received shortly after. For the first trial, the system was programmed to capture images. The images were sent via email using SMTP and multiple pictures were received, one picture every second.

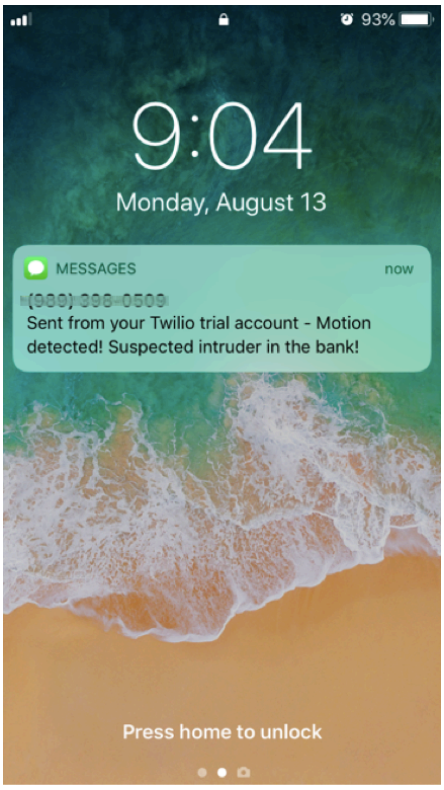

Fig. 7. Text message received

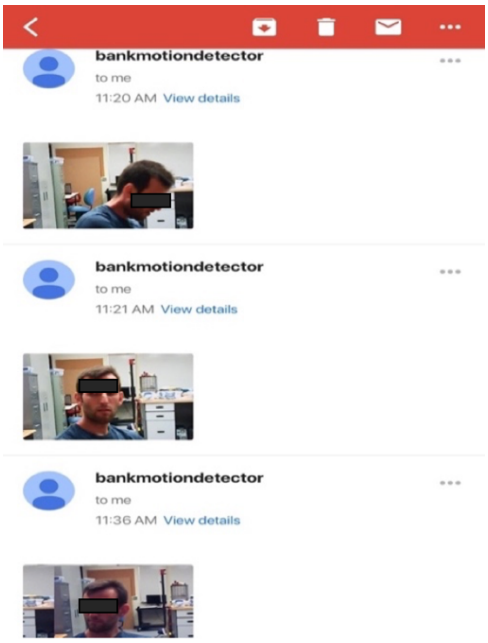

Fig. 8. Surveillance images received by email

In the second trial, the USB camera was programmed to start taking a video when motion was sensed and end the video when the motion stopped. An email was received directly after the motion stopped. The video file was attached in the email and was able to be viewed from other devices, such as a computer.

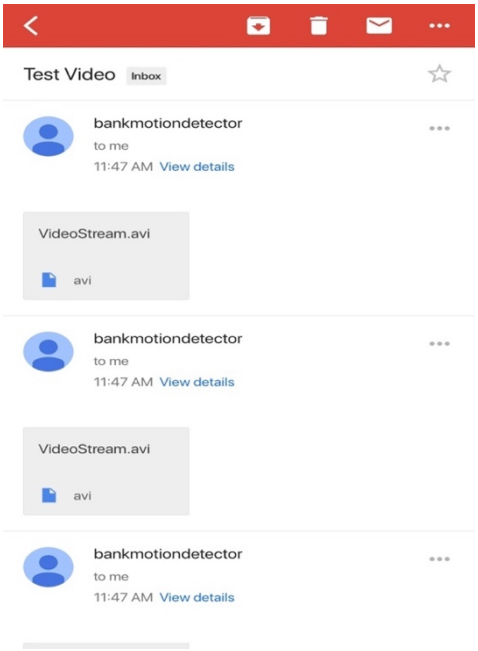

Fig. 9. Surveillance video received by email

V. Future Scope

To expand on this project, a facial recognition feature could be installed to help prevent false alarms. Adding facial recognition would allow the security system to scan the images from the USB camera and identify if the movement is caused by a bank employee or a stranger. This would decrease the risk of false alarms being sent. To install the facial recognition software onto the Raspberry Pi, OpenCV is required. OpenCV is a library of programming functions with the goal of real-time computer vision. The system will include a set of pictures of authorized bank employees so when the facial detector determines that the movement is being caused by an employee it will not send the alert to the manager or the police. The USB camera will take pictures of the room and the facial recognition software will then scan the images to recognize if the person in the room is a bank employee or a stranger. If the face detected matches the face of someone who is classified as authorized in the system, the alarm will not be sent as this user has the right to enter this secured area. If the face detected is not recognized and is not on the software, the alert will be sent. Because of time constraints, this project addition was not fully completed.

While face recognition could improve this project, the current system is very beneficial for many people, not just banks. This motion detection security system can be used in homes, schools, offices, and any other secured area. For example, home owners can use this security system to see who comes to their house while they are not home. They can view the surveillance footage right from their smart phone, tablet, computer, or other electronic device. In the case of a break in, the home owner and police would be notified in real-time and would therefore have faster reaction time and be able to stop and catch the criminal. This system can also be used to protect schools and offices from break ins as it would notify the administrators and the police right away to allow officers to have enough time to get to the scene.

Not only does this motion detector provide a fast security system, it can also function as a monitor for users to view their desired rooms. For example, pet owners can place this system in the pet's feeding room so they can monitor if and when their pet is eating while they are at work or on vacation.

VI. Lessons Learned

This program taught the participant in-depth lessons about engineering. The engineering topics the participant learned about include how to conduct a literature review to extract relevant and beneficial information, the parts and functions of a Raspberry Pi and how to use it, what the Python coding language is and how to write a personalized code, how to wire a system using Raspberry Pi, how to use a messaging service, and how to use simple mail transfer protocol. The first step in this research program was to conduct a literature review. The student learned how to find papers relevant to their topics and narrow down their findings leaving only the most important information. Next, a good understanding of Raspberry Pi was needed to create the project. The program participant spent over a week practicing with Raspberry Pi tutorials before reaching a good level of understanding to start their project. While getting familiar with the Raspberry Pi, the student learned about the parts of the Raspberry Pi and what each part does. For example, the pins connect the microcontroller to sensors, buttons, relays, and other Raspberry Pi tools. The input and output pins receive and send data and information from the Raspberry Pi respectively. With just this knowledge, a motion detector was able to be set up to

detect if there was motion in a room or not. The camera was also set up to take pictures and videos. To add on to this system, the participant then learned how to use the Twilio messaging service to send a text message to their phone alerting them of motion. A Twilio account was set up with a programmed number to send messages from. A phone number was chosen for the Twilio account to send messages from. Then the desired phone number for receiving messages was inserted into the Twilio account. To set up a message into the Python code, the Twilio account had to be installed into the Raspberry Pi terminal. The student learned that the terminal is the control center for the Raspberry Pi. In the terminal, commands can be edited, deleted, or installed. Once Twilio was installed into the terminal, the code was able to run on Python and send a message to the phone. The next step in this project was to learn how to send emails from the Raspberry Pi. To send emails, the student became familiar with the simple mail transfer protocol (SMTP). Like the Twilio messaging service, the SMTP was installed into the terminal then written into the Python code. SMTP stores a prewritten email and is then uses the protocol to forward it to the preprogrammed receiver across the network. In this system, the email was programmed to send the surveillance footage as soon as it was captured. The student successfully completed and tested their smart bank security project and obtained accurate, positive results. This program was very valuable and rewarding as it taught the participant about the Internet of Things, Raspberry Pi, Python coding, Twilio, and simple mail transfer protocol. As a pre-college student, this program gave them the valuable opportunity to conduct engineering research and work alongside engineering students, an opportunity that is only available to a select few. At the end of this summer research program, the participant left with a multitude of knowledge in engineering.

VII. Conclusion

The program participant conducted in-depth research to learn how to create their own project for a smart security solution. The IoT security system was successful in multiple trials. Upon motion detection, an alert was automatically sent to the Cloud. The USB camera successfully captured multiple pictures in the first trial and recorded a video in the second trial. The pictures and video were sent to the Cloud. From the Cloud, a text message was received reading “Motion detected! Suspected intruder in the bank!”. An email was then received following the text message with the pictures and video attached. The goal of creating a motion detection security system for banks was successfully accomplished. The student was able to achieve their goal of creating a smart device for their selected industry to provide faster communication with the manager and police to reduce the number of crimes in banks.

Acknowledgment

This work has been sponsored by the National Science Foundation under Grant no. 1542368.

Bibliography

[1] Tung, L. *IoT devices will outnumber the world's population this year for the first time | ZDNet*. 2018. [online] ZDNet. Available at: https://www.zdnet.com/article/iot-devices-will-outnumber-the-worlds-population-this-year-for-the-first-time/ [Accessed 14 Aug. 2018].

[2] L. D. Xu, W. He and S. Li, "Internet of Things in Industries: A Survey," in *IEEE Transactions on Industrial Informatics*, vol. 10, no. 4, pp. 2233-2243, Nov. 2014. doi: 10.1109/TII.2014.2300753

[3] S. Rimer, "An IoT architecture for financial services in developing countries," *2017 IST-Africa Week Conference (IST-Africa)*, Windhoek, 2017, pp. 1-10. doi: 10.23919/ISTAFRICA.2017.8102345

[4] Federal Bureau of Investigation. *Bank Crime Statistics 2016*. 2017. [online] Available at: https://www.fbi.gov/file-repository/bank-crime-statistics-2016.pdf/view [Accessed 14 Aug. 2018].
[5] Bjs.gov. 2018. [online] Available at: https://www.bjs.gov/content/pub/pdf/cvus/current/cv08107.pdf [Accessed 14 Aug. 2018].
[6] N. N. Dlamini and K. Johnston, "The use, benefits and challenges of using the Internet of Things (IoT) in retail businesses: A literature review," *2016 International Conference on Advances in Computing and Communication Engineering (ICACCE)*, Durban, 2016, pp. 430-436. doi: 10.1109/ICACCE.2016.8073787
[7] P. Gupta and J. Chhabra, "IoT based Smart Home design using power and security management," *2016 International Conference on Innovation and Challenges in Cyber Security (ICICCS-INBUSH)*, Noida, 2016, pp. 6-10. doi: 10.1109/ICICCS.2016.7542317
[8] S. Tanwar, P. Patel, K. Patel, S. Tyagi, N. Kumar and M. S. Obaidat, "An advanced Internet of Thing based Security Alert System for Smart Home," *2017 International Conference on Computer, Information and Telecommunication Systems (CITS)*, Dalian, 2017, pp. 25-29. doi: 10.1109/CITS.2017.8035326
[9] K. C. Sahoo and U. C. Pati, "IoT based intrusion detection system using PIR sensor," *2017 2nd IEEE International Conference on Recent Trends in Electronics, Information & Communication Technology (RTEICT)*, Bangalore, 2017, pp. 1641-1645. doi: 10.1109/RTEICT.2017.8256877
[10] S. Venkatesan, A. Jawahar, S. Varsha and N. Roshne, "Design and implementation of an automated security system using Twilio messaging service," *2017 International Conference on Smart Cities, Automation & Intelligent Computing Systems (ICON-SONICS)*, Yogyakarta, 2017, pp. 59-63. doi: 10.1109/ICON-SONICS.2017.8267822